Taxonomic Revision and Molecular phylogeny of the genus *Plectranthus* L'Hèr. (Lamiaceae) in India

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CERTIFICATE

This is to certify that all the corrections/ suggestions from the adjudicators have been incorporated and the thesis entitled "**Taxonomic Revision and Molecular phylogeny of the genus *Plectranthus* L'Hèr. (Lamiaceae) in India**" is resubmitted.

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CERTIFICATE

This is to certify that the thesis entitled "**Taxonomic Revision and Molecular phylogeny of the genus *Plectranthus* L'Hèr. (Lamiaceae) in India**" submitted to the University of Calicut by **Ms. Smitha, K.**, in partial fulfilment for the award of the degree of Doctor of Philosophy in Botany is a bonafide record of the research work carried out by her under my supervision and guidance. No part of the present work has formed the basis for the award of any other degree or diploma previously.

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DECLARATION

This thesis entitled **"Taxonomic Revision and Molecular phylogeny of the genus *Plectranthus* L'Hèr. (Lamiaceae) in India"** submitted by me in partial fulfillment of the requirements for the award of the degree of **Doctor of Philosophy** in **Botany** of the **University of Calicut** and it has not been submitted earlier either in part or in full for any other degree or diploma of any University.

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INTRODUCTION

Plants have had an immense role in the human development ever since the early civilization and perhaps continue to shoulder much greater role in the future as well. There has been a parallel between plants and humans in so far as the evolutionary aspect is concerned. Animals including humans need plants which, brought in civilization on earth. Human settlements came up on a realization that plants sustain their lives not only in providing food but also for all other primary requirements such as oxygen, housing, medicine and above all, unbeatable aesthetics. There are slightly more than one third of a million species of plants known to man today, the information having been accumulated through efforts of several millenniums.

Man has been classifying plants since the advent of civilization, and early Sanskrit works from the Vedic periods and ancient Hindu scriptures attempted to understand the plant world. The same efforts were taking place in the classical western world, especially in Greece. The urge to classify things is a fundamental human instinct and thus the horizon of taxonomy has considerably expanded over the years. Taxonomy is often defined as the 'science dealing with the study of classification, including its bases, principles, rules and procedures' (Davis and Heywood 1963). It is a fascinating multifaceted subject which act as a pedestal upon which biology is built and is the mother of all branches of biology. It provides the primary basic essential requirement, the correct identity of the organism to those who are doing research in other branches of biology like Anatomy, Cytology, Embryology, Genetics, Palynology or Phylogeny. It is considered as both the 'queen and servant' of biology (Sivarajan 1984). A successful taxonomist is one who has keen observational awareness, inquisitiveness, innate urge to create orderliness out of chaos, the perseverance and patience to do it. Above all he should have an instinctive inner sense where the peculiarities of various taxa seen by him are stored in his brain, and has the ability to retrieve the data for quick identification of taxa. Moreover, the innumerable names created for taxa over a long period of time and the perplexing identity of many such taxa could be clarified only through revisionary studies. This emphasizes the need of additional taxonomic studies and revision of plant kingdom at the generic level.

External characters were the sole basis for taxonomic analysis since pre-Linnaean period. Recent technological revolutions and its implication in scientific research propelled the revolutions in taxonomic research in many ways. Plant systematics is considered as a more inclusive field that includes and encompasses traditional taxonomy but its primary goal is to reconstruct the evolutionary history of plant life. Simpson (1961) defined systematics as a ‘scientific study of the kinds and diversity of organisms, and of any and all relationships between them’. It divides plants in to taxonomic groups, using morphological, anatomical, micomorphological and molecular data.

1.1 Relevance of the study

As presently circumscribed (Harley *et al.* 2004), Lamiaceae are the largest family-level clade within Lamiales (APG 2016). They are cosmopolitan in distribution with high economic potentialities. Indian region exhibit very high diversity of Lamiacean plants with many endemics having overlapping morphologic characters. Systematic studies on Indian taxa with special reference to the historical biogeography of endemic plants using classical and molecular approaches is important in studying the evolution of the family in tropics.

The proposed study focus on the systematic problem within the genus *Plectranthus* L'Hér. and the intra specific and inter generic relationship of the complex, using morphological, micromorphological and molecular approaches and to check the paraphyly of the genus. The main research problem addressed in this study is to confirm whether the genera *Plectranthus* and *Coleus* Lour. are congeneric or not?. Moreover, a combined approaches of morphology, micromorphology (SEM studies) and molecular data would be of much relevance in circumscribing the taxon boundary within the complex.

Plectranthus also known as 'spurflowers', is one of the largest genera of family Lamiaceae, subfamily Nepetoideae, tribe Ocimeae, and subtribe Plectranthinae. The genus consists of more than 300 species and plays a dominant role in both horticulture and traditional medicine (Lukhoba *et al.* 2006, Rice *et al.* 2011). The genus is distributed widely in tropical to southern areas of Africa and Madagascar, and also occurs in tropical Asia and Australia (Harley *et al.* 2004) (Fig. 1.1). It is an attractive and floriferous genus, plagued with numerous nomenclatural disharmonies and this has resulted in various taxonomic problems in naming of species. One of the main problems in the subtribe Plectranthinae is to circumscribe the generic limits of *Plectranthus* and *Coleus*. A quick count in Index Kewensis yielded about 490 names in the former and 312 in the latter (Codd 1971). Literature survey reveals that taxonomic identity of *Plectranthus* and *Coleus* has long been a matter of discussion among workers. Furthermore, nomenclatural disputations resulted in placing species of *Plectranthus* under various generic names like *Germanea* Lam., *Burnatastrum* Briq., *Englerastrum* Briq. etc. (Lukhoba *et al.* 2006). As a result of morphological studies, all these names have been synonymised under *Plectranthus* (e.g. Harley *et al.* 2004; Rice *et al.* 2011). Recent study on the molecular phylogeny of the tribe Ocimeae (Paton *et al.* 2004) revealed that the current circumscription of the genus *Plectranthus* is paraphyletic. They recognized two clades: *Coleus* and *Plectranthus* within subtribe Plectranthinae and opined that previously used morphological characters cannot diagnose clades within the subtribe. They emphasised the need of further sampling to support monophyly within the group.

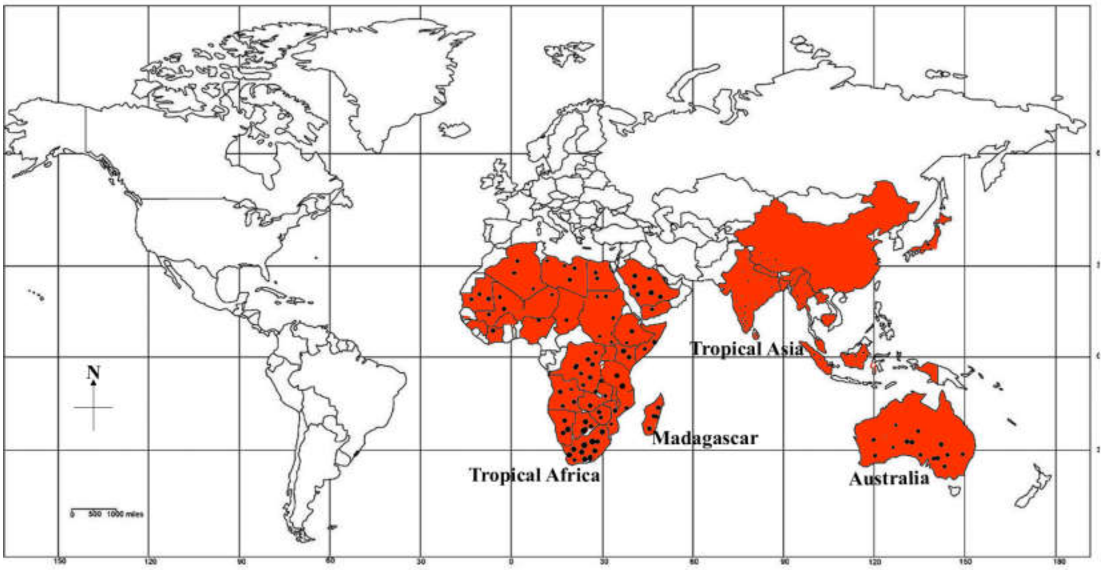

Fig. 1.1. Distribution of the genus *Plectranthus* in the world

Earlier works on Indian *Plectranthus* treated species distinctly under two generic names *Coleus* and *Plectranthus* and the genus *Isodon* (Schrad. ex Benth.) Spach was also treated congeneric with *Plectranthus* (Bentham 1831, 1832 & 1848; Hooker 1885; Gamble 1921; Mukerjee 1940; Cramer 1978, 1981). Later this point of view has changed due to the emergence of new evidences to support the monophyly of *Isodon* and its position in a separate subtribe within Ocimeae (Zhong *et al*. 2010; Yu *et al*. 2014). After Mukerjee's (1940) revision, no work was carried out with particular focus on Indian *Plectranthus*. Hence this study was conducted to generate an account of the genus *Plectranthus* in India by incorporating morphological, micromorphological and molecular data.

1.2 Objectives

1) Exploration, collection, documentation of species diversity and preparation of herbarium specimens for future reference.

2) The establishment and maintenance of germplasm in the Calicut University Botanic Garden (CUBG).

3) Revision of the genus *Plectranthus* using morphological characters.

4) To study the species level systematics and to analyze relationship with in the genus *Plectranthus*.

5) Reevaluate and propose boundaries for *Plectranthus*-*Coleus* complex using modern systematic and phylogenetic tools.

6) Identification of reliable characteristic features useful for species identification and diagnosis of the genus.

7) To examine endemicity and propose conservation strategies for species complex.

8) Species conservation assessments using IUCN guidelines.

To achieve these objectives, we performed our work under three phases

I. Taxonomy

II. Micromorphology

III. Molecular phylogeny

1.3 Taxonomy

1.3.1 Family Lamiaceae

Lamiaceae is considered to be one of the most highly evolved plant families with regard to floral structures. Many species produce essential oils and are therefore used by mankind as perfumes, flavorings, foods and medicinal drugs. It contains 236 genera and about 7173 species, almost cosmopolitan, but absent from the coldest regions of high altitude or latitude (Harley *et al.* 2004). The family is thought to be originated in the Cretaceous period. de Jussieu (1789) first used the name Labiatae in the family limits. The classification of Lamiaceae is a matter of debate since the period of Linnaeus. Bentham's (1832, 1848) attempt for a full taxonomic treatment of the family (modified in 1876) purely based on the floral structures are still valid today. Later Briquet (1897) made various modifications to Bentham's system.

Lamiaceae have long been considered closely related to Verbanaceae (Cantino 1992a; Cantino 1992b; Cantino and Sanders 1986; Olmstead *et al.* 1992). Erdtman (1945) subdivided the family in to two groups based on pollen morphology – Nepetoideae with hexacolpate pollen which is shed at the three-celled stage, and the Lamioideae which mostly have tricolpate pollen shed at the two celled stage. This division was further investigated by Cantino and Sanders (1986) using a much broader range of characters. According to them Nepetoideae are characterized with exalbuminous seeds, investing embryos and the presence of volatile terpenoides mainly monoterpenes. Whereas Lamioideae are characterized by albuminous seeds, spatulate embryos and the presence of iridoid glycosides. They concluded that Nepetoideae showed a number of synapomorphies and appeared to be monophyletic, the same was not true of Lamioideae.

Lamiaceae is the sixth largest family of flowering plants. The family has been divided recently into seven subfamilies: Ajugoideae, Lamioideae, Nepetoideae, Prostantheroideae, Scutellarioideae, Symphorematoideae and Viticoideae and ten genera that could not be placed in a subfamily were listed as incertae sedis (Harley *et al.* 2004). Among the above mentioned subfamilies, Nepetoideae is the largest, with clearly defined synapomorphic characters. The monophyly of five of the seven subfamilies (Ajugoideae, Lamioideae, Nepetoideae, Prostantheroideae, and Scutellarioideae) has been supported by molecular studies. In 2016, Li *et al.* presented a large-scale phylogenetic reconstruction of Lamiaceae using chloroplast sequences and three new subfamilies—Cymarioideae, Peronematoideae, and Premnoideae—were described.

1.3.2. Subfamily Nepetoideae

Nepetoideae is the largest subfamily in Lamiaceae (*sensu lato*) with c. 133 genera and 3685 species (Harley *et al.* 2004), and is characterized by hexacolpate, trinucleate pollen, lack of endosperm and iridoid glycosides, investing embryos, myxocarpy (nutlets producing mucilage), a high volatile terpenoid content, and highly unsaturated seed oils (Erdtman 1945; Wunderlich 1967; Cantino & Sanders 1986; Kaufmann & Wink 1994; Wagstaff *et al.* 1995; Ryding 1995). It contains most of the aromatic Lamiaceae. The monophyly of the subfamily was supported by cpDNA restriction site analysis (Wagstaff *et al*. 1995) and *rbcL* sequences (Kaufmann & Wink 1994). This subfamily consists of three tribes Elsholtzieae, Mentheae, and Ocimeae. Tribe Mentheae is large and contains well known genera such as *Mentha* (peppermint), *Nepeta* (catnip), *Origanum* (oregano), *Rosmarinus* (rosemary), *Salvia* (sage), and *Thymus* (thyme). Tribe Ocimeae is smaller, but also contains economically important genera such as *Plectranthus*, *Lavandula* (lavender), and *Ocimum* (basil) (Li *et al.* 2016).

1.3.3. Tribe Ocimeae

The tribe Ocimeae is economically very important. It contains approximately 35 genera and 1000 species (Suddee *et al.* 2004) and is chiefly distributed in the tropics and subtropics with the main centers of diversity in South America, Tropical Africa, Madagascar, China (Paton & Ryding 1998) and in India (Mukerjee 1940). The tribe is normally characterized by declinate stamens (spreading in some species) and synthecous anthers. In Asia, particularly in India, this tribe represents the largest group in the subfamily Nepetoideae. Tribe Ocimeae consists of five subtribes: Lavandulinae, Hanceolinae, Hyptidinae, Ociminae and Plectranthinae (Harley *et al.* 2004).

1.3.4. Subtribe Plectranthinae

Subtribe Plecranthinae consists of 11 genera and more than 400 species. Inflorescence thyrsoid, posterior calyx lobe larger than others sometimes decurrent on tube, but not appendaged, stamens exserted from tube and anterior and posterior pairs of stamens adjacent at attachment to corolla on the anterior side of the corolla throat (Harley *et al.* 2004). Recent study on molecular phylogeny of the tribe Ocimeae (Paton *et al.* 2004) confirmed monophyly of the subtribe Plectranthinae.

1.3.5. The genus *Plectranthus*

1.3.5.1. Botanical History and infra-generic relationships

The earliest known species of *Plectranthus* and *Coleus* were treated under the genus *Ocimum*. Linnaeus on the other hand considered the tooth on filaments of the stamens as the distinguishing character of *Ocimum*. L'Hèritier (1788) established the genus *Plectranthus* to accommodate the species which had no such tooth. He described the genus with two species, *P.*

fruticosus and *P. punctatus*. Later Nakai (1934) made *P. fruticosus* as type species of the genus *Plectranthus* as generic characters are based on this species. About the same time the genus *Germanea* was created by Lamarck (1788) for the same purpose but emphasized also the spurred or angled corolla tube which occurs in some species. Loureiro (1790) established the genus *Coleus* to include those species with united stamens producing a staminal sheath around the style. However, Brown (1810) and Blume (1826) considering that form of the corolla is the important factor and pointed out that staminal fusion is not a reliable character and they considered *Coleus* as a synonym under *Plectranthus.* Roth (1821) considered the spurred corolla to be the main character of *Plectranthus* and used it to distinguish the genus from *Ocimum*. Schumacher (1827) created the genus *Solenostemon* to contain species with a markedly bilabiate calyx. Later Bentham (1831, 1832 & 1848) recognized some of these groupings as natural and gave them sectional status. He considered both *Coleu*s and *Plectranthus* as distinct by giving overriding importance to fusion of stamens. Briquet (1897) also followed Bentham in emphasizing the importance of fusion of stamens and split off a number of species into the newly created genera *Burnatastrum* (species having the mature calyx with a curved tube swollen at the base), *Engleratrum* (species having a campanulate calyx with 5 equal deltoid teeth), *Neomullera* (species having a capsule-like fruiting calyx) and *Isodictyophorus* (species having a calyx with 5 equal ovate acuminate teeth and a terminal inflorescence). Chevalier (1920) established the genus *Leocus* for a *Coleus*-like plant from Guinea in which the calyx teeth are subulate-lanceolate, with the upper somewhat larger. Fries (1924), in his revision of the genus *Englerastrum*, emphasized the importance of arrangement of stamens and considered this genus to be a connecting link between *Coleus* and *Plectranthus*. He re-defined it so as to include those species in which one or both pairs of stamens were fused by their filaments along the bottom edge to form a grooved structure, whereas in *Coleus* he considered that the filaments were fused into a tube around the style, and in *Plectranthus* they were stated to be completely free.

Morton (1962) considered staminal fusion is an arbitrary character and treated *Plectranthus* and *Coleus* as conspecific. He followed Brown and Blume in combining the two genera under the prior name of *Plectranthus* and states that the genus *Plectranthus* is thus the residue remaining after the genera *Solemstemon*, *Englerastrum, Leocus, Neohyptis, Homalocheilos, Isodictyophomcs* and several non-West African genera have been split off. He studied the West African species and according to him the genus is characterized by ‘the sharply bent corolla tube with its large carinate lower lip which encloses the four declinate stamens, the filaments of which are free or fused and have no tooth; the calyx in which the upper lobe is broadly ovate and decurrent on the campanulate (not ventricose) tube but not exceeding the other teeth; the median lobes which are acuminate and not degenerate, and the lower lobes which are acuminate and free from each other’.

Later, Launert (1968) enlarged the generic description as Morton’s findings had some limitations with regard to some species (*C. amboinicus*). According to him *Plectranthus* include species in which superior tooth of the calyx is both longer than the other teeth and not conspicuously decurrent on the tube. He also united *Burnatastrum* with *Plectranthus* by stating that the nature of the calyx separating *Burnatastrum* from *Plectranthus* is an arbitrary character. Codd (1971) revaluated the discrepancy that exists in *Plectranthus*-*Coleus* complex and various segregate genera. He treated staminal fusion as unreliable character and presented tentative grouping in to sections in the genus *Plectranthus* and added *Isodon* as separate genus. A revision of Australasian *Plectranthus* was conducted by Blake (1971), treated *Plectranthus, Rabdosia, Amethystanthus, Ceratanthus, Homalocheilos, Coleus* and *Solenostemon* as separate genera and accepted the fusion of stamens as a valid distinguishing character of *Coleus*. Keng (1969) too agreed staminal fusion as a stable differentiating character in this complex in Malesia. As far as Sri Lankan species is concerned, Cramer (1978) opined that the fusion of stamens in combination with some secondary characters forms a sufficient basis and *Coleus* forms distinct genus in this complex. Concurrently, Keng (1978) treated *Coleus* as synonym under *Plectranthus* during the description of several species from Malesia.

Willemse (1979), opined that Cramer's view cannot be upheld for this complex, as it was based only on Sri Lankan specimens and agreed with Keng's opinion that *Coleus, Solenostemon*, *Rabdosia*, and probably some other closely related genera must be included in *Plectranthus*. Ryding (1993b) compared the two genera *Plectranthus* and *Isodon* and found to be dissimilar. *Isodon* was considered to be misplaced in Ocimeae subtribe Plectranthinae and was more closely related to subtribe Hyptidinae. He also compared the disjunct genus *Rabdosiella* to these two genera and regarded it to be polyphyletic. Paton and Ryding (1998) discussed the subtribes of the *Ocimeae* and new definitions of *Plectranthinae* and *Ociminae* were provided. The position of *Hanceola, Siphocranion* and *Isodon* within the tribe *Ocimeae* was also discussed and the three genera were placed as *incertae sedis*. A key to the subtribes of the *Ocimeae* and genera *incertae sedis* were also given and the genus *Skapanthus* was placed in synonymy with *Isodon*. Harley *et al.* (2003) recognized a new subtribe *Hanceolinae* (tribe *Ocimeae*) to accommodate *Isodon, Hanceola and Siphocranion*. Recent studies by Harley *et al.* (2004), Rice *et al.* (2011) and Suddee and Paton (2004) treated *Coleus* as congeneric with *Plectranthus*.

1.4 Micromorphology

Micromorphological and ultrastructural data (e.g. Cole and Behnke 1975) have contributed invaluable information to our understanding of the evolution and classification of angiosperms and play an important role in the modern synthetic systems of Angiosperms (e.g. Dahlgren 1979-80). During the last decade the application of scanning electron microscopes has greatly increased our knowledge of plant surfaces (Barthlott 1981).

The fruits of Lamiaceae family are schizocarps consist of indehiscent locules which separate to form four fruitlets, referred to as mericarps or nutlets. Morphology, shape, colour and size of the nutlets were used as diagnostic characters in classification (Schermann 1967). Mericarp morphology has been used as the most important character complex for a synthetic approach to the systematics of Lamiaceae that considers both phylogenetic and evolutionary aspects. Nutlet characters are potentially useful within the Lamiaceae at sectional, generic or species levels (Ryding1993a, 1994; Marin *et al.* 1994). Surface ornamentation of pollen has also been used successfully in a range of systematic studies. Pollen morphology including aperture number, size, shape and tectum ornamentation were studied in different members of the family Lamiaceae and found these features were helpful in its taxonomy (Abu-Asab and Cantino 1994; Bazarragchaa *et al.* 2012). Erdtman (1945) originally proposed a subfamilial level classification of Lamiaceae based only on pollen features. Hence a systematic study using SEM analysis of pollen and mericarps will be very useful to resolve the existing problem of generic level circumscription and species taxonomy of the *Plectranthus-Coleus* complex in India.

1.5 Molecular Phylogenetics

All known organisms both living and extinct are connected through descent from a common ancestor. The study of evolutionary relationships among organisms that share common ancestors is referred to as Phylogenetics. The output is mostly depicted as a bifurcating tree structure known as phylogenetic tree that represents their evolutionary history. The input datasets used to infer the trees can be morphological or molecular sequences. Morphological sequences are generated by observed morphological traits. Molecular data (DNA, RNA, Aminoacid) is obtained through sequencing technologies. Due to the continuously decreasing cost of Next-Generation Sequencing technologies, molecular sequences are nowadays the common source of data, especially for large scale datasets.

The basis of systematic study is derived from the classifications by Linnaeus (1735) who laid the frame work for later evolutionary schemes by dividing organisms into a hierarchic series of taxonomic categories. The naturalists of the 18th and early 19th centuries usually referred this hierarchy as the 'Tree of Life' (Fig. 1.2) which depicted the evolutionary history of all life forms on Earth, an analogy that was adopted by Darwin (1859). Thus the classification by Linnaeus therefore became reinterpreted as a phylogeny indicating not just the similarities between species but also their evolutionary relationships.

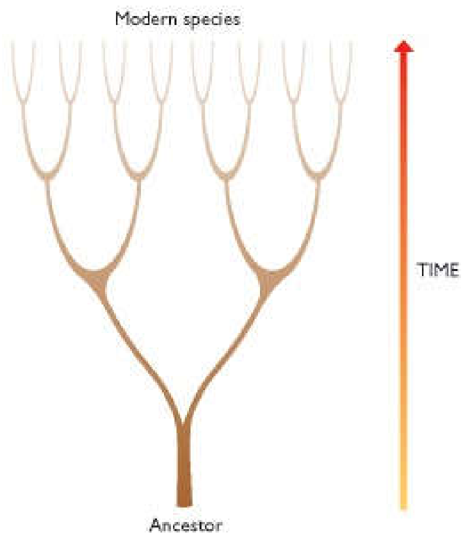

Fig. 1.2. The tree of life (Brown 2002)

Phylogenetic tree reconstruction is based on the assumption that present-day living organisms are the result of diversification and evolution from ancestral populations or genes. In computational phylogenetics, commonly used techniques to reconstruct evolutionary trees are maximum parsimony, maximum likelihood, and Bayesian techniques. Maximum parsimony used to find the phylogenetic tree that explains the evolutionary history of organisms by the least number of mutations. The statistical model of maximum-likelihood estimation in phylogenetics includes the calculation of probabilities for possible tree topologies (evolutionary hypotheses). However Bayesian inference assumes an *a priori* probability distribution of possible trees and employs Markov Chain Monte Carlo (MCMC) sampling algorithms. Both maximum likelihood and Bayesian inference rely on the likelihood function to assess possible tree topologies and explore the tree space. Now it reaches phylogenomic analyses with hundreds or even thousands of genes, which have led to the development of new, faster methods for phylogenetic reconstruction. Phylogenomic methods allow the exploration of the set of evolutionary trees for each gene in the genome of any species.

1.5.1. Molecular dating

The use of DNA sequences to estimate divergence times on phylogenetic trees (molecular dating) has gained increasing interest in the field of evolutionary biology in the past decade. Molecular dating provides detailed temporal frameworks for divergence events in phylogenetic trees, allowing diverse evolutionary questions to be addressed. Molecular dating combines information from the fossil or geological records and analyses of molecular data to estimate the ages of ancestral nodes. For determining the rate of molecular evolution and Calibrating the molecular clock, fossils of known age that represent the common ancestor of extant species or geological event of known age (such as the formation of a mountain range) that split the geographic range of a species in two, thus initiating a process of speciation were used. BEAUti/BEAST package is particularly applicable for species phylogenies for molecular dating. BEAST is a cross-platform program for Bayesian MCMC analysis of molecular sequences. It is orientated towards rooted, time-measured phylogenies inferred using strict or relaxed molecular clock models. It is intended both as a method of reconstructing phylogenies and as a framework for testing evolutionary hypotheses without conditioning on a single tree topology. BEAST uses MCMC to average over tree space, so that each tree is weighted proportional to its posterior probability. BEAUti (Bayesian Evolutionary Analysis Utility) is a graphical software package that allows the creation of BEAST XML input files (Drummond and Rambaut 2007).

1.6. Area of study

India is one of the most diverse biogeogrpahic regions of the world. The main land of India lies between 8° 4' and 37° 6' N latitude and 68° 7' and 97° 25' E longitude and it has a total area of 3287263 km^2, land boundary of about 15200 km and a coastline of 7517 km. It is bounded by the Indian Ocean on the south, the Arabian Sea on the south-west, and the Bay of Bengal on the southeast. It shares land borders with Pakistan to the west; China, Nepal, and Bhutan to the north-east; and Myanmar and Bangladesh to the east. In the Indian Ocean, India is in the vicinity of Sri Lanka and the Maldives; in addition, India's Andaman and Nicobar Islands share a maritime border with Thailand and Indonesia (Fig. 1.3).

1.6.1. Biogeographic Zones in India

India is country of vast biodiversity. It is divided into ten major biogeographic regions, based on the geography, climate and pattern of vegetation seen and the different organisms that live in them (Fig. 1.4). Each of these regions contains a variety of ecosystems such as forests, grasslands, lakes, rivers, wetlands, mountains and hills, which have specific plant and animal species.

1) Trans Himalaya

Trans Himalaya includes the Himalayan ranges immediately north of the Great Himalayan range. It covers an area of 186,200 km^2 in the cold and arid regions with sparse alpine steppe vegetation and several endemic species.

2) Himalaya

It covers an area of about 236,000 km^2. This area displays a wide altitudinal range and is among the richest zones in terms of species and habitat diversity. The zone has 56 protected areas and there are more endangered species in the Himalaya than anywhere else in India.

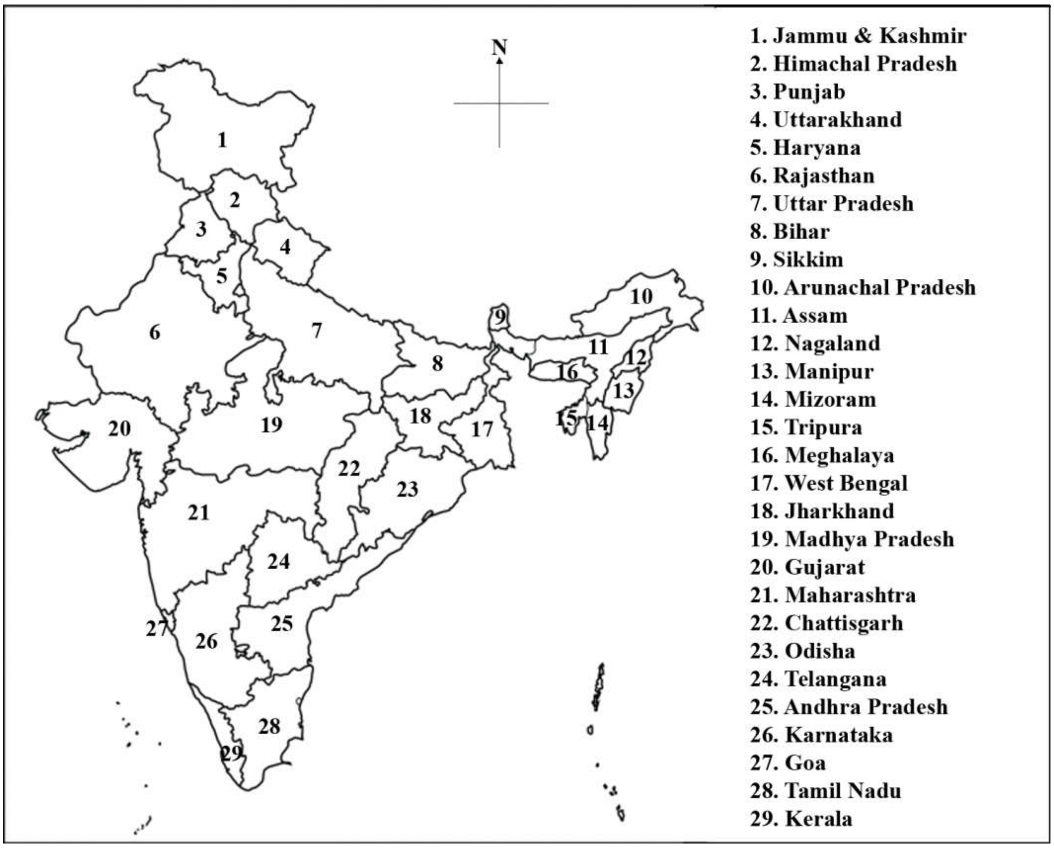

Fig. 1.3. Map of study area - India with state boundaries.

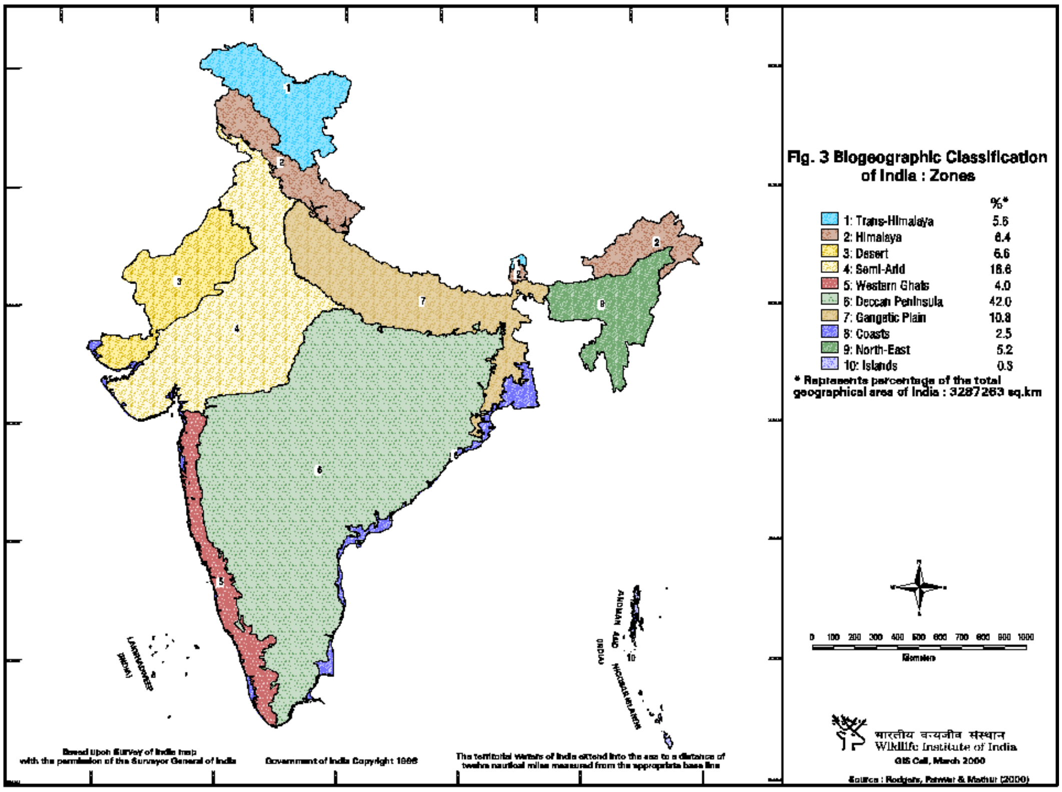

Fig. 1.4. Map of India with Biogeographic zones.

3) Indian Desert

It covers an area of 225,000 km^2, of which about 89 km^2 is protected. This is a part of Rajasthan state, from where, the great desert of western India namely 'Thar desert' starts. It is a highly fragile ecosystem and may lose it biodiversity richness rapidly and is characterized by dry and hot summer and cold winter.

4) Semi Arid

The semi-arid region spreads over 508,000 km^2 in the semi-arid regions. This area is found adjoining to the desert and a transitional zone between the desert and the denser forests of the Western Ghats. The natural vegetation is thorn forest. This region is characterized by discontinuous vegetation cover with open areas of bare soil and experience soil-water deficit throughout the year

5) Western Ghats

Western Ghats are a narrow stretch of mountain ranges running along the west coast of peninsular India. It extends from the southern tip of the peninsula northwards about 1600 km to the south of the river Tapti. The mountains rise to average altitudes between 900 and 1500 m above sea level, intercepting monsoon winds from the southwest and creating a rain shadow in the region to their East. The varied climate and diverse topography create a wide array of habitats that support unique sets of plant and animal species. The Western Ghats are amongst the 25 biodiversity hotspots recognized globally. The main vegetation types includes evergreen forest, semi-evergreen forest, moist deciduous forest, dry deciduous forest, dry scrub vegetation, the shoals and grass lands. The Western Ghats cover only 5% of India's land surface but contain more than a quarter (about 4,000) of the country's plant species.

6) Deccan Peninsula

The Deccan plateau lies in the rain shadow region of the Western Ghats. It forms the largest unit of peninsular plateau and covers about 43% of India's total land surface. The Deccan plateau is surrounded by the Western and the Eastern Ghats.

7) Gangetic Plain

The Gangetic plain extending up to the Himalayan foothills in the northern area. This area covers the eastern Rajasthan, Utter Pradesh, Bihar and West Bengal. The main diversity of this area is represented as secondary forest patches.

8) North-east India

North-east India is one of the richest flora regions in the country. It includes the seven sister states Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim and Tripura. The region is also known as the biogeographic gateway for plant migration as it is the meeting place of Himalayan Mountains with that of Peninsular India. The main vegetation types found here are tropical evergreen and semi evergreen forests, tropical deciduous forests, tropical bamboo forests, tropical grass lands, subtropical evergreen and semi evergreen forests, subtropical pine forest, temperate forest, swamp vegetation and sub alpine forests.

9) Coasts

Indian coastline extends over 5,500 km and larger parts of the coastal plains are covered by fertile soils on which different crops are grown. The backwaters are the characteristic features of the west coast and the east coast is characterized by extensive deltas of the east flowing rivers like Godavari, Krishna and Kaveri. Estuarine tracts with Mangrove vegetation is another characteristic feature of this coast.

10) Islands

There are two groups of Islands in India namely; the Arabian Sea islands and Bay Islands differ significantly in origin and physical characteristics. The Arabian Sea Islands (Lakshadweep) consists of 43 Islands and are the foundered remnants of the old land mass and subsequent coral formations. The Bay Islands include the Andaman and Nicobar Islands situated in the Bay of Bengal and includes 572 Islands. They are rich in diverse flora and have tropical rain forests.

1.6.2. Climate

The Indian plate experiences a wide range of climate. Koopen system revealed six major climatic subtypes, ranging from arid desert in the west, alpine tundra and glaciers in the north, and humid tropical regions supporting rainforests in the southwest and the island territories. Climatic regions in India include tropical wet, tropical dry, subtropical humid and mountain regions. India has four seasons: winter (December, January and February), summer (March, April and May), a monsoon rainy season (June to September), and a post-monsoon period (October to November). The Tropic of Cancer passes through the middle of India and hence the bulk of the country can be regarded as climatically tropical. The seasonality of rainfall is a remarkable feature of its climate with the monsoon winds over the Indian Ocean splitting in two directions, one move towards north crossing northeast India that forms the Bay of Bengal arm and the other moves from the southwest over the west coast towards northeast and forms the Arabian Sea arm.

1.6.3. Soil

According to The National Bureau of Soil Survey and the Land Use Planning, eight major groups of soil types are recognized. They are Alluvial soil, Red soil, Black soil, Laterite soil, Desert/arid soil, Peaty/marshy soil, Forest soil and Mountain soil. Alluvial soil occupy the major area of the country. Black soil is believed to be derived from the volcanic activity in the Deccan Plateau mainly occupies the Peninsular regions. Red soil mainly occupy eastern part of Peninsular India and respond to the proper use of fertilizers and irrigation. Laterite soil is found mainly in the Western Ghats, Eastern Ghats, Vindhya, Satpuras and Malwa Plateau and are rich in bauxite. Desert/arid soil seen under arid and semi-arid conditions and is deposited mainly by wind activities. Peaty/marshy soil is found in the areas of heavy rainfall and high humidity. Here the growth of vegetation is very less due to large quantity of dead organic matter/humus which makes the soil alkaline. Forest soil is mainly found in the regions of high rainfall and the soil is acidic due to the less humus content. Mountain soil can be found in the mountain regions of the country which is characterized by low humus and is acidic in nature.

1.7. A review of Ethnobotanical importance

Plectranthus is a large and widespread genus with a diversity of ethnobotanical uses. Of the 300 species of *Plectranthus,* 62 species are reported to be used as medicines, ornamentals, foods, flavours, fodder and material. Ethnobotanical uses of *Plectranthus* has been reviewed by Lukhoba *et al.* (2006). The aromatic nature of the genus is attributed to essential oil production. Monoterpenoids, sesquiterpenoids, diterpenoids and phenolics have been reported in species of this genus. The abietane diterpenoids are the most diverse of the diterpenoids isolated from species of *Plectranthus*. The labdane diterpenoid, forskolin, occurs in *P. barbatus* and could explain some of the traditional uses of this species. The important uses are cited below.

1.7.1. Medicine

The most frequently cited use of species of *Plectranthus* is for their medicinal properties, which accounts for over 85% of all uses. *P. amboinicus* and *P. barbatus* are used to treat a wide range of diseases and account for about 68% of all traditional uses of the genus.

1) Digestive conditions

Disorders of the digestive system are treated using 21 species of *Plectranthus* (Lukhoba *et al.* 2006). Species are used to treat stomach pain, nausea, vomiting, diarrhoea, mouth and throat infections and are used as purgatives, carminatives and as antihelmintics. *P. barbatus* is used for the treatment of stomachache and as a purgative (Kokwaro 1993), for nausea and for gastric and intestinal spasms in Brazil (Camara *et al*. 2003). *P. amboinicus* is popular in the treatment of dyspepsia, indigestion, diarrhoea and as a carminative in India and Africa (Morton 1992).

2) Skin conditions

A total of 20 species are recorded as being used for skin conditions. *P. barbatus* and *P. amboinicus* are the most frequently cited species for the treatment of burns, wounds, sores, insect bites and allergies. In Kenya *P. barbatus* is used in the treatment of wounds and ringworms (Githinji and Kokwaro 1993), to reduce swelling on bruises and for bathing babies suffering from measles (Kokwaro 1993). In addition it contains an essential oil that exhibits anti-allergic activities through passive cutaneous anaphylaxis inhibition. In India the juice of the leaves of *P. amboinicusis* used to treat skin allergies (Harsha *et al*. 2003).

3) Respiratory conditions

A total 15 species are recorded for the treatment of respiratory conditions. *P. barbatus* is the most frequently cited species used to relieve colds (Rajendran *et al.* 1999), cough (Neuwinger 2000; Chifundera 2001) and pneumonia and for general ailments (van Puyvelde *et al*. 1994). *P. amboinicus* is also frequently cited in the treatment of chronic coughs, asthma, bronchitis and sore throat in India and the Carribean (Morton 1992; Jain and Lata 1996; Ruiz *et al*. 1996).

4) Infections and fever

Fifteen species have been recorded for the treatment of infections and fever. *P. barbatus* is used to treat a range of infections including throat and mouth infections, tonsillitis (Neuwinger 2000), gastro-intestinal infections

(Gupta *et al*. 1993) as well as ear and eye infections. *P. amboinicus* is important in Asia and South America for the treatment of fevers (Morton 1992; Harsha *et al.*2003). It has also antimicrobial activity (Bos *et al*. 1983; Castillo and Gonzalez 1999) and it is reported to have antiviral activity against Herpes simplex virus-1 (Hattori *et al*. 1995) and anti- HIV inhibition activity (Kusumoto *et al*. 1995).

1.7.2. Horticultural uses

Almost 20 species were reported as having horticultural uses. The majority are ornamentals either planted for their colored and attractive foliage or for their beautiful flowers. Many species of *Plectranthus* grown as ornaments are resistant to diseases, they are usually succulent and can survive in dry conditions. Some species are planted as ornamentals in Africa, Asia, Northern and Southern America include *P. amboinicus, P. futicosus*, *P. ciliatus* (Garden Plants List 2004), *P. barbatus* (Bennet and Prance 2000) etc. *P. vertcillatus* (Garden Plants List 2004) are planted in gardens in South Africa. Cowpeas, green grams and maize are cultivated in areas where *P. barbatus* has been cleared as the plant is said to be a good indicator of fertile soil. The plant is used for making manure and is planted on the hillsides to prevent soil erosion.

1.7.3. Food

Nine species of *Plectranthus* are reported to be edible. The tubers of *P. rotundifolius* are a popular food in Tropical Asia (Ramachandran and Nair 1981; Purseglove 1987). The leaves of *P. mollis* (Maikhuri and Gangwar 1993) and *P. barbatus* (Fleurentine *et al*. 1983) are cooked as a vegetable. Leaves of *P. amboinicus* are chopped, made in to flour balls and fried in oil or butter (Dymoc 1885).

1.7.4. Food additives

The three species of *Plecranthus* reported as food additives. The leaves of *P. amboinicus* are used in food stuffings (Purseglove 1987), for flavouring and marinating beef and chicken to mask odor of strong smells associated with goat, fish and shellfish (Morton 1992) and to spice dishes containing tomato sauces. The leaves are sometimes eaten raw with bread and butter and in India, they may be added to beer and wine (Morton 1992).

1.7.5. Fodder

Different species of *Plectranthus* are mostly used as dry season fodder. *P. barbatus* is the most frequently cited among the economically important species. In Kenya and Yeman, it is fed to sheep, goats and cattle.

1.7.6. Other uses

In Kenya, the soft velvety leaves of *P. barbatus* are used as sanitary tissue (Githinji 1988), to clean milk guards and both the stems and leaves are used to hasten the ripening of bananas. *P. amboinicus* has scented leaves and these are often rubbed in to the hair and body after bathing (Morton 1992). A number of species are used for spiritual or religious purposes. For instance, *P. amboinicus* is offered to the spirits when a house is being built (Morton 1992). *P. mollis* is used to drive away evil spirits in India, Kenya and Tanzania (Githinji and Kokwaro 1993; Jain *et al*. 1994). The seeds of *P. mollis* are fried in mustard oil and then massaged all over the body as an insect repellant (Jain *et al*. 1994). *P. amboinicus* is also used as insect repellant (Prudent *et al*. 1995; Omolo *et al*. 2004).

1.8. Structure of the thesis

The remaining part of this thesis is organized as follows:

Chapter 2 provides a review of relevant literatures that are significant to the present study. A detailed review of earlier floristic works and Infrageneric classifications of the genus *Plectranthus*; review of pollen and mericarp micromorphology, molecular phylogenetics and biogeographic works with a special emphasis on family Lamiaceae are given.

Chapter 3 presents Taxonomic study, in which a complete taxonomic revision of the genus with a key to the species, descriptions, illustrations, photo plates, conservation status and other relevant notes are provided. A comparison of important morphological characters was also presented.

Chapter 4 describes SEM analysis of pollen and mericraps of the genus *Plectranthus.* In this chapter, we evaluated the systematic implications of pollen and mericarp micromorphology for providing reliable characters useful in separation of species within *Plectranthus–Coleus* complex.

Chapter 5 presents molecular phylogenetic studies using three chloroplast regions to analyze relationship with in the genus *Plectranthus* and revaluate and propose boundaries for *Plectranthus-Coleus* complex. This chapter also provides an attempt to molecular dating of *Plectranthus* based on already reported fossil evidence of Lamiaceae.

Chapter 6 provides a summary and conclusion of the work and addresses directions of future work.

In the chapters, from 3 to 5, a short introduction followed by materials and methods, results, discussion and conclusion are given to facilitate reading and showing the relevance of the approaches.

CHAPTER 2
REVIEW OF LITERATURE

CHAPTER 2
REVIEW OF LITERATURE

2.1. Taxonomy

In pre-Linnaean times the species of *Plectranthus* and *Coleus* were treated under the genus *Ocimum*. Later Linnaeus considered the important character of *Ocimum* as the tooth on the filaments of stamens. L'Hèritier (1788) established the genus *Plectranthus* to accommodate species which had no such tooth. He described the genus with two species *P. fruticosus* and *P. puntatus*. Later Nakai (1934) made *P. fruticosus* as type species of the genus and the generic characters of *Plectranthus* are based on this species. Infrageneric delimitation in *Plectranthus* is difficult due to lack of clear-cut morphological criteria and this has resulted in placing species under various generic names like *Coleus* Lour., *Solenostemon* Thonn., *Germanea* Lam., *Burnatastrum* Briq., *Englerastrum* Briq. etc. (Lukhoba *et al.* 2006). As a result of morphological studies, all these names have been synonymised under *Plectranthus* (Harley *et al.* 2004; Rice *et al.* 2011).

2.1.1. Earlier floristic works and Infrageneric classifications of the genus *Plectranthus*

Rheede (1678–1693) in his monumental work 'Hortus Malabaricus' mentioned three plants of the genus *Plectranthus* namely '*iribeli*' (Hort. Malab. 9:249, t.74, 1689) (=*Plectranthus vettiveroides* (Jacob) N.P.Singh & B.D. Sharma); *Perim-tolassi* (Hort. Malab. 10:299, t.74, 1689) (=*Plectranthus mollis* (Aiton) Spreng) and *Kurka* (Hort. Malab. 9:249, t.74, 1689) (=*Plectranthus rotundifolius* (Poir.) Spreng.).

Soon after the establishment of genus *Plectranthus* by L'Hèritier (1788), Lamarck (1788) created the genus *Germanea* in his Encyclopaedia based on two specimens which he named as *G. urticifolia* Lam. and *G. maculosa* Lam. Few years later, Salisbury (1796) identified that the specimens collected by L' Heritier and Lamarck are the same and he treated *Plectranthus fruticosus* L'Hèr. and *Germanea urticifolia* under *Plectranthus urticifolia*. Similarly, *G. maculosa* Lam., *P. punctatus* L' Hèr. and *Ocimum punctatus* of Linnaeus under *P. maculosa* Lam. During the same decade, Loureiro (1790) established the genus *Coleus* together with other 19 genera based on his collections from Huè and the nearby regions in Southern Vietnam. His descriptions were scanty and much of the type material has been lost. Several of his original descriptions do not uniquely match a single taxon in the Lamiaceae (Suddee *et al.* 2004). In the description of the only species *C. aromaticus,* Loureiro (1790) mentioned that the stamens are united at the base and this plant is similar to the *Marrubium zeylanicum odoratissimum*…of Hermann and *Marrubium odoratissimum zeylanicum*...of Burman. However, Brown (1810) and Blume (1826) did not consider this character of sufficient importance, and recognized only the genus *Plectranthus*. Brown (1810) in his '*Prodromous Florae Novae Hollandiae'* described six species of *Plectranthus.* Among these four species are now treated under *Plectranthus*. These are *P. australis* R.Br. (*P. parviflorus*), *P. graveolens* R.Br.*, P. congenitus* R.Br and *P. scutellarioides* R.Br.

Earlier works on Indian *Plectranthus* treated species distinctly under two generic names *Coleus* and *Plectranthus*. The genus *Isodon* (Schrad. ex Benth.) Spach was also treated congeneric with *Plectranthus* (Bentham 1831, 1832 & 1848; Hooker 1885; Gamble 1921, Mukerjee 1940). However, many species considered as *Plectranthus* or *Coleus* by these authors has been transferred to *Isodon* (Ryding 1993; Harley *et al.* 2003; Suddee *et al.* 2004). Bentham (1831, 1832 & 1848), also came to regard the fusion of stamens at the base as a character of over-riding importance and treated *Plectranthus* and *Coleus* as separate. In '*Plantae Asiaticae Rariores,*' Bentham (1831) described 13 species of *Plectranthus* under three sections (*Coleoides*, *Euplectranthus* & *Pyramidiu*m) and nine species of *Coleus* under three sections (*Calceolus*, *Aromaria* & *Solenostemon*). A year later, Roxburgh (1832) in his '*Flora Indica* or Descriptions of Indian Plants' described five species of *Plectranthus* without making any sections. In 1832 Bentham described 39 species of *Plectranthus* under seven sections (*Germanea, Coleoides, Heterocalyx, Melissoides, Isodon, Pyramidium* and *Amethystoides*) and 29 species of *Coleus* under three sections (*Calceolus, Aromaria* & *Solenostemon*). In DC Prodromous, Bentham (1848) described 66 species of *Plectranthus* under six sections (*Isodon, Pyramidium, Amethystoides, Melissoides, Germanea* and *Coleoides*) and 43 species of *Coleus* under three sections (*Calceolus, Aromaria* and *Solenostemon*).

Wight (1853) in his '*Icons Plantarum Indiae Orientalis'* illustrated two *Plectranthus* species (*P. wightii* Benth. and *P. macrai* Benth.) and three *Coleus* species (*C. spicatus* Benth., *C. barbatus* Benth. and *C. wightii Benth*.). Later Bentham & Hooker (1876) revised earlier classifications and rearranged the species under two sections. They are Sect. *Isodon* (which include *Isodon, Pyramidium, Amethystoides* and *Melissoides*) and Sect. *Germanea* (*Germanea* and *Coleoide*s). In sect. *Germanea*, with *Germanea* and *Coleoides* as subsections (in which the great majority of conventional *Plectranthus* spp. are placed), the calyx is 2-lipped with the upper lip consisting of a single broad tooth and the lower lip of four narrower acute or acuminate teeth: the cymes are usually (not always) sessile with the pedicels arising from the axis of the inflorescence. Sect. *Isodon*, with *Isodon*, *Pyramidium*, *Amethystoides* and *Melissoides* as subsections, was distinguished by the calyx being equally 5-toothed, in some groups more or less 2-lipped with the upper lip composed of 3 teeth and the lower lip of 2 teeth: the cymes are pedunculate and branched.

In *Flora of British India,* Hooker f. (1885) described 32 species of *Plectranthus* under 3 sections: Sect. *Isodon* (21 species), Sect. *Pyramidium* (1 sp.) and Sect. *Coleoides* (10 sp.) and eight species of *Coleus.* In '*A Hand Book to the Flora of Ceylon'*, by Trimen (1895) described six species of *Plectranthus* and four species of *Coleus*. Briquet (1897) in '*Die Natürlichen Pflanzen familien'* treated *Plectranthus* under six sections and *Coleus* under three sections (*Calceolus, Aromaria,* and *Solenostemonoides*). A similar classification was adopted by Briquet (1897), though *Germanea* and *Isodon* were treated as subgenera. In these subgenera the largest sections were *Coleoides* and *Isodon*, respectively. These sections were further subdivided into a number of series. A separate genus, *Burnatastrum* Briq. was based on three species previously in Bentham's Sect. *Isodon* namely, *P. lanceolatus* Benth. and *P. lavanduloides* Bak. (Both from Madagascar) and *P. spicatus* E. Mey. ex Benth. (From South Africa). The genus was separated on the grounds of circinnate calyx and the flowers being arranged in dichasia. However, when other species are taken into account, it will be seen that these characters tend to grade into *Plectranthus*.

Fyson (1915, 1932) gave an account of the endemic species of *Plectranthus* and *Coleus* seen in his floristic works. In his '*Flora of Presidency of Madras*' Gamble (1921) gave a detailed floristic account and an identification key for 14 species of *Plectranthus* and four species of *Coleus* without any sectional treatments. A true revisionary study on Lamiaceae so far known from Indian empire had been undertaken by Mukerjee (1940). He described 32 *Plectranthus* and 8 *Coleus* species in detail with an artificial key for identification. Of these, only 14 species are now treated as *Plectranthus* and most others were transferred to *Isodon.* It is considered as the only revisionary study undertaken after Bentham (1834), Hooker f. (1885) and Gamble (1921) on this genus in India.

2.1.2. Botanical works relevant to *Plectranthus* outside India

As part of an investigation concerning the factors affecting the frequency of polyploidy in the floras of the temperate and tropical regions of Africa and also as part of the revised edition of the Flora of the West Tropical Africa, Morton (1962) conducted a cytotaxonomic studies on the West African Labiatae. He thought that this cannot be done without revision of the genera. Following Brown (1810) and Blume (1826), he considered staminal fusion is an arbitrary character and treated *Plectranthus* and *Coleus* as conspecific with 15 species and one subspecies. Launert (1968), merged *Burnatastrum* and *Ascocarydion* under *Plectranthus* and gave illustrations of three species of *Plectranthus* namely *P. candelabriformis* Launert, *P. amboinicus* (Lour.) Sprengel and *P. mirabilis* (Briq.). While revising the Malesian Labiatae, Keng (1969) retained both *Plectranthus* and *Coleus* as separate. He identified five species of *Coleus* and eight species of *Plectranthus*.

Codd (1971), treated *Solenosteon, Englerastrum, Isodon*, and *Holostylon* as separate genera along with *Plectranthus*. He made tentative grouping of the genus *Plectranthus* in to five sections with the section subdivided in to three subsections. The sections and subsections were not given any formal names. Blake (1971) treated *Plectranthus, Coleus, Solenostemon, Rabdosia* and *Ceratanthus* as separate genera. He recognized 17 species of *Plectranthus* without any sectional classifications. During the preparation of a check-list of the flora of Jebel Marra Wickens & Mathew (1971) described a new species *Plectranthus jebel-marrae* Wickens & B.Mathew.

Codd (1975) presented a revision of 40 species of *Plectranthus*, one species of *Rabdosia* and three species of *Solenostemon* in Southern Africa. *Coleus* and certain other genera are made synonymous with *Plectranthus*. He provided detailed descriptions, illustrations, keys and distribution data for each species. Codd divided the genus *Plectranthus* in to six subgenera viz. Subgen. *Nodiflorus* (two species), Subgen. *Xerophilus* (one species), Subgen. *Burnatastrum* (five species), Subgen. *Coleus* (two species), Subgen. *Calceolanthus* (five species) and Subgen. *Plectranthus* (Sect. *Coleoides* with six species and four varieties; Sect. *Plectranthus* with 19 species and one variety). Mathew (1976) in his notes regarding expedition to Malaŵi described four species of *Plectranthus* from Malawi.

Cramer (1975, 1978), however, disagrees with the opinion of Morton (1962), Launert (1968), Codd (1971) and Keng (1969). Based on his studies on 40 specimens of eleven different species of *Coleus* from various localities in Sri Lanka, he opined that "the fusion of stamens in *Coleus* species are best observed in fresh material and pressing can at times cause a tearing of the staminal sheath towards the base, which may mislead in character analysis". In his opinion, the fusion of stamens in *Coleus*, in combination with secondary characters of calyx and floral leaves, forms a sufficient basis for circumscribing *Coleus* as a valid genus distinct from *Plectranthus*. He recognized 11 species and two varieties, including two new species *C. grandis* L.H.Cramer (=*P. barbatus* var. *grandis* (L.H.Cramer) Lukhoba & A.J.Paton) and *C. kanneliyensis* L.H.Cramer & S.Balas. (=*P. kanneliyensis* (L.H.Cramer & S.Balas.) R.H.Willemse. In this revision a key to the species and descriptions of new taxa are also provided.

Keng (1978) in *Flora Malesiana* treated *Coleus* as synonym under *Plectranthus*. He described 15 species of *Plectranthus* from Malesia. Examining all these views, Willemse (1979), opined that Cramer's view cannot be upheld for this complex, as it was based only on Sri Lankan specimens and agreed with Keng's opinion that *Coleus, Solenostemon*, *Rabdosia*, and probably some other closely related genera must be included in

Plectranthus. Wood (1984) described *Plectranthus hyemalis* J.R.I.Wood from Yemen along with species from other families. Paton & Brummit (1991) described a new species *P. seyanii* Paton & Brummitt from Malawi and adjacent countries. Forster (1992) described five new species *P. graniticola*, *P. minutus*, *P. nitidus*, *P. omissus* and *P. torrentícola* endemic to Queensland except for *P. nitidus* which also occurs in New South Wales. All are restricted in distribution and are endangered species.

Ryding (1993b) compared the two genera *Plectranthus* and *Isodon* and found to be dissimilar. The genus *Isodon* was considered to be misplaced in Ocimeae subtribe Plectranthinae and more closely related to subtribe Hyptidinae. He also compared the disjunct genus *Rabdosiella* to these two genera and regarded it to be polyphyletic. In this study the African *R. calycina* (Benth.) Codd was returned to *Plectranthus* as *P. calycinus* Benth., while the Asian *R. ternifolia* (D. Don) Codd was placed in *Isodon* sect. *Pyramidium* as *I. ternifolius* (D. Don) Kudo. Sykes and De Lange (1993) recorded *Plectranthus parviflorus* Willd. from the Kawhia and Tairua Ecological Districts of the North Island. They also found that this species is possibly indigenous and a new key was also given to the four species of *Plectranthus* that occur outside cultivation in New Zealand.

Forster (1994) described ten new species of *Plectranthus* from Queensland. In this account all species were illustrated and notes on their distribution, habitat, affinities and conservation status were provided. A key to the species of *Plectranthus* in Queensland was also presented. Ryding (1997) described a new species, *P. globosus* from Zaire. Four new *Plectranthus* taxa from South Africa were described and a species from *Coleus* was transferred to *Plectranthus* by Van Jaarsveld (1997). Subsequently Forster (1997) described and illustrated *Plectranthus amoenus* and *P. thalassoscopicus* as new species. Affinities and conservation status of both species were also discussed.

Paton and Ryding (1998) discussed the subtribes of the *Ocimeae* and new definitions of *Plectranthinae* and *Ociminae* were provided. The position of *Hanceola, Siphocranion* and *Isodon* within the tribe *Ocimeae* was also discussed and the three genera were placed as *incertae sedis*. A key to the subtribes of the *Ocimeae* and genera *incertae sedis* were also given and the genus *Skapanthus* was placed in synonymy with *Isodon*. Morton (1998a & b) transferred many *Coleus* species to *Plectranthus* from Ethiopian region and new names were put forwarded to some species. At the same time he described two new species of *Plectranthus* from Ethiopia and northern Kenya.

Ryding (1999) discussed the identity of *P. barbatus* and *P. comosus* along with two new species and the monotypic genus *Capitanya* was merged under *Plectranthus.* Edwards *et al.* (2000) described a new species *Plectranthus porphyranthus* from Zimbabwe. Later on Lukhoba and Paton (2000) described two new species from East Africa. A distinctive rheophyte *Plectranthus cataractarum* was described by Pollard and Paton (2001) from western Cameroon and Equatorial Guinea. Notes on its conservation, on the status of *Solenostemon* Thonn. and on rheophytism in Labiatae were also discussed in this study.

Ryding and Paton (2001) identified that *Ocimuma zatarhendi* Forssk., *O. aegyptiacum* Forssk. and *Plectranthus crassifolius* Vahl were conspecific with *P. tenuiflorus* (Vatke) Agnew and *P. aegyptiacus* (Forssk.) C. Chr. was regarded as the correct name of the taxon. A neotype of *O. aegyptiacum* and a lectotype of *Coleus tenuiflorus* Vatke were also designated. Lukhoba and Paton (2003) described a new species, *P. caespitosus* Lukhoba & A. J. Paton, similar to *P. pubescens* Baker. Two varieties within *P. barbatus* Andrews, namely *P. barbatus* var. *barbatus* and *P. barbatus* var. *grandis* (L. H. Cramer)

Lukhoba & A. J. Paton were delimited. They emphasized that *P. barbatus* var. *grandis* is widely cultivated and its treatment here reflects the ease of its distinction from other forms in Africa south of Ethiopia, while recognizing the morphological continuity within the *P. barbatus* complex.

Harley *et al.* (2003) made several new combinations and new synonomies affecting the following genera of Labiatae: *Keiskea, Collinsonia, Chingyungia, Perrierastrum, Plectranthus, Nepeta* and *Pitardia*. Apart from this a new subtribe *Hanceolinae* (tribe *Ocimeae*) was recognized to accommodate *Isodon, Hanceola* and *Siphocranion*.

In 2004, Suddee *et al.* revised the subtribe Plectranthinae as part of a revision of the tribe Ocimeae in continental South East Asia. A detailed account of descriptions, full synonyms relevant to South East Asian Floras, maps, line drawings, information about ethnobotany, distributions, habitats, ecology, endemism and conservation, selected specimen citations and an index to accepted names and synonyms were provided here for the different genera. Fourteen species of *Plectranthus* which include seven species (*P. amboinicus, P. barbatus, P. caninus, P. glabratus, P. mollis, P. rotunifolius, P. scutellarioides*) from India were described in this study.

Subsequently, Suddee and Paton (2004) lectotypified a little known species *Plectranthus montanus* described from India. They also synonymized a widespread African species *Plectranthus cylindraceus* under *P. montanus* after a detailed critical analysis of type specimens of both species. Along with this study, *Plectranthus griffithii* Hook.f. was transferred to the genus *Paralamium* and a new combination was made.

Ryding (2005) described a new species *Plectranthus igniarioides* from northern Somalia and the circumscription of *Plectranthus gillettii* which has been reported to occur in Somalia, was refined to include only the material known from Ethiopia and Kenya. Pollard (2005) erected and typified two new names, *Plectranthus epilithicus* and *P. occidentalis* in *Plectranthus* to accommodate taxa transferred from *Solenostemon.*

Edwards (2005) described two newly discovered species of *Plectranthus* from the Pondoland Centre of Plant Endemism, on the eastern seaboard of South Africa. The known distribution ranges of two other narrow endemics of the region. *P. emstii* and *P. praetermissus*, were expanded with new distribution records.

Pollard *et al.* (2006) described a new species *Plectranthus inselbergi* from Equatorial Guinea and Gabon and its ecology and taxonomic relationships are also discussed. Three new combinations and a new name in *Plectranthus* were provided for related species formerly placed in *Solenostemon* Thonn., and conservation assessments were made for all five species.

Lukhoba *et al.* (2006) carried out a review of ethnobotanicl uses of *Plectranthus*. The main aim of this review was to gather together all ethnobotanical information on *Plectranthus* and to map the data onto the most up-to-date phylogenetic classification in order to see if there are similar uses among related species and hence provide a framework for the prediction and exploration of new uses of species. The uses of 62 species of *Plectranthus* were mapped onto a current phylogeny based on DNA sequence data. The phylogeny revealed two major Clades, 1 and 2 and the members of Clade 1 (corresponding to the formally recognized genus *Coleus*) were richer in number and diversity of uses than members of Clade 2 (comprising the remaining species of *Plectranthus*).

A new species (*Plectranthus batianoffii*) known from several continental islands in north-east Queensland was described and illustrated by

Forster (2008) and a conservation status of Vulnerable was recommended. Meanwhile, Pollard and Paton (2009) made two new combinations, one new and one resurrected name in *Plectranthus* that are formerly placed in *Leocus* A. Chev. Forster (2011) described five new species of *Plectranthus* from Queensland are described together with notes on their habitat, distribution, affinities and conservation status.

Rice *et al*. (2011) in their article entitled "*Plectranthus*: A plant for the future?" described the various potential of southern African *Plectranthus* species. They pointed out that this genus is a significant, prolific and extensively used genus in southern Africa and plays a dominant role in both horticulture and traditional medicine.

Pollard and Paton (2012) made a new combination with *Isodictyophorus reticulatus* to *Plectranthus* (*Plectranthus reticulatus*) and thus the inclusion of *Isodictyophorus* Briq. in *Plectranthus* was completed. In 2014, Suddee *et al*. described a new species *Plectranthus phulangkaensis* from Thailand.

Abdel-Khalik (2016a) described a new species, *Plectranthus hijazensis* from Al-Baha Province in Saudi Arabia. Along with the description and its affinity with other species, a key to *Plectranthus* species of Saudi Arabia and the relevant morphological characters, particularly seed, pollen grains, trichomes, and anatomy of stem and leaf were also provided.

Concurrently, Abdel-Khalik (2016b) undertook a systematic revision of the genus *Plectranthus* in Saudi Arabia based on morphological, palynological, and micromorphological Characters of Trichomes. He conducted a critical systematic revision of 7 species in Saudi Arabia by means of numerical analyses based on thirty-one morphological characters, including vegetative parts, seeds, pollen grains, and trichomes. Macro- and micromorphological characters like, seed and pollen shape, size, coat sculpture, trichome structure were also included. It revealed the presence of seven species including two endemic species.

2.1.3. Recent Indian floristic works

As part of general floristic studies, taxonomic studies and field explorations of Lamiacean plants in India had been carried out elaborately in the recent past. The major local floras published in India which included *Plectranthus* and *Coleus* is enumerated in Table 2.1.

Table 2.1. Number of *Plectranthus* and *Coleus* species mentioned in the local floras in India.

Name of the State/ District	Authors of the flora	Year of publication	No. of species	
			Plectranthus	***Coleus***
Andhra Pradesh				
Visakhapatnam	Subba Rao, G.V. & Kumari, G.R.	2008	1	1
Arunachal Pradesh				
Arunachal Pradesh	Giri, G.S.*et al.*	2008	-	1
Bihar				
West Champaran	Battacharya, P.K. & Sarkar, K.	1998	1	-
Bihar (analysis)	Singh, N.P. *et al.*	2001	1	3
Hazaribagh	Paria, N.D. & Chattopadhyay, S.P.	2005	1	-
Chattisgarh				
Raipur, Durg, Rajnandgaon	Verma, D.M. *et al.*	1985	1	-
Bilaspur	Murthi, S.K. & Panigrahi, G.	1999	1	1
Indravathi Tiger Reserve	Kumar, A.	2003	1	-
Gujarat				
Saurashtra	Bole, P.V. & Pathak, J.M.	1988	-	2
Himachal Pradesh				

Himalayas	Atkinson, E.T.	1980	1	-
Himachal Pradesh	Chowdhery, H.J. & Madhwa, B.M.	1984	1	1
Jharkhand				
Chota Nagpur	Haines, H.H.	1910	1	-
Karnataka				
Banglore	Ramaswamy, S.V. & Razi, B.A.	1973	1	1
Hassan	Saldanha, C.J. & Nicolson, D.H.	1976	2	-
Mysore	Rao, R.R. & Razi, B.A.	1981	2	2
Karnataka analysis	Sharma, B.D. *et al.*	1984	8	-
Eastern Karnataka	Singh, N.P.	1988	3	-
Coorg	Keshava Murthy, K.R. & Yoganarasimhan, S.N.	1990	1	-
Uduppi	Bhat, K.G.	2003	3	1
Rajiv Gandhi N.P.	Manikandan, R. & Lakshminarasimhan, P.	2013	2	-
Kerala				
Travancore	Rama Rao, M.	1914	5	4
Calicut	Manilal, K.S. & Sivarajan, V.V.	1982	-	2
Cannanore	Ramachandran, V.S. & Nair, V.J.	1988	1	-
Silent Valley	Manilal, K.S.	1988	-	3
Malappuram	Babu. A.	1990	2	2
Palghat	Vajravelu, E.	1990	-	2
Thiruvananthapuram	Mohanan, M. & Henry, A.N.	1994	2	
Nilambur	Sivarajan, V.V. & Mathew, P.	1996	-	1
Agasthyamala	Mohanan, N. & Sivadasan, M.	2003	4	-
Parambikulam	Sujanapal & Sasidharan, N	2005	3	-
Pathanamthitta	Anilkumar, N. *et al.*	2005	1	
Alappuzha	Sunil, C.N. & Sivadasan, M.	2009	1	1
Madhya Pradesh				
Pachmarhi & Bori Reserves	Mukherjee, A.K.	1984	1	-
Madhya Pradesh	Mudgal, V. et al.	1997	1	3
Maharashtra				

Khandala	Santapau, H.	1967	2	-
Nassik	Lakshminarasimhan, P. & Sharma, B.D.	1991	3	-
Raigad	Kothari, M.J. & Moorthy, S.	1993	1	-
Mahabaleshwar & Adjoinings	Deshpandey, S.D. *et al.*	1995	1	-
Mizoram				
Mizoram	Sinha, G.P.*et al.*	2012	-	1
Punjab				
Punjab Plains	Nair, N.C.	1978	-	2
Punjab plants - Checklist	Sharma, M.	1990	-	3
Rajasthan				
Rajasthan	Shetty, B.V. & Singh, V.	1991	1	-
Tamil Nadu				
Nilgiri & Pulney hill tops	Fyson, P.F.	1915	2	-
Ooty, Coonoor, Kotagiri, Kodaikanal	Fyson, P.F.	1932	2	1
Nilgiri	Sharma, B.D.	1975	3	1
Tamil Nadu	Henry, A.N. *et al.*	1987	13	-
Coimbatore	Chandrabose, M & Nair, N.C.	1988	-	2
Central Tamil Nadu	Matthew, K.M.	1991	4	1
Pulney hills	Matthew, K.M.	1999	8	-
Tripura				
Tripura	Deb, D.B.	1983	-	2
Uttar Pradesh				
Allahabad	Sharma, B.D. & Pandey, D.S.	1984	-	1
Uttarakhand				
Mussorie	Raizada, M.B. & Saxena, H.O.	1978	-	1
Chamoli	Neithani, B.D.	1985	1	1
Union Territories				
Goa, Diu, Daman, Dadra & Nagar Haveli	Rao, R.S.	1986	1	-

2.2. Micromorphology

Micromorphological and ultrastructural data (e.g. Cole and Behnke 1975) have contributed invaluable information to our understanding of the evolution and classification of angiosperms and play an important role in the modern synthetic systems of Angiosperms (e.g. Dahlgren 1979-80). During the last decade the application of scanning electron microscopes has greatly increased our knowledge of plant surfaces (Barthlott 1981).

2.2.1. Mericarp micromorphology

Among various taxonomic data sources, fruit morphology has proven particularly interesting in the family Lamiaceae and has been used regularly for the past 150 years (Bentham 1832; Gray 1878; Briquet 1897). Subsequently, workers with Old World species have also demonstrated the taxonomic utility of fruit morphology as well as anatomy (Fabre and Nicoli 1965; Wojciechowska 1966, 1972; Wunderlich 1967; Ryding 1992a, b). Morphology, shape, colour and size of the nutlets were used as diagnostic characters in classification (Schermann 1967). Studies of nutlets in Lamiaceae have progressed over the past two decades from purely light microscopy to scanning electron microscopy. Nutlet characters can be used successfully at different taxonomic levels, depending on the characters chosen and the variation present.

Witztum (1978) studied the structure and development of the unusual epidermal mucilage cells in the epidermis of *Coleus blumei* nutlet which produce pentagonal and hexagonal plates. The possible function of this cell type is also discussed.

Mericarp micromorphology of Great Plains *Scutellaria* was investigated by Lane (1983). He emphasized that Scanning electron and light microscopic studies of mericarps of the Great Plains species of *Scutellaria* have proven taxonomically very useful. Each species produces mericarps with a unique suite of morphological characters like fruit color, size and shape; conformation of papillae; and epidermal cell type and pattern. This information supports the reduction of *S. wrightii* to synonomy with *S. resinosa*, and the treatment of *S. parvula* as having three varieties, rather than as three separate species.

Husain *et al.* (1990) conducted a micromorphological study of some representative Old World genera in the tribe Saturejeae. In their study Scanning electron micrographs of nutlet surface show a wide range of variation, not only among genera, but also at lower levels of classification. In this view, they could seen that nutlet surface structure, as seen with the SEM, of representative species of eight genera in the tribe Saturejeae provided useful additional character combinations in delimiting these closely related genera. Rejdali (1990) performed the seed morphology and taxonomy of the North African species of *Sideritis* L. This study found that seed sculpturing was found to be of great value for separating taxa at all levels of the hierarchy.

Ryding (1993a, 1994, 1995) studied the nutlet characters especially the pericarp structure of some genera of the family Lamiaceae using scanning electron microscopy. Cantino (1992a) and Ryding (1998) used characters like ultrastructure, surface morphology and shape in cladistic analysis within the family Lamiaceae.

Nutlet sculpturing of 23 *Teucrium* species was studied by Marin et al (1994). They discussed the significance of nutlet microcharacters as additional taxonomical markers in the infrageneric classification of the genus *Teucrium*. They found that the nutlets of analysed species were characterized by the presence of the oil glands of various densities.

Turner and Delprete (1996) also studied the Nutlet sculpturing of 22 taxa of *Scutellaria* sect. *Resinosa* and the monotypic genus *Salazaria* by scanning electron microscopy. They discussed the significance of nutlet microcharacters within sect. *Resinosa* especially as compared to closely related sections. They opined that *Salazaria* had nutlet sculpturing quite different from all taxa belonging to sect. *Resinosa*. The results showed that species could be grouped by surface sculpturing into seemingly meaningful phenetic clusters.

Oran (1996) investigated the gross nutlet morphology and surface sculpturing of *Salvia* species and found that these characters are variable and taxonomically useful and developed descriptive categories for shape, surface sculpturing pattern and cellular deposits.

The detailed SEM study of nutlet morphology of 156 species of tribe *Nepeteae* of the family Lamiaceae was examined by Budantsev and Lobova (1997). They recognized two main types of mericarp surfaces, ie, smooth and sculptured and also discussed the taxonomic significance of these characters. The authors also investigated the pericarp structure of 34 species. Based on the combination of nutlet morphology, pericarp structure and vegetative and floral features recognized three informal generic groups within the tribe.

Duletiae-Lauseviae and Marin (1999) analyzed the pericarp structure of 37 species representing 13 genera of four tribes of Nepetoideae (Lamiaceae). They found that pericarp characters studied are of taxonomical significance and mainly correlated with the generic or infrageneric classification of some genera.

Nutlet morphology of *Hemigenia* and *Microcorys* using SEM were examined by Guerin (2005). He found that significant variation, mainly useful at the infrageneric level, was found in nutlet shape, nature of the attachment scar, nature of surface sculpturing, exocarp cell shape and sculpturing, and nature of the indumentums.

Moon and Hong (2006) studied the Nutlet morphology and pericarp structure of 16 *Lycopus* species by light microscopy (LM) and scanning electron microscopy (SEM), and a detailed description of nutlet morphological features for all examined taxa was also provided. The study proved that the nutlets of all taxa were well adapted to typical hydrochory (or nautochory) with an air-filled pericarp, and myxocarpy was not at all found. The authors also found that present nutlet morphological and anatomical data that appear to be useful as diagnostic characteristics for delineation purposes at the specific or interspecific levels.

Kaya and Dirmenci (2008) investigated nutlet morphology of 39 taxa of Turkish *Nepeta* species using both stereoscopic and scanning electron microscopy (SEM) and opined that nutlet characters within the genus are of taxonomic significance. In this study, the authors found three main types of surface ornamentations, smooth, partly smooth, and sculptured, and 7 subtypes, undulate-ridged, cellular, reticulate, protuberance, papillate, verrucate, and tuberculate. They concluded that external nutlet characters, especially surface texture, could help in the classification of species of the complex genus *Nepeta* in future.

Salmaki *et al.* (2008) undertook a detailed study on the nutlet micromorphology of 31 taxa of *Stachys* distributed in Iran by light and scanning electron microscopy. They concluded that the type of sculpturing is more useful for separating species within the sections, rather than correlating the related ones to each other. However, nutlet microsculpturing is not useful in separating large natural groups like sections in this genus. It seems also that contrary to other genera of Lamiaceae, nutlet characters are of low phylogenetic value in this genus, especially due to high variation even among closely related species.

Comparative anatomical and micromorphological studies on *Teucrium creticum* and *Teucrium orientale* var. *orientale (Teucrium* sect. *Teucrium*, Lamiaceae) were carried out by Dinc *et al.* (2009). The results obtained from studies carried out under scanning electron microscope (SEM) showed that the nutlet micromorphology varies between the two taxa and in both taxa, the nutlet surfaces are reticulate and glandular. Eglandular hairs are also present.

Moon *et al.* (2009) documented the nutlet morphology (SEM) of the tribe Menthae and the presence or absence of myxocarpy in 65 genera in order to assess the systematic value of nutlet characters and to evaluate the existing molecular phylogenies for this group. The result showed significant variation in nutlet shape, morphology of the abscission scar, distribution of trichomes, and surface sculpture. They recognized that the representative nutlet features proved to be phylogenetically informative in Mentheae mainly at the generic level.

Ozkan *et al.* (2009) examined the mericarp morphology of 12 *Salvia* (Lamiaceae: sub-family Nepetoideae: tribe Mentheae: sub-tribe Salviinae) taxa from Turkey using scanning electron microscopy. The mericarps exhibited variation in size, shape, colour, and surface sculpturing. Ryding (2009) investigated pericarp and seed structure in 16 species of the old *Caryopteris* s.l. and in a few species of the related *Rubiteucris, Amethystea, Trichostema* and *Ajuga*. They found that pericarp structure was found to be very variable, and the variation largely matches the most recent classification.

Kaya *et al.* (2009) investigated the nutlet surface features of *Satureja* species using both stereoscopic and scanning electron microscopy (SEM). It is clear that in future studies, external nutlet characters, especially surface texture, could be useful in species classification of the complex *Satureja* genus. Kahraman *et al.* (2010) studied the morphology, anatomy, palynology and nutlet micromorphology of the rediscovered Turkish endemic *Salvia ballsiana* (Lamiaceae) and their taxonomic implications.

To reconstruct the evolutionary history of tribe Mentheae, Moon *et al.* (2010) analyzed the distribution of selected morphological characteristics such as nutlet shape and existence of abscission scar and its form. Eshratifar *et al.* (2011) conducted Micromorphological studies on nutlet and leaf indumentum of genus *Teucrium* L. (Lamiaceae) in Iran. They studied 12 species belonging to the 6 sections of the genus *Teucrium* L. by scanning electron microscope (SEM).

Mericarp morphology of 15 taxa of *Salvia* section *Hymenosphac*e Benth. in Turkey were investigated by Kahramen *et al.* (2011) using light microscopy (LM) and scanning electron microscopy (SEM) to evaluate the utility of mericarp characters in systematic studies. The authors found that variation in the nature of surface sculpturing, mericarp shape and size, exocarp cell shape, nature of transverse sections and abscission scar diameter were formed useful diagnostic characters. They also proved that variation was sufficient to distinguish taxa at species level, including morphologically similar species and the data provided here are also relevant to phylogenetic questions at higher levels within *Salvia*.

Coisin and Gostin (2011) studied the nutlet micromorphology of *Salvia glutinosa* using scanning electron microscopy (SEM). They proved that the nutlet characters are important taxonomic indices for a correct determination of species. Satil *et al.* (2012) investigated the nutlet morphology of 32 taxa of *Stachys* sect. *Eriostomum* (Lamiaceae) using scanning electron microscopy (SEM), and a detailed description of the nutlet morphological features of all examined taxa was provided. They also discussed the systematic and biological implications of the nutlet characteristics within the genus.

Capitani *et al.* (2013) described the nutlet micromorphology, anatomy, myxocarpy (mucilage exudation) and mucilage structure of Argentinean chia (*Salvia hispanica* L.) using scanning electronmicroscopy (SEM). The proximal composition of nutlets and mucilage was also studied. The nutlet morphology of 11 taxa of *Mentha* L. distributed throughout Turkey was investigated by Tarimcilar *et al* (2013) using scanning electron microscopy (SEM). This study showed that some nutlet morphological characteristics can be utilised as additional diagnostic characteristics in delimitations of *Mentha* at the species and infraspecific levels.

Dogu *et al.* (2013) reevaluated the taxonomic status of subspecies *Teucrium lamiifolium* subspecies in Turkey based on macro and micromorphology, anatomy and chemistry. Light and scanning electron microscope analyzes revealed striking differences in colour, size, sculpture and gland density between nutlets of the two taxa. Leaf indumentum and nutlet surface micromorphology of 13 taxa belonging to the *Teucrium* sect. *Teucrium* was studied by Genc *et al.* (2015) with the aid of scanning electron microscope. Macro and micro morphology of nutlets of 23 taxa belonging to 12 genera of Lamiaceae from Al-Taif, Saudi Arabia was studied for the first time by Hassan and Al-Thobaiti (2015) using both light and scanning electron microscope. Observations revealed that nutlet color, shape, size and presence of areole are of limited taxonomic value. However the pericarp sculpturing are the most important diagnostic characters for differentiating the species through a constructed key.

Kaya *et al.* (2015) examined the morphological characters of the nutlets of *Cyclotrichium* in Turkey using scanning electron microscopy (SEM). The results suggested that nutlet morphology of the examined specimens exhibits some variation in size, shape and sculpture and the micromorphological characters were very much useful in solving taxonomic problems of *Cyclotrichium*.

Krawczyk and Głowacka (2015) presented results of examination of fruit surface in the genus *Lamium* L. (Lamiaceae) using scanning electron microscopy (SEM). The purpose of this study was to define new features that differentiate taxa difficult to identify on the basis of macromorphological features, such as species of hybrid origin and subspecies within *Lamium.* Their results showed that the SEM analysis of fruit surface allowed defining new diagnostic features for almost all studied representatives of the genus *Lamium* except for some species.

Abdel-Khalik (2016) conducted a systematic revision of the genus *Plectranthus* (Lamiaceae) in Saudi Arabia Based on Morphological, Palynological, and Micromorphological Characters of Trichomes. The author investigated the morphology and ultrastructure characters of seeds, pollen grains and trichomes in order to evaluate their systematic value of these characters in specific and intraspecific separation of the Saudi Arabian *Plectranthus* species. A critical systematic revision of 7 species of *Plectranthus* in Saudi Arabia was also conducted by means of numerical analyses based on thirty-one morphological characters, including vegetative parts, seeds, pollen grains, and trichomes. Studied Macro and micromorphological characters like seed and pollen shape, size, coat sculpture and trichome structure. It revealed the presence of seven species, including two endemic species. The results proved that pollen and trichome characters were found to be valuable while seed characters presented only minor taxonomic value. They also suggested that the results offer useful data for evaluating the taxonomy of *Plectranthus* both at subgeneric and sectional levels.

Genc *et al.* (2017) examined the nutlet and leaves micromorphology of 27 *Teucrium* taxa using SEM. The result shows that significant variation was noticed on the nutlet surface ornamentation and indumentum and this was mainly useful at the sectional level. The epidermal features of the nutlets which are specific to each section were also determined in this study.

2.2.2. Pollen micromorphology

Earlier studies on pollen of Lamiaceae was based mainly on the use of the light microscope. Nabli (1976), who started to use both Scanning Electron microscopy (SEM) and Transmission Electron microscopy (TEM) to investigate the surface structure and exine ultra-structure of pollen of *Teucrium* and various other selected genera of the family. Erdtman (1945) originally proposed a subfamilial level classification of Lamiaceae based only on pollen features. Pollen morphology including aperture number,size, shape and tectum ornamentation were studied in different members of the family Lamiaceae and found these features were helpful in its taxonomy (Abu-Asab and Cantino, 1994; Bazarragchaa et al., 2012). However, Perveen and Qaiser (2003) and Al-Watban et al. (2015) studied pollen morphology of several species in different genera of the family Lamiaceae and suggested that it is useful in grouping and identifying the species.

Erdtman (1952) summarized previous light microscope studies of pollen of Lamiaceae, notably those of Leitner (1942) and Risch (1940), and later Risch (1956) gave a general description of pollen of Lamiaceae. Most light microscope examinations have concentrated on general shape and measurements and numbers of colpi, rather than details of surface ornamentation, which can be seen most clearly with the SEM. Seven species of the Hyptidinae have previously been studied in this way by Leitner (1942) and are all hexacolpate, which is characteristic of some subfamilies of the Lamiaceae.

Waterman (1960) examined 50 species of pollen grains of the family Lamiaceae of Michigan. The characteristics of pollen grain morphology were discussed and a key was also constructed based on pollen characters. Henderson *et al.* (1968) studied the pollen morphology of *Salvia* and some related genera. They used pollen morphology as an additional useful taxonomic tool in assessing relationships and delimiting taxa both in *Salvia* and its putative allies

The pollen morphology of subtribe Hyptidinae of family Lamiaceae was investigated by Rudall (1980). He found that the pollen grains are 6-colpate, with reticulate surface sculpturing, ranges from a type with large lumina surrounding numerous small puncta to a type with smaller lumina surrounding fewer larger puncta. The result also proved that the range of surface characters appears to represent an evolutionary series, but taxonomic applications are limited.

Cantino and Sanders (1986) attempted a subfamilial classification of family Lamiaceae and reported the number of pollen cells and colpi for 108 genera of the family. They summarized and discussed the character data that support Erdtman's subfamilial classification and evaluated Bentham's and Briquet's treatments of the family in the light of support from Erdtman's subfamilies.

To understand the relationship of *Trichostema* to other genera, Abu-Asab and Cantino (1989) examined the pollen of 16 species of *Trichostema* (including *Isanthus*) by using both light microscopy and scanning electron microscopy. They included monotypic genera *Amethystea* and *Cardioteucris* in the survey because their floral morphology suggested a close relationship to *Trichostema*. They found that pollen of all three genera was 3-zonocolpate and tectate-perforate, with conical supratectal projections of varying size.

Harley *et al.* (1992) studied the pollen of 20 species of Ocimum and four closely allied genera with the aid of light, scanning electron and transmission electron microscopy. Four pollen types were described, three were subdivided. Keys were also provided to the types and subtypes. Results showed some notable parallels with taxonomic opinion. Pozhidaev (1992) suggested that in the family Lamiaceae 6-colpate pollen grains originated from 3-colpate ones.

Trudel and Morton (1992) examined pollen morphology of 118 species of Lamiaceae native to North America using SEM. They found that pollen in this family is subspheroidal and either tricolpate (subfamily Lamioideae) or hexacolpate (subfamily Nepetoideae). They also discussed the value of pollen as a taxonomic character in this family and stated that pollen provides the primary basis for recognition of subfamilies in the Labiatae.

Abu-Asab and cantino (1992) undertook a palynological survey of subfamily Lamioideae and revealed that majority of the genera have tricolpate, inoperculate pollen with a tectate-perforate to microreticulate exine, suprareticulate sculpturing and simple columellae. Similar study on the pollen morphology in tribe Mentheae was carried out by Wagstaff (1992). The study found that all pollen has simple columellae with a tectate-perforate to semitectate exine structure. Harley (1992) reviewed the pollen morphological studies in subtribe Ociminae and evaluated the potential value of pollen characters both in taxonomic revisions and in the understanding of relationships and evolution within the family Lamiaceae.

The pollen morphology of 15 species of *Caryopteris* (Lamiaceae) was documented by Abu-Asab *et al.* (1993). Pollen morphology and correlated variation in floral and fruit morphology suggested that *Caryopteris* comprises three primary phenetic groups. Subsequently Abu-Asab and Cantino (1993) conducted a palynological survey of Tribe Prostanthereae (Labiatae) and revealed that the pollen is tricolpate or 6- (8) colpate, tectate-perforate to reticulate, with or without spinulose sculpturing; the columellae are simple and the colpal membranes bear sexine elements. At the same time Abu-Asab and Cantino (1993) also conducted a palynological survey of tribe Ajugeae (Labiatae) and in their study five pollen types were distinguished based on differences in colpal structure (operculate vs. inoperculate), supratectal sculpturing, and the structure of the columellate stratum.

Pollen morphology was surveyed in 60 genera of subfamilies Lamioideae and Pogostemonoideae and two genera of uncertain subfamilial affinities: *Anisomeles* and *Eurysolen* by Abu-Asab and cantino (1994). They found that pollen in all Pogostemonoideae, most Lamioideae, *Anisomele*s, and *Eurysolen* is tricolpate with suprareticulate sculpturing. Variants found in a few genera of Lamioideae include tetracolpate and hexapantocolpate pollen and psilate, granulate, and rugulate sculpturing.

Zhou *et al.* (1997) attempted a SEM study of pollen morphology in *Mosla* and the representative species of the allied genera, *Collinsonia, Elsholtzia, Keiskea, Perilla*, and *Perillula* and the result revealed that the pollen surface sculpture of *Mosla* (except *M. cavaleriei*) and *Perilla* has discontinuous ridges, while that of the other genera has the suprareticulate ornamentation. Mártonfi (1997) studied the pollen size and exine structure of 11 *Thymus* species from the Carpathians and Pannonia by using light and scanning electron microscopy. He concluded that the pollen grains of all 11 species are hexazonocolpate, varying in shape from suboblate to euprolate. The value of pollen characters for taxonomic purposes and the position of the taxa studied within the framework of tribe Mentheae were also discussed in this study. Azizian *et al*. (2001) described and compared the pollen morphology of 8 species of the genus *Nepeta* L. native to Iran based on SEM studies. Taxonomic value of pollen morphology was also discussed in this study.

Moon and Hong (2003) studied and documented details of pollen morphology of 15 species of the genus *Lycopus* (Lamiaceae, Mentheae) using light microscopy (LM), scanning electron (SEM), and transmission electron microscopy (TEM). The result showed that pollen is mostly medium or sometimes small in size, with a circular amb, oblate prolate in shape, hexacolpate with granular membranes; the exine is bireticulate, unbranched columellae and a continuous, lamellated endexine. The result also indicated that the value of pollen characters for taxonomic applications was limited.

The pollen morphology of six species of *Keiskea* and three representative taxa of *Collinsonia* was studied in detail using LM, SEM, and TEM by Hong (2007). The work suggested that in both genera, pollen grains are monad, hexacolpate, and mostly medium in size. This study demonstrated that the pollen morphology of the two genera was well distinguished and easily supporting the separation of *Keiskea* from *Collinsonia*.

Celenk *et al.* (2008) carried out a detailed study of the pollen morphology of forty taxa of the genus *Nepeta* L. using light microscopy (LM) and scanning electron (SEM) microscopy. They concluded that the pollen grains are hexacolpate (very rarely tetracolpate) with granular membranes. Also compared the pollen morphology of the genus with infrageneric relationships. Subsequently Celenk *et al.* (2008) undertook a palynological study of the genus *Mentha* L. (Lamiaceae). They investigated the pollen morphology and exine structure of 10 *Mentha* species using light microscopy and scanning electron microscopy and found that the pollen grains of all the species were hexazonocolpate with granular membranes and a circular amb, varying in shape from prolate-spheroidal to suboblate. The results indicated that the pollen characters of the genus are valuable for taxonomic applications and may be useful for classification.

Akgul *et al.* (2008) examined the morphological features of pollen of 19 Turkish species of the complex genus *Marrubium* using light and scanning electron microscopy. In this study they recognized three main types in the genus based on exine sculpturing and revealed that palynological characters are of taxonomic significance in the genus.

Moon *et al*. (2008) investigated the pollen morphology and ultrastructure of the subtribe Salviinae with light, scanning electron, and transmission electron microscopy. In addition, cladistic analyses of the obtained morphological data, supplemented with *rbcL* data from GenBank, were also conducted in order to assess the phylogenetic signal of palynological characters. The result found that *Salviinae* pollen was small to large, oblate to prolate in shape, with a circular to slightly elliptic amb, and mostly hexacolpate. Their combined phylogenetic analyses showed that the addition of palynological characters contributed to improved resolution and also increases bootstrap support values in comparison with molecular phylogenetic analyses.

Pollen grains of 30 taxa of the genus *Stachys* and one species of its closely related genus *Sideritis* (*S. montana*) distributed in Iran were examined by Salmaki *et al.* (2008) using light and scanning electron microscopy. The result shows that the basic shape of the pollen grains in most taxa studied is prolate-spheroidal, but subprolate, spheroidal and oblatespheroidal pollen grains can also be found in few species and the grains are usually tricolpate and tetracolpate. The surface showed variation from microreticulate (the frequent type), reticulate, perforate, foveolate-psilate to foveolate. They compared the major pollen morphological features and discussed on the basis of taxonomical concepts.

Arogundade and Adedeji (2009) studied the pollen grain morphology of three species and a variety of *Ocimum* L. (Lamiaceae) in Southwestern Nigeria using light microscopy. They emphasized that this study was an attempt to use the pollen characteristics to delimit, classify and trace probable evolutionary relationships among the taxa. Kahraman *et al*. (2010) in their study on anatomy, trichome morphology and palynology of *Salvia chrysophylla* Stapf (Lamiaceae) included SEM studies on the pollen grains of the species and revealed that they are oblate-spheroidal and their exine ornamentation is bireticulate-perforate.

Jang & Hong (2010) investigated the pollen morphology of 13 taxa (34 specimens) of the genera *Glechoma* L., and *Marmoritis* Benth. using light, scanning electron, and transmission electron microscopy. The result found that pollen grains of all studied taxa are prolate-spheroidal to prolate in shape and mostly hexacolpate with granular membranes. The results also revealed that *Glechoma* and *Marmoritis* have rather similar pollen morphological features, however, fine details of sexine ornamentation are characteristic to differentiate the pollen taxa and these differences may be useful in establishing the taxonomic boundary between two genera, they are too weak to segregate diagnostic characters.

Concurrently, Jang *et al*. (2010) studied the pollen morphology of 18 species (32 specimens) representing all three currently recognized sections of the genus *Elsholtzia* (Elsholtzieae - Lamiaceae) in detail using light, scanning electron and transmission electron microscopy. The study proved that the pollen grains are mostly prolate-spheroidal to prolate, and rarely oblate-spheroidal to subprolate in shape, hexacolpate with granular aperture membranes and sexine ornamentations observed are perforate, rugulose-bireticulate, and bireticulate. They concluded that among the present palynological data, the variability observed in sexine ornamentation of the genus could be of systematic significance and current infrageneric classification of the genus *Elsholtzia* is partially congruent with pollen morphological data.

Kose *et al*. (2011) examined pollen morphological structures of eight Turkish species of *Ajuga* under light and scanning electron microscopes. It was revealed that the pollen grains of *Ajuga* taxa are more or less suboblate-subprolate in shape, tricolpate and the exine sculpture is granulate or reticulate. Floral and pollen grains of *Pogostemon cablin* (Lamiaceae) from three different habitats were studied by Li *et al.* (2011) using stereoscope and scanning electron microscope (SEM). They provided the micrographs and morphological differences among the three different populations were also tabulated. Apart from that the results provided scientific basis for recognition and distinction of *Pogostemon cablin* varieties.

Ozler *et al.* (2011) undertook a detailed study on the pollen morphology of 30 taxa of the genus *Salvia* from Turkey by light (LM) and scanning electron microscopy (SEM). They recognized that the basic shape of the pollen grains in most taxa is suboblate, subprolate, oblate–spheroidal or prolate–spheroidal and the grains are hexacolpate in all taxa, but in *S. recognita* octacolpate pollen was also found. Reticulate–perforate, reticulate–granulate and bireticulate are the different exine sculpturing types present in this genus. They compared the pollen morphological characteristics and discussed on the basis of taxonomical concepts. And it is found that in some cases, these characters are useful in distinguishing the sections and also to delimit the species.

Bazarragchaa *et al.* (2012) examined the pollen morphology of 21 taxa belonging to 16 genera of the subfamilies: Ajugoideae, Scutellarioideae, Nepetoideae and Lamioideae from Mongolia using scanning electron microscope (SEM). Their study suggested that pollen characters form a useful tool to differentiate various genera in the family Lamiaceae. They found that tricolpate pollen were found in the genera belonging to subfamilies Ajugoideae, Scutellarioideae, Lamioideae, whereas, hexacolpate pollen were found in genera belonging to the subfamily Nepetoideae.

Boi *et al.* (2013) studied the pollen micromorphology of plants from four populations of the Tyrrhenian insular endemic *Stachys salisii* using light and scanning electron microscopy. The preliminary results showed some differences between the populations analyzed as regard to pollen surface micromorphology and dimensions.

Similar study on the pollen morphology of 29 species of *Scutellaria* from both the Old and the New World was conducted to evaluate their taxonomic importance for infrageneric classification of the genus by Jamzad & Hasani-Nejad (2014). The study revealed that all examined pollen grains are isopolar, tricolpate, suboblate, oblate spheroidal, prolate spheroidal to subprolate and the exine is mainly bireticulate perforate. The study also concluded that the exine ornamentation was a diagnostic character useful for the infrageneric classification of *Scutellaria*.

Al-Watban *et al*. (2015) investigated the pollen morphological characters of 6 species belonging to 4 genera of the subfamily Stachyoideae (Lamiaceae) growing naturally in Saudi Arabia with the aid of light microscope (LM) and scanning electron microscope (SEM). This study was conducted to find new features that might increase knowledge of pollen morphology of the species, and also to help the taxonomic characterization of the Stachyoideae genera. The study showed that pollen grains are mainly 6-zonocolpate or rarely 3-zonocolpate.

The pollen morphology of 48 taxa of the genus *Lamium* was investigated and documented by Atalay *et al.* (2016) using light microscopy (LM) and scanning electron microscopy (SEM). Result found that pollen grains are oblate-spheroidal to subprolate in shape and tricolpate. Three major exine sculpturing patterns: reticulate, granulate and microreticulate were observed. The results indicated that the exine sculpturing pattern of this genus is systematically informative at sectional level, but not at the species and infraspecific levels. In the present study, the palynological data are compared with available phylogenetic studies to evaluate the systematic value of pollen characters in the genus.

Azzazy (2016) examined the pollen morphology of seven taxa belonging to Lamiaceae which are commonly used as medicinal plants by light microscopy and scanning electron microscopy. The main shape of pollen grains in the most taxa were suboblate, subprolate, oblate-spheroidal or prolate-spheroidal and the grains were hexacolpate or octacolpate. He noticed that three distinct exine sculpturing existed: reticulate-perforate, reticulate, granulate, and bireticulate.

Doaigey *et al*. (2017) investigated the pollen morphology of 20 species belong to 16 genera of the Lamiaceae using Light Microscopy (LM) and Scanning Electron Microscopy (SEM). The study revealed that the pollen grains were characterized by 3-zonocolpate or 6-zonocolpate and size of the pollen is variable between the genera but not among the species of the same genus. The surface pattern of the exine varies from fine reticulate, rough reticulate, mega-reticulate, reticulate-perforate, bireticulate-perforate or granulate, leading to 6 types of pollen grains. These variations revealed by this study imply that pollen morphology may be of significant value sharing in solving problems in the classification of Lamiaceae members. They also provided a key to the species based on the morphological features of pollen grains. Pollen morphology of *Plectranthus asirensis* was also included in this study.

2.3. Molecular Phylogeny

Lamiaceae, one of the largest and most distinctive angiosperm families, have long been considered a "natural" group (Stevens 1984). Lamiaceae has traditionally been considered closely related to Verbenaceae, but recent phylogenetic studies shows that many genera classified in Verbenaceae should be transferred to Lamiaceae (Schäferhoff *et al.* 2010; Li *et al.* 2016). However the polyphyly of Lamiaceae was first proposed based on gynoecial morphology (Junnel 1934), palynology(Abu-Asab and Cantino

1992), and phylogenetic analyses of non-DNA data (Cantino 1992) and subsequently corroborated by molecular research (Wagstaff & Olmstead 1997; Wagstaff *et al.* 1998). Based on these studies, the traditionally circumscribed family Verbenaceae was thought to be paraphyletic, but more recent molecular studies of Lamiales (Refulio-Rodriguez & Olmstead 2014; Schäferhoff *et al.,* 2010) have shown that Verbenaceae as traditionally circumscribed were polyphyletic, with genera such as *Vitex* L., *Clerodendrum* L., and *Callicarpa* L. being more closely related to the traditional Lamiaceae than they are to Verbenaceae *s. str*. Recent phylogenetic studies of angiosperms (Soltis *et al*. 2011), and especially Lamiales (Refulio-Rodriguez & Olmstead 2014; Schäferhoff *et al.,* 2010), place both Lamiaceae and Verbenaceae within a large clade called "core Lamiales" where Lamiaceae are sister to a well-supported clade comprising Orobanchaceae and several small families (Mazaceae, Paulowniaceae, Phrymaceae, Rehmanniaceae), and Verbenaceae are sister to the small African family Thomandersiaceae.

In Lamiaceae, Harley *et al.* (2004) recognized 236 genera (comprising more than 7000 species), 226 of which were assigned to seven subfamilies: Ajugoideae, Lamioideae, Nepetoideae, Prostantheroideae, Scutellarioideae, Symphorematoideae and Viticoideae. Ten genera that could not be placed in a subfamily were listed as incertae sedis. The monophyly of five of the seven subfamilies (Ajugoideae, Lamioideae, Nepetoideae, Prostantheroideae, and Scutellarioideae) has been supported by molecular studies (Roy and Lindqvist 2015).

Reconstructions of phylogenetic history often provide the basis for conclusions concerning evolution and biogeography. In Earlier days morphological, cytological, and isozyme analysis were used to infer the pattern of phylogenetic divergence. A numerical phenetic study conducted by El- Gazzar and Watson (1970) provided support for Erdtman's subfamilial classification. Affinities of Lamiales were evaluated by Cantino (1982) based on cladistic principles.

Independent analyses of phylogenetic relationships in the *Scutellaria angustifolia* complex were carried out by Olmstead (1989) using both molecular and morphological data. A best estimate of the phylogenetic relationships among the ten taxa of this species complex was derived from a synthesis of the molecular and morphological analyses. This approach provided greater resolution than the congruence approach and retains the interpretative value of using two independent data sets, which would be lost if the data were combined. They found that the phylogeny based on morphology is both less well resolved than, and not congruent with, the phylogeny based on molecular data. However, morphology provided important clues to help resolve one portion of the phylogeny that is poorly resolved using the molecular data.

Nunez *et al.* (1990) proposed a new taxonomic division of the section *Sideritis* (Lamiaceae) on the basis of morphological, cytological and chemical characters and possible evolutionary pathways were also discussed.

The pericarp structure of 205 species of Lamiaceae subfamily Nepetoideae tribe Ocimeae has been investigated by Ryding (1992a). The result showed that in its basic structure, the pericarp of Ocimeae corresponds to that of other Nepetoideae and the exocarp has usually both mucilaginous and nonmucilaginous cells. Unlike other Labiatae, Plectranthinae (except *Alvesia*, *Isodon* and *Siphocranion*) has a plate like content in the mucilaginous cell. On the basis of pericarp characters an informal division of Ociminae was suggested. Considering the distribution of stamen and pericarp characters, it is found that the genera *Capitanya*, *Pycnostachys* and *Solenostemon* are suggested to originate from *Plectranthus*. The author concluded that Ocimeae species which grow in arid habitats tend to produce more mucilage and to have a larger plate like content in the mucilaginous cells than species from moist or wet habitats.

A preliminary cladistic analysis by Cantino (1992a) suggested the polyphyletic origin of Lamiaceae. This analysis supported the hypothesis of origin of gynobasic-styled Labiatae in southern China or Indomalaysia (Wu & Li, 1982). An Australian origin was hypothesized here for the cosmopolitan genus *Teucrium* based on the distributions of its closest relatives. At the same time Cantino (1992b) carried out a cladistic analysis to evaluate the major classifications of Lamiaceae in Bentham's (1876), Briquet (1895-1897), Erdtman (1945) and Wunderlich's (1967) systems.

Kaufmann and Wink (1994) studied the molecular systematics of the Nepetoideae using *rbcL* gene sequences. Sequences were evaluated with character states (maximum parsimony; PAUP) and distance methods (neighbor- joining; MEGA). This study also agreed with classical systematics that all taxa studied cluster within the Nepetoideae and are clearly distinguished from members of the subfamily Lamioideae.

Ryding (1995) investigated the pericarp structure in 158 species of the families Lamiaceae and Verbenaceae. A cladistic analysis was performed on the basis of pericarp characters only. The abandonment of subfamily Pogostemonoideae as a taxonomic unit was considered in this analysis.

Wagstaff *et al*. (1995) carried out a parsimony analysis of cpDNA restriction site variation which supported the monophyly of subfamily Nepetoideae. However, a close relationship among Nepetoideae and other gynobasic-styled Labiatae was not supported, indicating that a gynobasic style has evolved independently in at least two clades of Labiatae. The inferred relationships were also congruent with the classification of Cantino (1992b), Harley (1992), and Wagstaff (1992) but conflict to varying degrees with traditional classifications. The analysis also supported the monophyly of four tribes of Nepetoideae.

Wagstaff and Olmstead (1997) undertook a parsimony analysis of Labiatae and Verbenaceae using *rbcL* sequences which supported the monophyly of Labiatae *s.l.* The result also revealed that the representatives of subfamily Verbenoideae (Verbenaceae *s.str.*) do not support for a monophyletic group with the Labiatae *s.l.* The inferred phylogeny also provided a framework to interpret character evolution.

Subsequently, Wagstaff *et al.* (1998) analysed cpDNA sequences (*rbcL* and *ndhF*) independently and in combination to resolve phylogenetic relationships in Labiatae *s.l.* All three analyses supported the monophyly of Labiatae *s.l.*

Interrelationships within the *Leucas* group was investigated by Ryding (1998) using cladistic analysis of gross morphological, anatomical and cytological data. Different analyses were made, with and without continuous characters, and with and without characters with overlapping states. The result suggested that continuous characters and characters with overlapping states may contain a considerable amount of phylogenetic information. The result also revealed that *Leucas* is paraphyletic with *Acrotome* and *Leonotis* as subgroups, but no changes in the genus delimitations have been proposed. The endemic *Leucas* species from Asia (excluding Arabia) and Socotra formed monophyletic groups. The study concluded that *Leucas* was suggested to have originated in northeast tropical Africa, and to have migrated from this area over Arabia to the Indian subcontinent.

To determine the origin of Macaronesian *Sideritis*, Barber *et al*. (2002) constructed independent phylogenies comprising sequence data from both chloroplast and nuclear markers. Sampling included 7 island taxa drawn from the Macaronesian subgenus *Marrubiastrum* and 25 continental taxa representing all four sections of subgenus *Sideritis*. They showed that Subgenus *Marrubiastrum* and the two continental perennial sections form well-supported monophyletic groups in both individual and combined analyses while the annual sections are not monophyletic in any analysis and emphasized that further sampling of annual taxa is needed to resolve these relationships.

Prather *et al*. (2002) investigated the phylogenetic relationships of 16 species of *Monarda* (Lamiaceae) using sequences of ITS. *Thymus* and *Mentha* were used as outgroups, and *Blephilia, Clinopodium, Conradina, Hesperozygis, Monardella, Pycnanthemum*, and *Ziziphora* were included in the ingroup to test the monophyly of *Monarda.* Two parsimony searches were conducted after removing redundant sequences from the analysis, one with indels scored as missing and a second with indels treated as binary characters. The analysis revealed that both searches yielded congruent results, but the treatment of indels as binary characters resulted in considerably more resolution within Monarda.

As a part of the Ph.D. work Bunsawatt (2002) carried out phylogenetic analysis using chloroplast *trnL-trnF* and nuclear ribosomal internal transcribed spacer (ITS) to test the monophyly of *Mentha.* Based on *trnL-trnF* data, *Mentha* appears monophyletic. However, ITS data place the *Mentha* species into two distinct clades that include 12 other *Mentheae* genera.

Lindqvist and Albert (2002) evaluated the origins of the Hawaiian mints using phylogenetic analyses of DNA sequence data from the plastid *rbcL* and *trnL* intron loci and the nuclear ribosomal 5S NTS. From analysis the Hawaiian genera were found to be monophyletic but deeply nested inside another lamioid genus, *Stachys*. The result revealed that Hawaiian mints were found to be most closely related to a group of temperate North American

Stachys from the Pacific coast, suggesting that the Hawaiian mints derived from a single colonization event from western North America to the Hawaiian Islands. Based on chromosomal evidence and phylogenetic analyses, they hypothesized that the Hawaiian mints may be polyploid hybrids whose reticulate genomes predate the Hawaiian dispersal event and are derived from *Stachys* lineages with flowers exhibiting insect- vs. bird-pollination characteristics. Thus the result also suggested that the Hawaiian endemic mints may provide yet another insular system for the combined study of polyploidy, hybrid cladogenesis, and adaptive radiation.

Jamzad *et al.* (2003) studied the phylogenetic relationships in *Nepeta* L. (Lamiaceae) and related genera based on ITS sequence data. In this study 43 species of *Nepeta* and representatives of closely related genera and outgroups were sequenced. Parsimony analysis indicated that *Nepeta* is monophyletic and composed of five major monophyletic groups, most of which comprises species belonging to more than one section in previous classification.

Steane *et al.* (2004) studied the phylogenetic relationships between *Clerodendrum* (Lamiaceae) and other Ajugoid genera inferred from nuclear and chloroplast DNA sequence data. Here they showed that the Australian monotypic genus *Huxleya* evolved from within *Clerodendrum* hence they sunk *Huxleya* into *Clerodendrum* and make a new combination, *Clerodendrum linifolium*.

Walker *et al.* (2004) conducted a preliminary investigation of infrageneric relationships within *Salvia*, and the monophyly of the genus and its relationship to other members of the tribe Mentheae using the chloroplast DNA regions *rbcL* and *trnL-F*. The study concluded that *Salvia* is not monophyletic, *Rosmarinus* and *Perovskia* together were sister to an Old World clade of *Salvia.*

Paton *et al.* (2004) presented a phylogeny of basils and allies (Lamiaceae, tribe Ocimeae) based on sequences of the *trnL* intron, *trnL–trnF* intergene spacer and *rps16* intron of the plastid genome. The authors used maximum parsimony with equally and successively weighted characters, bootstrap resampling, and Bayesian inference to reconstruct phylogenies and to assess statistical support for clades. This phylogenetic study was used to investigate the distribution of morphological, pericarp anatomical, chemical, and pollen characters as well as the geographical distribution of the clades. The result found that tribe Ocimeae is monophyletic and easily diagnosable with morphological synapomorphies and there are monophyletic clades within Ocimeae that broadly correspond to currently recognised subtribes: Lavandulinae, Hyptidinae, Ociminae, and Plectranthinae. Only Lavandulinae has clear non-molecular synapomorphies and several currently recognised genera are not monophyletic. This phylogenetic study revealed that the current circumscription of the genus *Plectranthus* is paraphyletic. They recognized two clades: *Coleu*s and *Plectranthus* within subtribe Plectranthinae and opined that previously used morphological characters cannot diagnose clades within the sub-tribe. They emphasised the need of further sampling to support monophyly within the group. The study also supported an Asiatic origin for Ocimeae and there are several secondary occurrences in Asia arising from the African Ociminae and Plectranthinae clades. Colonisation of Madagascar occurred at least five times, and New World colonisation occurred at least three times.

Phylogenetic analyses of nucleotide sequences of the ITS and 5.8S subunit of nuclear ribosomal DNA and the *trnL* gene and *trnL-trnF* spacer of the chloroplast genome for 33 of the 72 genera in the Mentheae tribe were performed by Trusty *et al.* (2004). Maximum parsimony analysis of the combined data set shows moderate bootstrap support (74%) that *Bystropogon* is sister to the Old World taxa *Acinos, Ziziphora*, and *Clinopodium vulgare*.

When analyzed separately, the ITS and *trnL/F* data sets do not agree as to the sister group to *Bystropogon*, although none supports a sister relationship with *Minthostachys*. The cpDNA phylogeny strongly supports a relationship of *Bystropogon* with a clade of New World mint taxa (90% bootstrap value). Due to the apparent conflict between chloroplast and nuclear characters observed in the phylogenies, the authors were not certain of the true biogeographic relationship of *Bystropogon*.

Brauchler *et al*. (2005) performed a parsimony analysis of *trnK* intron sequence data of 51 accessions representing 15 genera of Nepetoideae and two genera of subfamily Ajugoideae to test the monophyly of the genus and to elucidate its phylogenetic placement within subtribe Menthinae. Tree topology revealed a well supported "core group" indicating four distinct lineages. Based on the phylogenetic reconstructions the result concluded that the genus as currently circumscribed is polyphyletic.

To investigate the monophyly of *Conradina* and its relationship to other endemic mints of the southeastern United States and to understand the patterns of diversification in *Conradina* Edwards *et al*. (2006) carried out a molecular phylogeny inferred by sequencing ITS and plastid regions. The study found that ITS sequence data strongly support monophyly of *Conradina*, in agreement with evidence from morphology but plastid sequence data do not support a monophyletic *Conradina* and place the genus as paraphyletic to *Clinopodium, Stachydeoma*, and *Piloblephis*.

Walker (2007) presented an evolutionary interpretation of staminal variation within the tribe Mentheae to characterize the staminal morphology of the various lineages of *Salvia* and related genera. The result concluded that the independent origin of the staminal lever mechanism on at least three different occasions in *Salvia* and supported polyphyly of the genus.

Barber *et al.* (2007) presented a phylogenetic study of the genus *Sideritis* (Lamiaceae) from sequences of the nuclear ribosomal DNA internal transcribed spacers (ITS) and two plastid regions (*trnL* intron, *trnT-trnL* intergenic spacer) in order to reconstruct relationships among all extant island taxa using both nuclear and chloroplast data. The result suggested that individual phylogenies reconstructed from the nuclear and chloroplast sequence data were incongruent, and differing placements of taxa were well supported in each of the two datasets. This incongruence had enabled them to identify several instances of potential cytoplasmic introgression, suggested that hybridization may have been important in the evolution of *Sideritis* in Macaronesia.

Scheen *et al*. (2008) conducted a molecular phylogenetic analysis of tribe Synandreae (Lamiaceae) using plastid *trnL-trnF* region and *trnS-trnG* spacer and the nuclear ribosomal 5S non-transcribed spacer (5S-NTS). They did the analysis to assess phylogenetic relationships within Melittidinae and the result showed that the monophyly of subtribe Melittidinae is not supported either by molecular or morphological data.

Conn *et al.* (2009) assessed the generic delimitations of seventy species of the tribe Chloantheae using chloroplast *ndhF* and nuclear ITS nucleotide sequence data. They used maximum parsimony and Bayesian phylogenetic inference methods for analyses of the two datasets independently and in combination. The result of the analysis revealed that topologies derived from each marker were broadly congruent, but better resolution and stronger branch support was achieved by combining the datasets and the monophyly of the Chloantheae was also confirmed.

Phylogenetic analysis of 14 taxa of *Isodon* (Lamiaceae) found in Japan and South Korea was examined by Maki *et al*. (2010) using sequence variations in 11 chloroplast DNA regions. They concluded that the phylogenetic tree based on the sequence of 6478 bp did not reflect the previous taxonomic treatment of the genus at sectional level because the three main clades contained species in different sections. Apart from this, it was clear that individuals from different populations in the same species were rarely monophyletic in the tree. The authors realized that lineage sorting of chloroplast DNA variations following rapid divergence of the taxa was likely to have caused complex phylogeny of the taxa and another possible explanation could be ancient introgressions and resultant chloroplast capture.

Yuan *et al.* (2010) employed a phylogenetic study using four chloroplast DNA regions, *trnT-L*, *trnL-F*, *trnD-T,* and *trnS-fM*, to clarify the generic boundaries of *Clerodendrum* and its relationship to allied genera. The results concluded previous studies that there are three well-supported clades in the currently recognized *Clerodendrum*: an Asian clade, an African clade, and a Pantropical Coastal clade. The results also pointed out that *Clerodendrum* as currently circumscribed is not monophyletic and also sheds light on the evolution of an intriguing breeding strategy that avoids self-pollination or/and sexual interference.

To reconstruct the evolutionary history, test previous hypotheses of classification, explain biogeographic patterns and to elucidate character evolution of subtribe Menthinae, Brauchler *et al.* (2010) analysed two chloroplast (*trnK* intron, *trnL-F*) and one nuclear (ITS) regions of 278 accessions, representing 38 out of 40 genera of subtribe Menthinae and 11 outgroups. Maximum parsimony (MP) and Bayesian analysis were used for separate and combined data to interpret the results. This study revealed that low sequence divergence resulted in low phylogenetic resolution especially at the base of the clade indicated a rapid radiation accompanied by considerable ecological diversification and speciation.

Scheen *et al.* (2010) presented a phylogenetic analysis of Lamiaceae subfam. Lamioideae (including subfamily Pogostemonoideae) based on chloroplast sequences: *trnL* intron, *trnL-trnF* intergenic spacer, and *rps16*. It was considered as the first analysis that included all major lamioid and pogostemonoid genera. This study strongly supported the monophyly of Lamioideae *s.l.* (i.e., including Pogostemonoideae). The Pogostemonoideae which sometimes considered as a subfamily was found subsumed in Lamioideae *s.l*. Based on their findings they divided Lamioideae into nine tribes by adding three new tribes: Gomphostemmateae Scheen & Lindqvist, Phlomideae Mathiesen, and Leucadeae Scheen & Ryding.

Zhong *et al*. (2010) presented a phylogenetic analyses of *Isodon* and related genera using the nuclear ribosomal internal transcribed spacer (nrITS), cpDNA regions *trnL–trnF* region and *rps16* intron), and morphological data. The results clarified the relationships among *Isodon* with its putative related genera. The question of monophyly of *Isodon* and its relationship with *Siphocranion* was also discussed. They also described a new subtribe Siphocranioninae of tribe Ocimeae to accommodate species of *Siphocranion.* They found the current circumscription of genus *Isodon* including *Skapanthus oreophilus* as monophyletic. The work revealed that *Isodon* forms a distinct subtribe Isodoninae within tribe Ocimeae and three strongly supported subclades within the genus.

Mathiesan *et al.* (2011) studied the Phylogeny and biogeography of the lamioid genus *Phlomis* (Lamiaceae) based on three cpDNA regions (*trnL* intron, the *trnL – F* intergenic spacer, and the *rps16* intron). The results supported a split of the genus into two separate groups that are recognised here as the genera *Phlomoides* and *Phlomis* in order to decrease taxonomic complexity. The close relationship between *Phlomis s.l.* and *Eremostachys*, pointed out by several authors, was also confirmed. The results suggested that the *Phlomis s.l.* lineage has a Central Asian origin in an area around Western China.

Bendiksby *et al.* (2011) presented an updated phylogeny and classification of Lamiaceae subfamily Lamioideae based on DNA sequence data from four chloroplast regions (*matK*, *rpsl6*, *trnL* intron and *trnL-F* spacer). The phylogenetic positions of 10 out of 13 previously unplaced small or monotypic Asian lamioid genera and 37 additional lamioid species have been identified, and the classification was updated accordingly. Results from parsimony and Bayesian phylogenetic methods corroborate earlier results, but phylogenetic resolution as well as overall branch support are improved in this analysis.

Pastore *et al.* (2011) presented a phylogenetic analyses of the subtribe Hyptidinae (Lamiaceae) based on nuclear ITS and ETS, and plastid *trnL-F*, *trnS-G*, *trnD-T*, and *matK.* The monophyly of Hyptidinae and almost all genera was well-supported, with noticeable paraphyly of *Hyptis* which is ancestor of all remaining genera of Hyptidinae. A preliminary discussion on the taxonomic treatment of the complex and the subdivision of *Hyptis* were also presented.

Curto *et al.* (2012) discussed the Development of phylogenetic markers from single-copy nuclear genes for multi locus, species level analyses in the mint family (Lamiaceae). They presented the strategy and results of marker development for phylogenetic analysis in *Micromeria*, using publicly available DNA sequences and ESTs from related genera from Lamiaceae, subfamily Nepetoideae.

Drew and Sytsma (2012) presented a detailed perspective on the evolution of the tribe Mentheae based on a phylogenetic analysis of cpDNA and nrDNA. This is one of the most comprehensive analyses using a fossilcalibrated chronogram, and an examination of staminal evolution. They analyzed data from four cpDNA and two nrDNA markers representing all extant genera within the tribe Mentheae using the programs BEAST, Lagrange, S-DIVA, and BayesTraits. They work concluded that tribe Mentheae and all five of its subtribes have a Mediterranean origin and have dispersed to the New World multiple times. It is also concluded that worldwide cooling trends probably played a large role in the diversification and present day distribution of the tribe Mentheae and additional work is needed to ascertain relationships within some Mentheae genera, especially in the subtribe Menthinae.

Salmaki *et al.* (2013) performed molecular phylogeny of tribe Stachydeae (Lamiaceae subfamily Lamioideae). In this study they carried out parsimony and Bayesian phylogenetic analyses of nuclear (ribosomal ITS) and plastid (*trnL* intron, *trnL– trnF* spacer, *rps16* intron) DNA sequence data from a taxonomically and geographically broad sampling of the tribe to identify major evolutionary lineages and to test taxonomic hypotheses within this largest of all lamioid tribes. The result showed that both nuclear and plastid data corroborate monophyly of the tribe, with *Melittis* as sister to all remaining Stachydeae.

Drew and Sytsma (2013) presented a phylogenetic analysis of 72 accessions representing 31 species of *Lepechinia* using data from three plastid (*trnL-F*, *ycf1*, *ycf1-rps15* spacer) and four nuclear [internal transcribed spacer (ITS), external transcribed spacer (ETS), granule-bound starch synthase I (GBSS)I, pentatricopeptide repeat region (PPR)-AT3G09060] DNA regions. In this study data were analyzed using parsimony, maximum likelihood and Bayesian approaches. Divergence time estimation using BEAST showed *Lepechinia* had a mid/late Miocene origin.

In 2014, Yu *et al.* presented a Phylogeny and historical biogeography of *Isodon* (Lamiaceae) using sequences of three plastid markers, the nuclear ribosomal internal transcribed spacer (nrITS), and a low-copy nuclear gene (LEAFY intron II). The evolution of chromosome numbers in this genus was also investigated using probabilistic models. Their results supported a monophyletic *Isodon* that includes the two disjunct African species, both of which likely formed through allopolyploidy. They suggested that an overland migration from Asia to Africa through Arabia during the early Miocene as the most likely explanation for the present disjunct distribution of *Isodon* and the opening of the Red Sea in the middle Miocene may appear to have had a major role in disrupting floristic exchange between Asia and Africa. In addition, they also suggested a rapid radiation of *Isodon* occurred in the late Miocene and it corresponds with one of the major uplifts of the QTP and subsequent aridification events. The result also supported the hypothesis that geological and climatic events play important roles in driving biological diversification of organisms distributed in the QTP area.

Roy and Lindqvist (2015) investigated the evolutionary relationships within the subfamily Lamioideae (Lamiaceae) based on pentatricopeptide repeat (PPR) nuclear DNA sequences and compared the phylogenetic results with previously published sequence data from a concatenated data set comprising four cpDNA loci. They incorporated representatives of all 10 lamioid tribes and some unclassified taxa, analyzed the data using phylogenetic inference, and estimated divergence times and ancestral areas for major nodes. The results showed overall topological similarities between the cpDNA and PPR phylogenies with strong support for most tribes and also suggested an Oligocene-Miocene origin of the Lamioideae crown group. Asia and the Mediterranean region appear to have been centers of diversity and place of origin for many lamioid tribes. This study represented the first phylogeny of subfamily Lamioideae inferred from low-copy nuclear DNA data. They showed that most lamioid tribes were corroborated, although the exact circumscription of two tribes was questioned. The result also shed further light on the evolutionary relationships within Lamioideae, and this study demonstrates the utility of the PPR region for such subfamilial-level phylogenetic studies.

Yao *et al.* (2016) conducted a phylogenetic analyses of the genus *Pogostemon* s.l. (Lamiaceae) using the ITS and five plastid regions (*matK*, *rbcL*, *rps16*, *trnH-psbA*, *trnL-F*) and this study confirmed the monophyly of *Pogostemon* and its sister relationship with the genus *Anisomeles.* Molecular dating and biogeographic diversification analyses revealed that *Pogostemon* split from its sister genus in southern and Southeast Asia in the early Miocene and the early strengthening of the Asia monsoon system that was triggered by the uplifting of the Qinghai–Tibetan Plateau may have played an important role in the subsequent diversification of the genus. In addition, their results suggested that transoceanic long distance dispersal of *Pogostemon* from Asia to Africa occurred at least twice, once in the late Miocene and again during the late-Miocene/early-Pliocene.

Welch *et al.* (2016) carried out a resolved maternal phylogeny of extinct and endangered Hawaiian endemic mints (Lamiaceae) using complete plastid genomes. Taxon sampling relied largely on herbarium samples collected during the last century. Their results demonstrated the potential of high-throughput sequencing of historic material for evolutionary studies in rapidly evolving lineages and also highlighted the challenges of resolving relationships within recent radiations even at the genomic level.

Li *et al.* (2016) presented a large-scale phylogenetic reconstruction of Lamiaceae using chloroplast sequences with the most comprehensive sampling of the family (288 species in 191 genera, representing approximately 78% of the genera of Lamiaceae). The study inferred twelve strongly supported primary clades which form the phylogenetic backbone of Lamiaceae. As a result of the analysis three new subfamilies— Cymarioideae, Peronematoideae, and Premnoideae—were described, and the compositions of other subfamilies were updated based on new findings from the last decade.

Recently to fill the gap of underrepresentation of Old World *Salvia* species, Will and Claßen-Bockhoff (2017) reconstructed the phylogeny of *Salvia* (Lamiaceae) with a wide sampling of taxa. The aim of their study was to check the polyphyletic nature of the genus and the identification of well-supported clades that provide the basis for evolutionary and taxonomic conclusions. To conduct this analysis they used ITS and *rpl32-trnL* plasid marker and analysed the results using BI and ML approaches. They confirmed the polyphyly, however, phylogenetic data clearly indicated that the floral trait (lever-like stamens) and other morphological characters evolved in parallel.

Li *et al.* (2017) carried out a phylogenetic analysis of tribe Elsholtzieae (Nepetoideae, Lamiaceae) using two nuclear (ETS, ITS) and five chloroplast (*rbcL*, *matK*, *trnL-F*, *ycf1*, *ycf1-rps15*) genes to reconstruct the phylogeny, biogeographic history, and patterns of diversification. They concluded that tribe Elsholtzieae is monophyletic and divided into five clades. Molecular dating showed that the five major clades were established during the Eocene period and the ancestral area reconstructions revealed that the tribe originated in East Asia, and then dispersed to Southeast Asia and North America. Finally the study highlighted the important roles of the uplifts of the Qinghai-Tibetan Plateau (QTP) and climate changes from Middle Miocene onwards in promoting species diversification of Elsholtzieae.

CHAPTER 3
TAXONOMY

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3.1. Introduction

Plectranthus L’Hér. with about 300 species worldwide (Harley *et al*. 2004), is one of the largest genera of subfamily Nepetoideae and among the largest genera of family Lamiaceae. The genus also plays an important role in both horticulture and traditional medicine (Lukhoba *et al.* 2006; Rice *et al*. 2011). It is distributed widely in tropical to southern areas of Africa and Madagascar, and also occurs in tropical Asia and Australia (Harley *et al.* 2004). Infrageneric delimitation in *Plectranthus* is difficult due to lack of clear-cut morphological criteria and this has resulted in placing species under various generic names like *Coleus* Lour., *Solenostemon* Thonn., *Germanea* Lam., *Burnatastrum* Briq., *Englerastrum* Briq. etc. (Lukhoba *et al.* 2006). As a result of morphological studies, all these names have been synonymised under *Plectranthus* (Harley *et al*. 2004; Rice *et al.* 2011).

The earlier works on Indian *Plectranthus* treated species distinctly under two generic names *Coleus* and *Plectranthus* (Mukerjee 1940; Cramer 1978). The genus *Isodon* (Schrad. ex Benth.) Spach was also treated congeneric with *Plectranthus* (Bentham 1831, 1832 & 1848; Hooker 1885; Gamble 1921). However, many species considered as *Plectranthus* or *Coleus* by these authors has been transferred to *Isodon* (Ryding 1993b; Harley *et al*. 2004; Suddee and Paton 2004). The earlier works in India treated different species of *Plectranthus* and *Coleus* under different sections. The sectional classification of these two genera *Plectranthus* and *Coleus* in classical literature in India is shown in the table 3.1. In this account, the generic circumscription used by Harley *et al.* (2004) is followed considering *Coleus* under *Plectanthus*. This is consistent with recent papers treating Indian species of the *Plectranthus* complex (Matthew 1993; Smitha and Sunojkumar 2015, 2016, 2017 and Mathew *et al*. 2017).

Table 3.1. The sectional classification of *Plectranthus* and *Coleus* in previous Indian literature

References	***Plectranthus***	***Coleus***	**Total no. of species**
Bentham (1831)	Sect.1. *Coleoides* Sect. 2. *Euplectranthus* Sect. 3. *Pyramidiu*m	Sect.1. *Calceolus* Sect. 2. *Aromaria* Sect. 3. *Solenostemon*	13+9
Bentham (1832)	Sect. 1. *Germanea* Sect. 2. *Coleoides* Sect. 3. *Heterocalyx* Sect. 4. *Melissoides* Sect. 5. *Isodon,* Sect. 6. *Pyramidium* Sect. 7. *Amethystoides*	Sect.1. *Calceolus*, Sect. 2. *Aromaria* Sect. 3. *Solenostemon*	39+29
Bentham (1848)	Sect. 1. *Isodon,* Sect. 2. *Pyramidium,* Sect. 3. *Amethystoides* Sect. 4. *Melissoides* Sect. 5. *Germanea* Sect. 6. *Coleoides*	Sect.1. *Calceolus* Sect. 2 *Aromaria* Sect. 3. *Solenostemon*	66+43
Bentham & Hooker (1879)	Sect. 1. *Isodon,* Sect. 2. *Germanea*		
Hooker (1885)	Sect. 1. *Isodon* (21 sp.); Sect. 2. *Pyramidium* (1 sp.); Sect. 3. *Coleoides* (10 sp.)	Eight species (no sectional treatments)	32+8

Plectranthus consists of annual and perennial prostrate to ascending herbs or woody subshrubs. Most of the species prefer wet habitats of high altitude areas growing attached to wet rocky surfaces. Some species like *P. mollis* grow as weeds along road sides and *P. subincisus* in sandy soil found only along coastal areas of Alappuzha district of Kerala state. The genus can be recognized from related genera of Lamiaceae in having declinate stamens held in the boat-shaped lower lip of the corolla and these being contiguous or shortly fused at the point of attachment at the base of the lower lip. After a critical revision of the genus, 22 species are recognized in India with 11 endemics confined to Southern Western Ghats.

The aim of the present study is to provide a reliable updated key for species identification in India and an updated description of the species and to present information on typification, accepted names, synonyms, delimitation of taxonomically difficult species and distribution of the species. This study is a first contribution towards a comprehensive morphological and phylogenetic investigation of the genus *Plectranthus* in India.

3.2. Materials and methods

3.2.1. Literature survey

The relevant literature and information regarding the present work were collected from various resources including institution libraries and electronic information retrieving systems like UGC-JCC-infonet database, JSTOR, Elsevier, Science Direct, Wiley, Springer link, DOAJ, Oxford Journals, Pergamon, Shodhganga, Database of Indian Dissertation and PhD thesis repository etc. Literatures from institutional libraries were accessed directly or by personal communication. Some important old literatures were accessed from online resources such as www.biodiversitylibrary.org, www.botanicus.org, and www.archives.com.

3.2.2. Herbaria reference

During the present study, specimens including type materials were examined by consulting different herbaria like BM, CAL, CALI, FRC, FRLH, G, JCB, K, KFRI, L, MH, P, PDA, RHT, TBGT, UPS, etc.

3.2.3. Specimen collection

Extensive field trips were conducted throughout India in different seasons to collect different species of *Plectranthus.* Multiple accessions of different species from different localities were made to analyse variations within and between species. Collected specimens were duly tagged and processed for further studies. Different parts of the collected specimens were preserved in Formalin-Acetic-Alcohol (FAA) mixture for further laboratory studies and for preparing illustrations. Collection details such as locality, altitude, vegetative characters like stem and leaf nature, flower colour, and other floral characters were noted down in the field book from the field itself. During specimen collection, digital photographs of the plant materials and the details of the habitat where the species grow were taken by using SLR Digital Cameras (Canon EOS 1200D, Sony-SLT A65V and Sony-SLT A58).

3.2.4. Herbarium preparation

Specimens (plant parts) collected from the field with appropriate size were processed for making herbarium. Conventional method of herbarium preparation is followed. Dried specimens were mounted on standard herbarium sheets of the size 28 × 42 cm and labelled properly. All the relevant information about the plant specimen are mentioned in the label. The herbarium specimens were deposited in Calicut University Herbarium (CALI).

3.2.5. Plant identification

The collected specimens from the field were identified with the help of taxonomic keys provided in revisionary works, Floras, Monographs, by personal communications with experts in the subject area and by referring other relevant literature. The identities of the specimens were further confirmed by comparing with type materials deposited in various herbaria and also with the protologue information of the taxa.

3.2.6. Description, Illustration and photographs

The fresh specimens collected from the field as well as preserved specimens were brought to laboratory for careful study. Each plant parts were observed in detail with the help of Leica M80 Stereo Microscope. Detailed descriptions were prepared based on the observation. Botanical Latin (Stearn 1998) was referred for this purpose. Measurements were also recorded for the important parts. Drawings were made for important plant parts based on direct observation and with the help of Camera Lucida fitted with Leica M80 Stereo Microscope. Illustrations were prepared on standard gateway paper with the help of 0.1mm and 0.2mm micro tip pen (Rotring Isograph). Proportionate scale for each part was also marked on the sheet. Photomicrographs of the floral as well as some vegetative parts were taken with the help of Leica M80 Stereo Microscope fitted with Leica EC3 image analyzer.

3.2.7. Nomenclature and citations

Nomenclatural clarifications were made according to the Melbourne International Code of Nomenclature for algae, fungi, and plants (ICN; McNeill *et al.* 2012). Citations for plant names were obtained from International Plant Name Index (IPNI- http://www.ipni.org/), WCSP (http://wcsp.science.kew.org/) and The Plant List (http://www.theplantlist. org/). Author names were written based on the guidelines provided by

Brummitt and Powell (1992). Herbarium acronyms were based on Index Herbariorum (http://sweetgum.nybg.org/science/ih/).

3.2.8. Presentation of data and conservation measures

Systematic treatment in the thesis begins with the generic treatment, its citations, type details, description, phenology, distribution and habitat notes, ethnobotanic notes if any and other relevant notes. This is followed by key to the species and species treatments. The species treatments are given with citations, type, detailed description, and other relevant notes. The species are presented in alphabetic order. Details such as phenology, habitat and ecology, distribution, ethnobotanical notes if any, conservation status and nomenclatural notes are included for each taxon. All specimens studied were cited under specimen examined. Fresh specimens collected from the field during this study were planted in Calicut University Botanical Garden (CUBG) for further studies. Conservation status for each species was also provided according to the IUCN (2012) guidelines.

3.3. Taxonomic treatment

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(Fig. 3.1)

Type:—*Plectranthus fruticosus* L'Hér., (type cons; Lectotype species)

Fig. 3.1. *Plectranthus fruticosus*-Lectotype species of the genus *Plectranthus* (L'Heritier, Stirp. Nov. 4: 84, t. 41).

= *Germanea* Lam., Encycl. 2: 690.1788.

Type:—*Germanea urticifolia* Lam. (= *Plectranthus fruticosus* L'Her.) (Lectotype chosen by Suddee *et al.* 2004).

= *Coleus* Lour., Fl. Cochinch.: 372. 1790; Benth. in Wall., P1. Asiat. Rar. 2: 15. 1830; Labiat. Gen. Spec.: 47. 1832; in DC., Prodr. 12: 70. 1848; Benth. in Benth. & Hook. f., Gen. P1. 2: 1176. 1876; Hook. f., Fl. Brit. India 4: 624. 1885; Trimen, Hanb. Fl. Ceylon 3: 373. 1895; Briq. in Engl. & Prantl, Nat. Pflanzenfam. 4 (3A): 359. 1897; Rama Rao, Fl. Plants Travancore 322. 1914; Gamble, Fl. Madras 2. 1123. 1921; Fyson, Fl. South Indian Hill stations 2: 406. 1932; Mukerjee, Rec. Bot. Surv. India 14: 51. 1940; Keng, Gard. Bull. Singapore 24: 48. 1969; S.V.Ramaswamy & Razi, Fl. Banglore Dist. 510. 1973; L.H.Cramer, Kew Bull. 30 (1) 35. 1975; Kew Bull. 32 (3) 551. 1978; Raizada & H.O.Saxena, Fl. Mussorie 1: 596. 1978; N.C.Nair, Fl. Punjab Plains 21 (1): 212. 1978; L.H.Cramer in Dassan. & Fosberg, Rev. Handb. Fl. Ceylon 3: 136. 1981; R.R.Rao & Razi, Synop. Fl. Mysore Dist.510. 1981; Deb, Fl. Tripura State 319. 1983; H.J.Chowdhery & B.M.Madhwa, Fl. Himachal Pradesh Analysis 2: 563. 1984; B.D.Neithani, Fl. Chamoli 2: 506. 1985; Chandrab. & N.C.Nair, Fl. Coimbatore 242. 1988; Manilal, Fl. Silent Valley 217. 1988; Bole & J.M.Pathak, Fl Sourashtra 2: 215. 1988; Vajr., Fl. Palghat Dist. 374. 1990; Li & Hedge in Wu & Raven, Fl. China 17: 292. 1994; S.K.Murthi & Panigrahi, Fl. Bilaspur Dist. 2: 483. 1999; N.P.Singh et al., Fl. Bihar Analysis 410. 2001; N.Anilkumar *et al.,* Fl. Pathanamthitta 398. 2005; G.S.Giri *et al*., Fl. Arunachal Pradesh 2: 278. 2008; Sunil & Sivad., Fl. Alappuzha Dist. 734. 2009; G.P.Sinha et al., Fl. Mizoram 2: 315. 2012;

Type:—*Coleus amboinicus* Lour. [= *Plectranthus amboinicus* (Lour.) Spreng.]

= *Solenostemon* Schumach. & Thonn., Beskr. Guin. Pl.: 271. 1827; Benth. in Benth. & Hook. f., Gen. P1. 2: 117. 1876; Briq. in Engl. & Prantl Nat. Pflanzenfam. 4 (3A): 359. 1897; Morton, J. Linn. Soc., Bot. 58: 251. 1962.

Type:—*Solenostemon monostachyus* (P. Beauv.) Briq. [*Ocimum monostachyum* P. Beauv. = *Plectranthus monostachyus* (P. Beauv.) B. Pollard].

= *Englerastrum* Briq., Bot. Jahrb. Syst. 19: 178. 1894.

Type:—*Englerastrum schweinfurthii* Briq.

= *Neomuellera* Briq., Bot. Jahrb. Syst. 19: 186. 1894.

Type:—*Neomuellera welwitschii* Briq.

= *Burnatastrum* Briq., in Engl. & Prantl, Nat. Pflanzenfam. 4 (3A): 358. 1897.

Type:—*Burnatastrum spicatum* (E.Mey. ex Benth.) Briq.

= *Leocus* A.Chev., J. Bot. (Morot) 22: 125. 1909.

Type:—*Leocus lyratus* A.Chev.

= *Ascocarydion* G.Tayl., J. Bot. Lond. 69. Suppl. 2: 162. 1931.

Type:—*Ascocarydion mirabile* (Briq.) G.Tayl.

= *Rabdosiella* Codd, Bothalia 15: 9. 1984.

Type:—*Rabdosiella calycina* (Benth.) Codd (= *Plectranthus calycinus* Benth.)

Erect or prostrate, annual or perennial herbs or undershrubs. Stems quadrangular or round-quadrangular, often succulent, branched. Leaves petiolate, opposite, membranous to chartaceous, sometimes fleshy, serrate or crenate, sometimes irregularly lacinate. Inflorescence terminal, simple or branched; verticils varying from clearly interrupted to closely spaced to form a lax spike-like inflorescence; cymes sessile or pedunculate, condensed and becoming fasciculate or glomerulate, or dichasially branched at first node and producing long or short lateral cincinni; bracts caducous or persistent, usually forming an apical coma; pedicels erect. Calyx campanulate or tubular in flower and fruit, straight or declinate, bilabiate; posterior lip 1-lobed, broad, decurrent or continuing on tube; anterior lip 4-lobed, with teeth similar in shape and size or lateral teeth much wider and of various lengths, sometimes very short with rounded or truncate apex, median teeth free or connate to varying degrees; tube constricted at throat or not, sometimes ventrally dilated, with 10–12 longitudinal veins, often gibbous at anterior base; throat glabrous or with a ring of hairs. Corolla long-exserted from calyx tube; posterior lip 4-lobed, subequal or with 2 median lobes larger; anterior lip 1-lobed, concave or flattened, longer than posterior, usually pubescent outside, glabrous, pubescent or villous inside, margin entire or ciliate, sometimes frilled at apex; tube curved or conspicuously sigmoid below the middle, pubescent. Stamens 4, didynamous, declinate, included or exserted, inappendiculate, glabrous, anterior pair longer; posterior and anterior pairs attached close together at or just below the base of anterior corolla lip; filaments free or connate to varying degrees, anthers reniform, synthecous, often confluent. Ovary glabrous or hairy. Style declinate, clearly or shortly bifid at apex with equal or subequal branches. Disc with anterior side well developed, sometimes very thick. Mericarps ovoid, ellipsoid, oblong or globose, smooth or minutely tuberculate, producing mucilage when wet or not.

Distribution: The genus distributed mainly in tropical to Southern areas of Africa and Madagascar and also occurs in tropical Asia and Australia.

3.4. Character explanation

3.4.1. Habit

Among the taxa studied some species are annual, whereas majority of the species are herbaceous perennial. *P. anamudianus* exhibit woody prostrate habit with reduced internodes. *P. deccanicus* and *P. glabratus* are woody subshrubs. Stems quandrangular or terrete in cross section, glabrous or hairy, with or without purple dots. In some species (*P. beddomei*, *P. malabaricus*, *P.*

sahyadricus) stem is winged. A ring of white hairs can be seen at the nodal region of *P. deccanicus* and *P. malabaricus* complex

3.4.2. Leaves

Leaves are simple, petiolate, opposite, membranous to chartaceous, sometimes fleshy, green or purple in color. Petioles may be slender or fleshy or sometimes ridged, glabrous or hairy. The shape of the lamina varies between species. It may be linear, oblong, ovate or ovate-cordate. Leaf base can be cuneate or rounded or cordate-sub cordate or truncate. Margins crenate, serrate, or entire towards base. Apex can be acute or acuminate or rounded or sometimes obtuse. Venation eucamptodromous with 6–10 lateral veins from the leaf base. Upper and lower surface of the leaves can be pubescent to villous or glabrous or sometimes pubescent along margin only.

3.4.3. Inflorescences

Inflorescence terminal, simple or basally branched; verticils varying from clearly interrupted to closely spaced to form a lax spike-like inflorescence; cymes sessile or pedunculate, condensed and becoming fasciculate or glomerulate, or dichasially branched at first node and producing long or short lateral cincinni. Based on the pattern of inflorescence, there are mainly four groups: 1) Cymes unbranched, 1–3-flowered, if flowers are more than 3-flowered the cymes become dense and glomerulate without lateral branches (*P. amboinicus, P. barbatus, P. caninus, P. hadiensis, P. mollis, P. montanus, P. rotundifolius, P. scutellarioides, P. subincisus*); 2) Cymes branched, usually more than 3-flowered, lax and forming lateral branches (*P. malabaricus, P. sahyadricus, P.* sp.1*, P.* sp.2); 3) Inflorescence basally branched and the cymes with lateral branches > 4 cm long (*P. beddomei, P. bishopianus, P. deccanicus, P. glabratus*); 4) Inflorescence basally unbranched and the cymes with lateral branches < 4 cm long (*P. anamudianus, P. bourneae, P. gamblei*) (Fig. 3.2, 3.3 & 3.4).

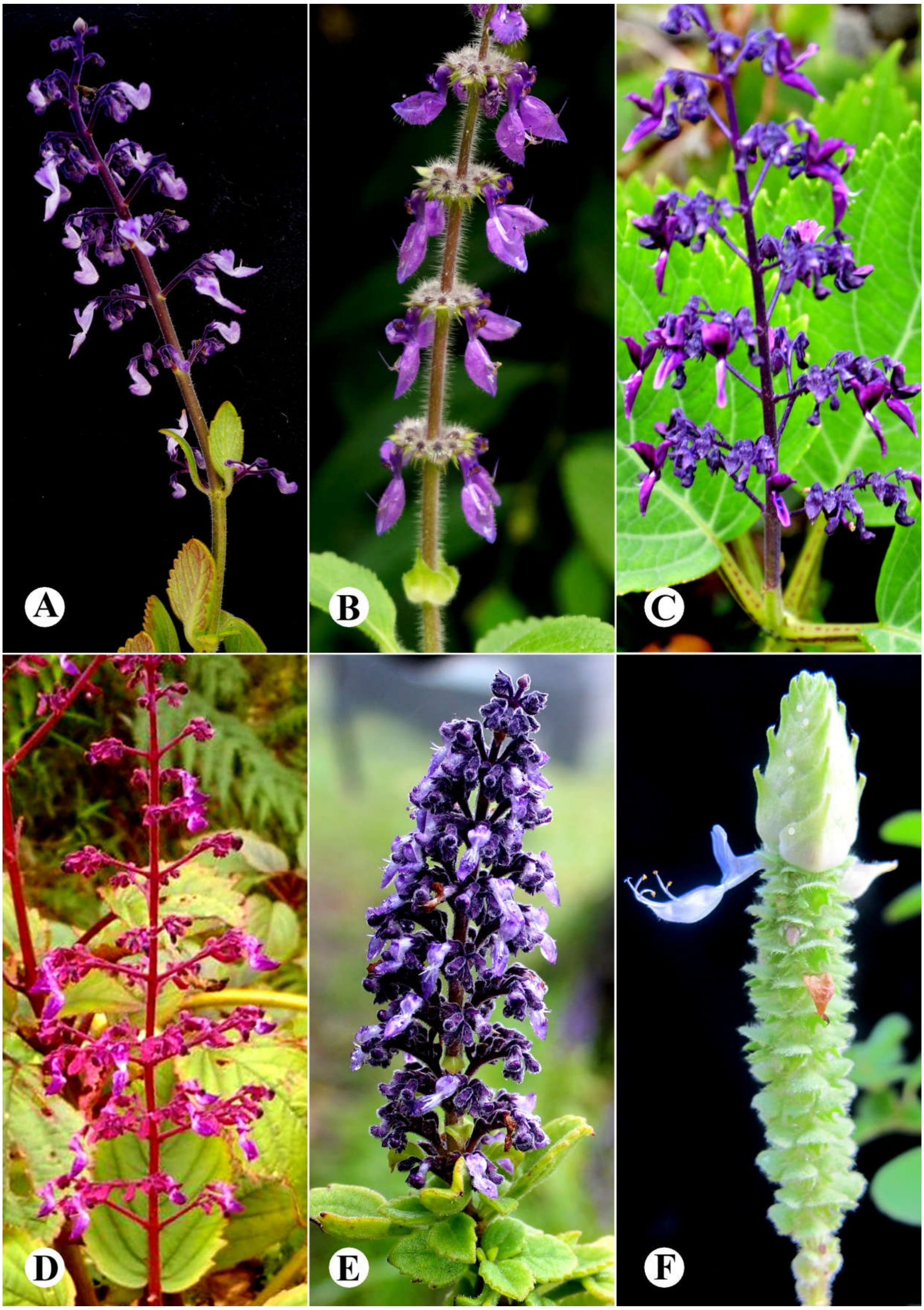


Fig. 3.2. Inflorescence pattern. A. *P. anamudianus*; B. *P. barbatus*; C. *P. beddomei*; D. *P. bishopianus;* E. *P. bourneae*; F. *P. caninus*.

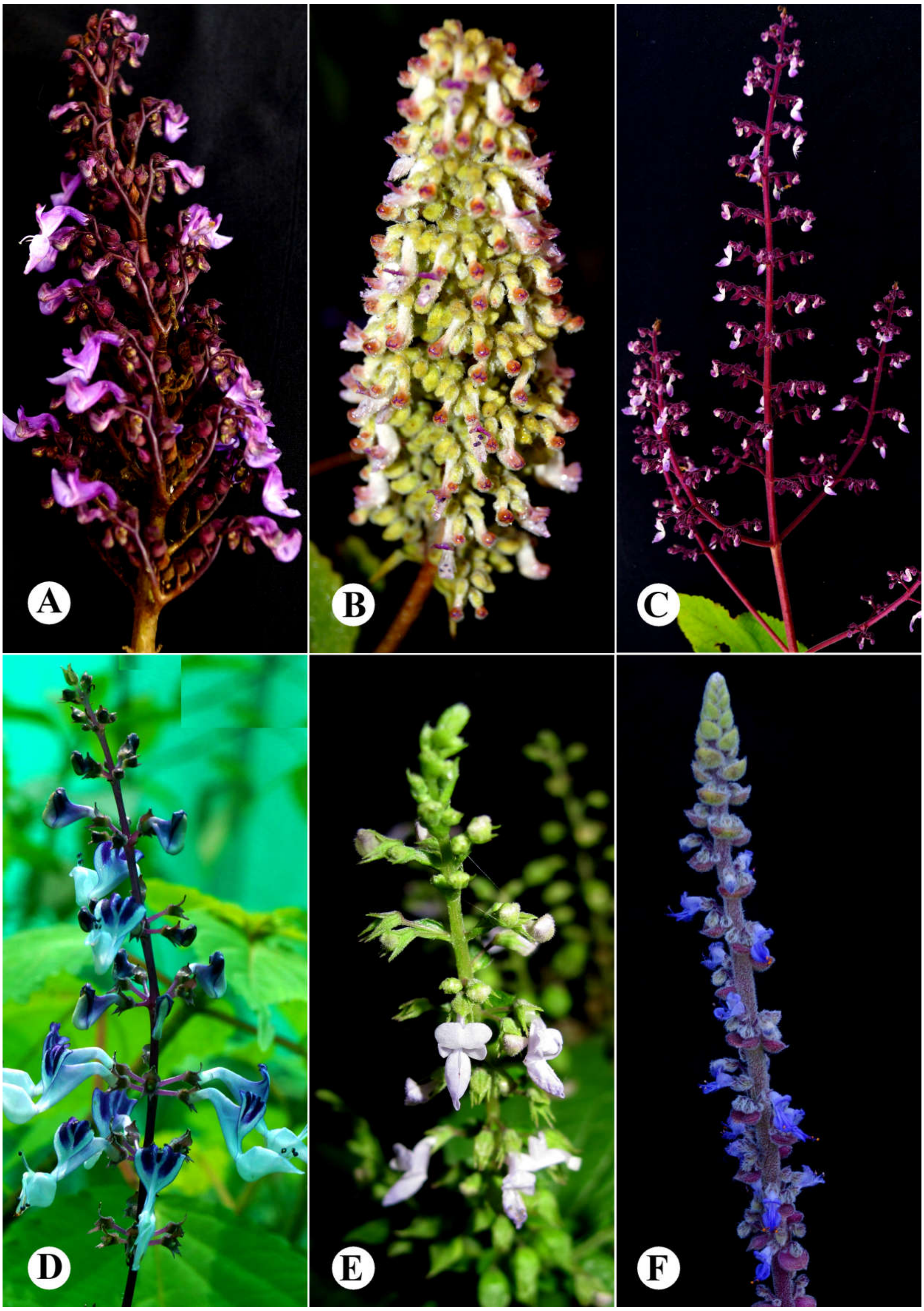


Fig. 3.3. Inflorescence pattern. A. *P. deccanicus*; B. *P. gamblei*; C. *P. glabratus*; D. *P. malabaricus;* E. *P. mollis*; F. *P. montanus*.

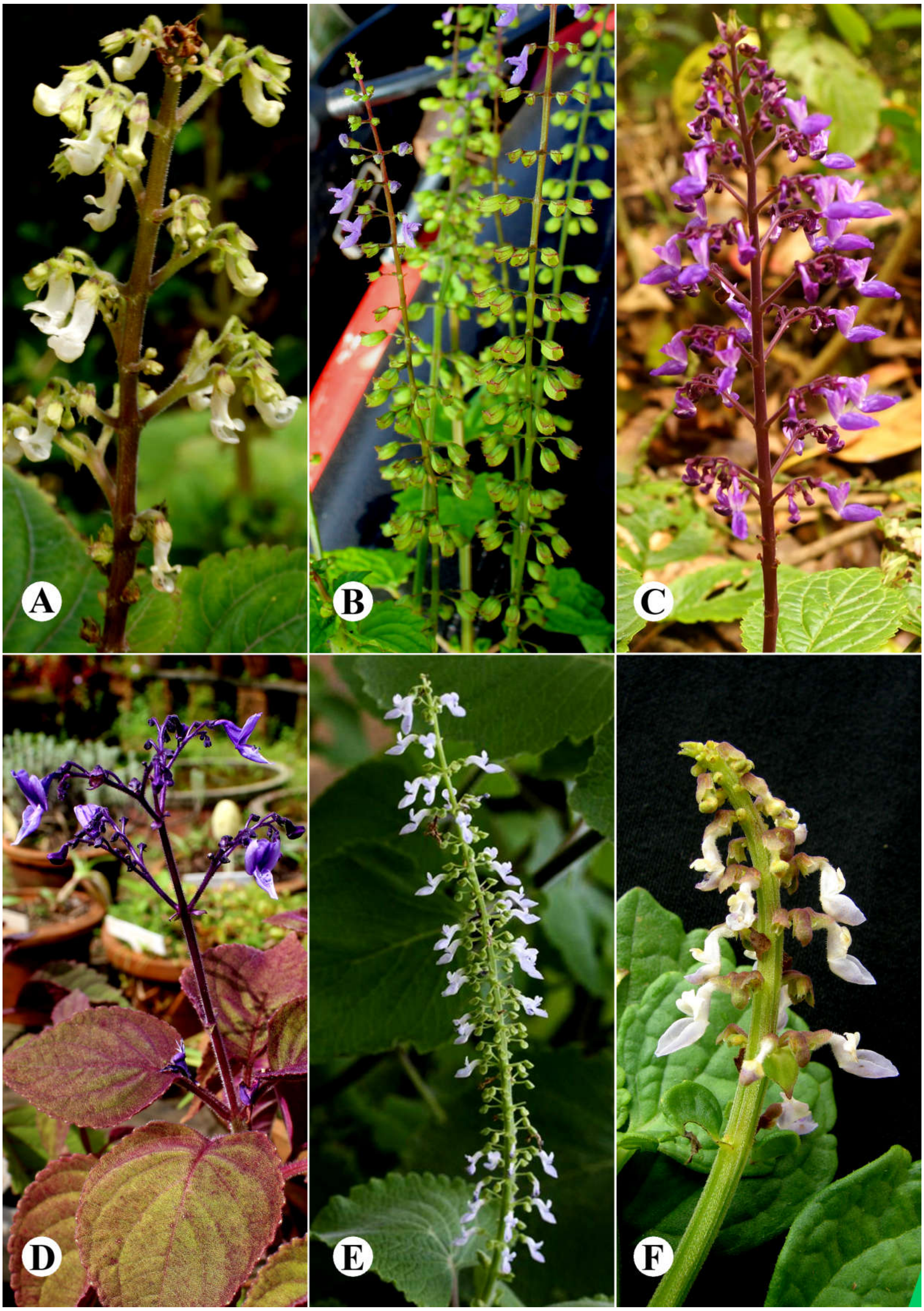


Fig. 3.4. Inflorescence pattern. A. *P. sahyadricus*; B. *P. subincisus*; C. *Plectranthus* sp.1; D. *Plectranthus* sp.2*;* E. *P. hadiensis*; F. *P. rotundifolius*.

3.4.4. Bracts

Bracts caducous or persistent, usually forming an apical coma. They are purple or green in color, margin ciliate or glabrous, rhombic, lanceolate, ovate-cordate in shape.

3.4.5. Calyx

Calyx campanulate or tubular in flower and fruit, straight or declinate, bilabiate; posterior lip 1-lobed, broad, decurrent or continuing on tube; anterior lip 4-toothed, with teeth similar in shape and size or lateral teeth much wider and of various lengths, sometimes very short with rounded or truncate apex, median teeth free or connate to varying degrees; tube constricted at throat or not, sometimes ventrally dilated, with 10-12 longitudinal veins, often gibbous at anterior base; throat glabrous or with a ring of hairs (*P. barbatus*, *P. caninus*) (Fig. 3.5).

3.4.6. Corolla

Corolla white, purple or blue in color, long-exserted from calyx tube; posterior lip 4-lobed, subequal or with 2 median lobes larger; anterior lip 1-lobed, concave or flattened, longer than posterior, usually pubescent outside, glabrous, pubescent or villous inside, margin entire or ciliate, sometimes frilled at apex; tube curved or conspicuously sigmoid below the middle, pubescent or glandular.

3.4.7. Stamens

Stamens four, declinate held in the boat-shaped lower lip of corolla, included or exserted, inappendiculate, glabrous, anterior pair longer; posterior and anterior pairs attached close together or attached just below the base of anterior corolla lip. The filaments being free or fused (*P. amboinicus, P. barabtus, P. cainus* and *P. malabaricus*) to half of length to form a staminal sheeth around the style. Anthers bilobed, dorsifixed, and dehisce longitudinally.

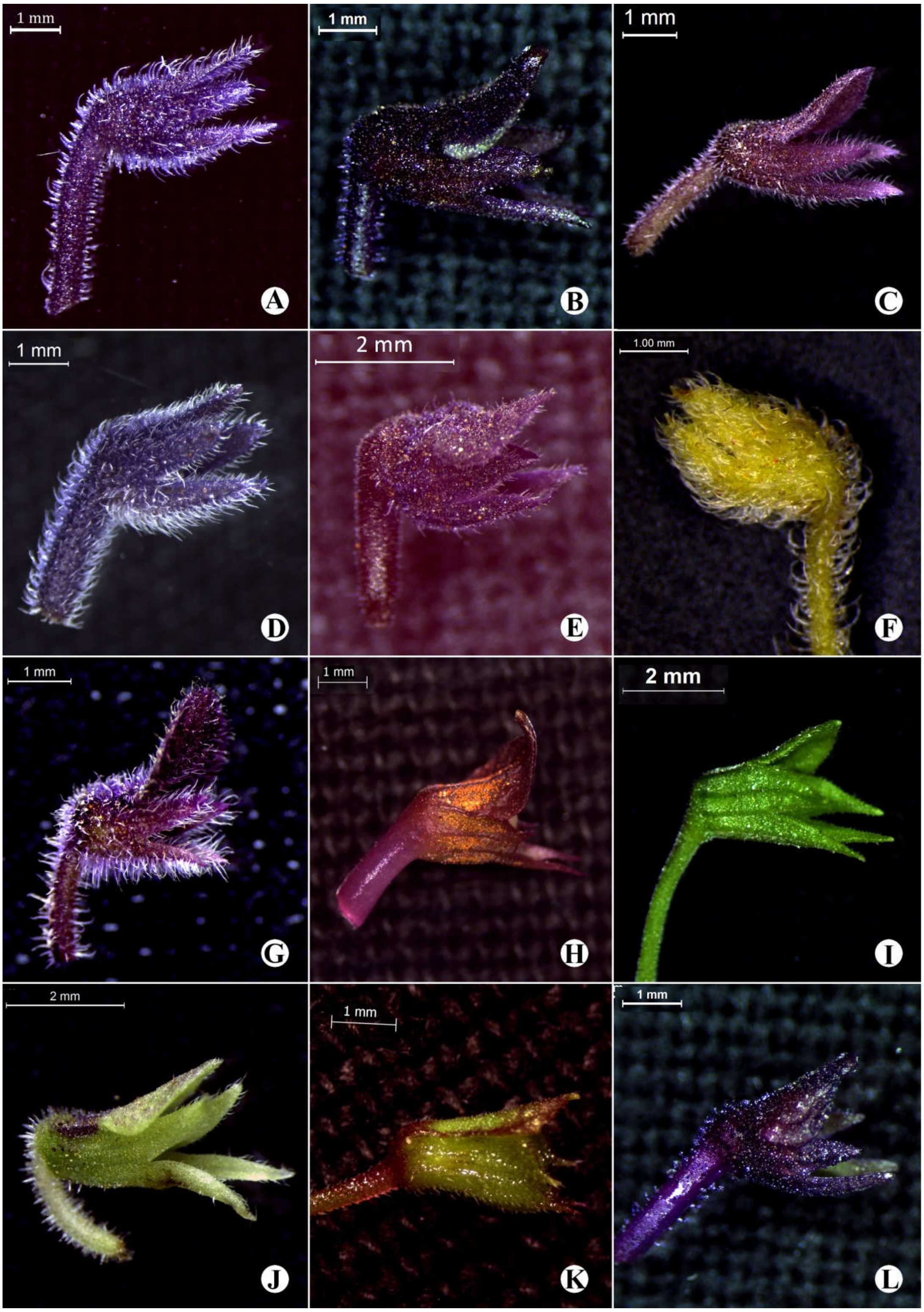


Fig. 3.5. Calyces in *Plectranthus*. A. *P. anamudianus*; B. *P. beddomei*; C. *P. bishopianus*; D. *P. bourneae*; E. *P. deccanicus*; F. *P. gamblei*; G. *P. glabratus*; H. *P. malabaricus*; I. *P. mollis*; J. *P. sahyadricus*; K. *P. subincisus*; L. *Plectranthus* sp.2.

3.4.8. Ovary

Ovary superior, doubly carpellate but appearing equally four-lobed when mature. Style simple, usually gynobasic, shortly bifid above. Ovary in Lamiaceae usually placed on a hypogynous membranous or non-membranous disc and its anterior side is enlarged to form a prominent disc lobes.

3.5. Diagnostic key to the species of *Plectranthus* in India

1. Roots producing tubers 2
- Roots not producing tubers 3
2 Stem winged and tubers not edible ....**P. beddomei**
- Stem not winged and tubers edible ....**P. rotundifolius**
3 Leaves variegated and attractive ....**P. scutellarioides**
- Laves always green or purplish 4
4 Roots black colored and strongly aromatic on drying................**P. vettiveroides**
- Roots not black and aromatic on drying...5
5 Corolla > 2 cm long; corolla tube always straight, > 1.5 cm long…..................... ....**P. verticillatus**
- Corolla < 2 cm log; corolla tube sigmoid, < 1.5 cm long……………...……6
6 Stamens fused to half of their length and form a sheath around style….…7
- Stamens free and not forming a sheath around style………….……...…10
7 Calyx with a ring of hairs inside throat ……………...............…..................8
- Calyx without a ring of hairs inside throat ……… 9
8 Leaves obovate; 20–35 × 15–30 mm; inflorescence spike-like, adjacent verticils touching……… .... **P. caninus**
- Leaves ovate-lanceolate; 60–90 × 25–35 mm; inflorescence not spike-like, verticils clearly interrupted, 5–25 mm apart…………….......... **P. barbatus**
9 Upper lip of calyx continuous with the tube; stamens exserted beyond the anterior lip of the corolla……………………………........…**P. amboinicus**

- Upper lip of the calyx decurrent on the tube: stamens included in the anterior lip of the corolla………………………..……….**P. malabaricus**

10 Cymes unbranched, 1–3-flowered, if more than 3-flowered cymes becoming dense and glomerulate, without lateral branches……….................……11

- Cymes branched, usually more than 3-flowered, lax and forming lateral branches …….. …..14

11 Inflorescence terminal and axillary; spike-like, adjascent verticils rarely separated…..….. .**P. montanus**

- Inflorescence always terminal; lax and adjascent verticils clearly interrupted ....……12

12 Leaves with apex obtuse, base truncate and strongly aromatic ….………… ....**P. hadiensis**

- Leaves with apex acute to acuminate, base cordate and less aromatic ……..……… ....…13

13 Fruiting calyx 6–9 mm long; anterior lip of corolla glabrous inside; mericarps 2 mm long, smooth with black spots……….…..……..**P. mollis**

- Fruiting calyx 5–6 mm long; anterior lip of corolla hairy inside; mericarps 1 mm long, rugose without black spots…………….............**P. subincisus**

14 Flowering calyx green, anterior lip of corolla not fully opened, form an inverted dome over mouth to partially close opening…................. ....**P. sahyadricus**

- Flowering calyx purplish, anterior lip of corolla fully opened and boat shaped……………………….........................………….………..15

15 Leaves with a small leafy appendages at the base…… ....…..**P. sp1**

- Leaves without an appendages at the base…………………….......……16

16 Corolla with posterior lip equal to or larger than anterior lip..…...……....**P. sp2**

- Corolla with posterior lip always smaller than anterior……….......………..17

17 Inflorescence basally branched and the cymes with lateral branches > 4 cm long………..18

- Inflorescence basally unbranched and the cymes with lateral branches < 4 cm long……. .... …20

18 Stem with a ring of white hairs at nodes……………………… **P. deccanicus**

- Stem without a ring of white hairs at nodes, …………..…………………...19

19 Posterior lip of the calyx always longer than the anterior lip……..**P. glabratus**

- Posterior lip of the calyx always equal to the anterior lip……....**P. bishopianus**

20 Internodal length is always < 1 cm, bracts rhombic………….………... ………………………………………………………**P. anamudianus**

- Internodal length is always > 1 cm, bracts cordate or elliptic……....….21

21 Cymes lax, up to 4 cm long, 10–12-flowered, puberulous with purplish hairs, ovules hairy……………...……………………….…..**P. bourneae**

- Cymes compact, up to 2 cm long, 8–10-flowered, densely villous with white hairs, ovules glabrous…………………………..…..….**P. gamblei**

3.6. Enumeration of taxa

3.6.1. Plectranthus amboinicus (Lour.) Spreng., Syst. Veg. 2: 690. 1825; Keng in Steenis, Fl. Males. 8 (3): 387. 1978; Willemse, Blumea 25 (2): 509. 1979; A.N.Henry., Fl. Tamil Nadu 2: 181. 1987; K.M.Matthew, Fl. Pulney hills 2: 1002. 1999; Suddee et al., Kew Bull. 59 (3): 391. 2004.

(Fig. 3.6 & 3.7)

≡ *Coleus amboinicus* Lour., Fl. Cochinch.: 372. 1790; Mukerjee, Rec. Bot. Surv. India 14: 54. 1940; Gamble, Fl. Madras 2: 1123. 1921; Keng, Gard. Bull. Singapore 50: 141. 1969; Cramer, Kew Bull. 32 (3): 555. 1978; N.C.Nair, Fl. Punjab Plains 21 (1): 212. 1978; L.H.Cramer in Dassan. & Fosberg, Rev. Handb. Fl. Ceylon 3: 138. 1981; K.M.Mathew, Materials for Fl. Tamil Nadu Karnatic 305. 1981; Manilal & Sivar., Fl. Calicut 237. 1982; Deb, Fl. Tripura State 319. 1983; N.P.Singh et al., Fl. Bihar Analisis 410. 2001; K.G.Batt, Fl. Udupi 512. 2003; Sunil & Sivad., Fl. Alappuzha 574. 2009.

Type:—Rumphius Ic. in Herb. Amb. 5: t. 102, f. 2. 1750 (Lectotype illustration!, chosen by Cramer 1918).

= *Majana amboinica* (Lour.) Kuntze, Revis. Gen. Pl. 2: 524. 1891.

Type:—as for *C. amboinicus*.

= *Coleus aromaticus sensu* acutt. Benth. (non *Plectranthus aromaticus* Roxburgh, 1814) in Wall., Pl. Asiat. Rar. 2: 15. 1830; Labiat. Gen. Spec.: 51. 1832; in DC., Prodr. 12: 72. 1848; Hook.f, Fl. Brit. India 4: 625. 1885; Rama Rao, Fl. Pl. Travancore 322. 1914.

= *Coleus crassifolius* Benth. in Wall., Pl. Asiat. Rar. 2: 15. 1830; Benth., Labiat. Gen. Spec.: 52. 1832.

Type:—India, Tamil Nadu: Dindigul, Herb Wight s.n. in *Wall. Cat.* 2731 (Lectotype K!; designated here)

= *Plectranthus aromaticus sensu* Roxb. (*non* Roxb. 1814), Fl. Ind. ed. 2 (3): 22. 1832.

= *Coleus carnosus* Hassk. Flora 25, ll: 25. 1842.

Type:—Indonesia, *Zolling* 1950 [Holotype G-DC]

= *Coleus suborbicularis* Zoll. & Moritzi, Syst. Verz. Java: 54. 1846.

Type:—Indonesia, *Zolling* 1950 [Holotype G-DC]

Erect perennial herbs up to 1 m tall, strongly aromatic. Stem woody, branched, round or round-quadrangular, glabrescent below, pubescent to villous above with simple, gland tipped hairs, internodes 2–3.5 cm long. Leaves simple, fleshy, orbicular or broadly ovate, 3–6 × 2–5 cm, apex rounded or obtuse, base round or truncate, margin crenate, with 25–28-toothed, hirsute above, pubescent to tomentose beneath, veins conspicuous beneath; eucamptodromous; petioles fleshy, 0.5–2.5 cm long, pubescent to villous. Inflorescence terminal, simple up to 25 cm long, axis fleshy,

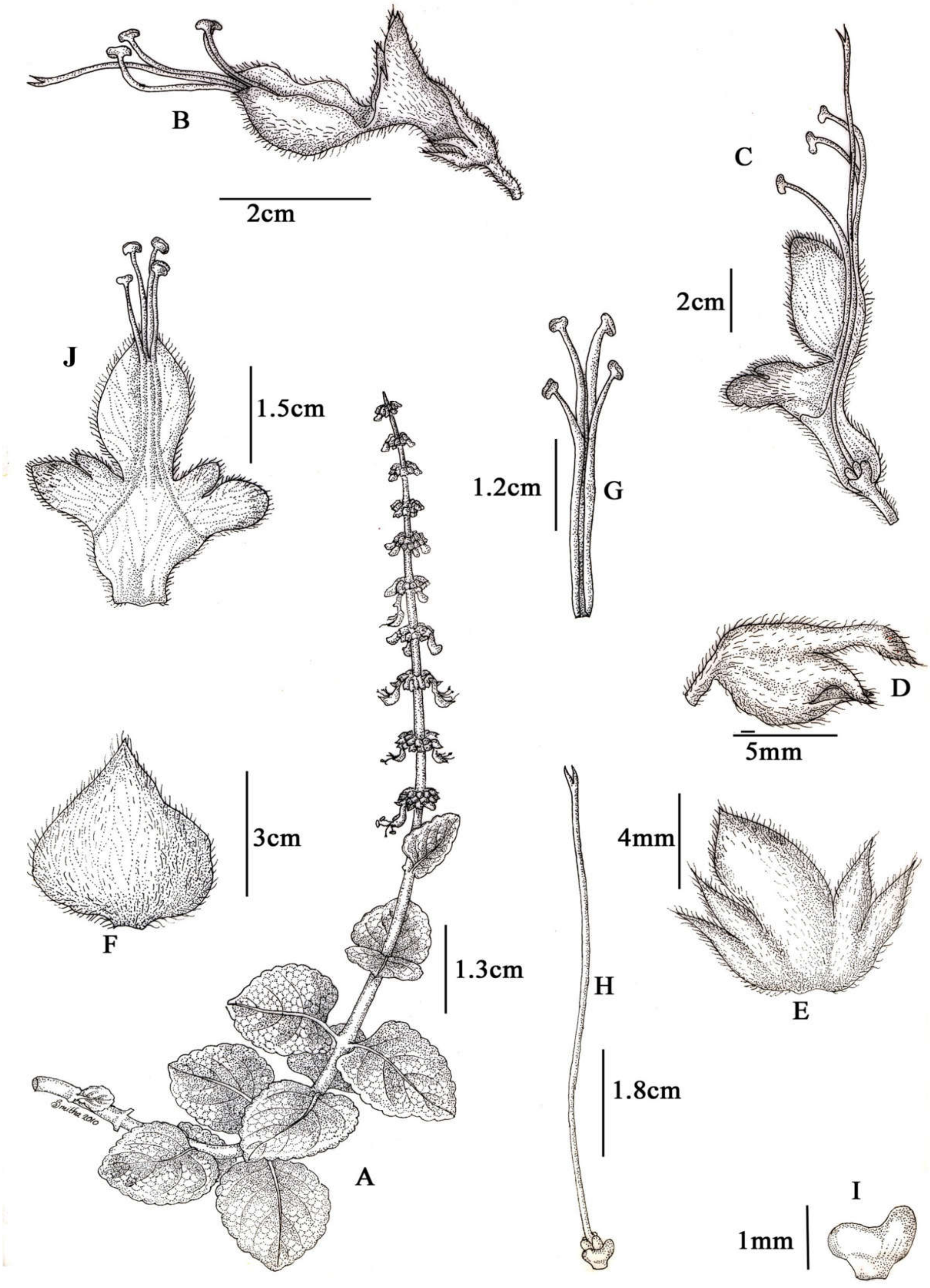


Fig. 3.6. *Plectranthus amboinicus*. A. Habit; B. Flower; C. Corolla L.S.; D. Flowering calyx; E. Calyx opened; F. Bract; G. Stamen; H. Gynoecium; I. Disc; J. Corolla tube opened.

Fig. 3.7. Lectotype of *Plectranthus amboinicus* (Rumphius Ic. In Herb. Amb. 5: t. 102. 1750).

pubescent to villous, verticils 1–2 cm apart, cymes sessile, glomerulate, several flowered; bracts sessile, caducous, ovate up to 3 mm long, pubescent, acuminate, shortly ciliate. Calyx campanulate, 3–5 mm long; posterior lip oblong, twice as long as anterior lip, acute at apex, margin ciliate, not decurrent on tube, hirsute on both sides; anterior lip with tip minute, acuminate, subequel in length, hirsute, tube 10-nerved, densely hirsute outside, gibbous at anterior base. Corolla purple, 10–15 mm long; posterior lip densely pubescent on back, median lobes rounded at apex, larger than lateral lobes; anterior lip ovate-oblong, 5–6 mm long, glabrous inside, tube 4–5 mm long widely expanded at throat, densely pubescent with sessile glands outside. Stamens 4, filaments 10–12 mm long united to half of their length, long, exserted from anterior corolla lip, anthers bithecous. Disc with anterior side enlarged not exceeding ovary, 1mm long; ovary 0.5 mm high; style sigmoid, 1.7 cm long, glabrous; stigma bifid with equal lobes.

Phenology:—May–December.

Habitat and Distribution:—Cultivated, sometimes naturalized. Pantropical distribution, possibly native to India (Keng 1978) and widely cultivated in the tropics

Notes:—Common names: Panikoorka / Kanhikoorka (Malayalam), Country borage/ Indian borage (English).

Uses:—The leaves are highly aromatic with a strong flavour of mixed herbs. Common home remedy for infantile cough, cold, fever and headache. Cures poisonous affections, stimulates liver function, useful in kidney and bladder stones, diarrhoea, dysentry and indigestion.

Specimens Examined:—India. **Kerala**: Idukki district, 05 March 1986, *K.M.Mathew 44510* (RHT!); Kottayam district, Kuruvilangad, 10 March 2010, *Smitha & Sunojkumar 124112*; Malappuram district, Kottakkal, 3 March 2010, *Smitha & Sunojkumar 124105* (CALI!); **Maharashtra**:

Cuddapah district, July 1884, *Gamble 15197* (CAL!); Poona, BSI compound, 22 April 1961, John Cherian 68255 (CAL!); **Tamil Nadu**: Coimbatore, Bailur, 20 March 1906, *C.E.C.Fisher 920* (CAL!); Madurai, 21 February 1958, *K.Subramanyam 5402* (CAL!); Madurai, Murugumalai, 12 June 1961, *K.M.Sebastine 12511* (CAL!); Ramanathapuram, 21 February 1979, *S.R.Srinivasan 61049* (CAL!); Kodaikanal, Anna, 02 January 1986, *K.M.Mathew 43747* (RHT!); Kodaikanal, Thandigudi Ghat road, 27 April 1984, *K.M.Mathew 44534* (RHT!); Coimatore district, Udumalpet, Parappalar dam, 11 November 1988, *K.M.Mathew 47291* (RHT!); Anna, Thandiankudisai-Adalur road, 29 December 1987, *K.M.Mathew 52317* (RHT!); Thiruvannamalai, Valasarmalai, 20 July 2000, *P.Durai 30856* (FRLH!).

3.6.2. Plectranthus anamudianus Smitha & Sunojk., Phytotaxa 284 (1): 51. 2016 **(Fig. 3.8 & 3.9)**

Type:—India. Kerala: Idukki district, in valley, wet rocky surfaces, Rajamala, elev. 1900 m, 15 December 2012, *Smitha & Sunojkumar 135412* (Holotype CALI!, Isotypes CALI!, MH!).

Plectranthus petricola J.Mathew & B.J.Conn, Telopea 20: 77 (2017) ***syn. nov.***

Type:—India: Kerala: Idukki District, 10 km away from Udumbanchola, Chemmannar Hills, alt. 1602 m a.s.l., 20 Feb 2010, J. Mathew 4417 (holotype TBGT!, isotype MSSRF!)

Erect or prostrate perennial (stem woody, leaves fleshy) herbs, up to 60 cm tall. Stem woody, light green, branched, quadrangular to cylindrical, scarcely pubescent with simple white hairs, internodes 0.5–1 cm long. Leaves simple, fleshy, smooth, ovate, 2–5 × 1–3 cm, apex acute, base truncate to slightly cuneate, margin mainly crenate, 14–16-toothed, upper surface pubescent with simple hairs, lower surface pubescent along veins only, with sessile glands beneath, margin pubescent, 6–8-nerved, venation eucamptodromous; petioles

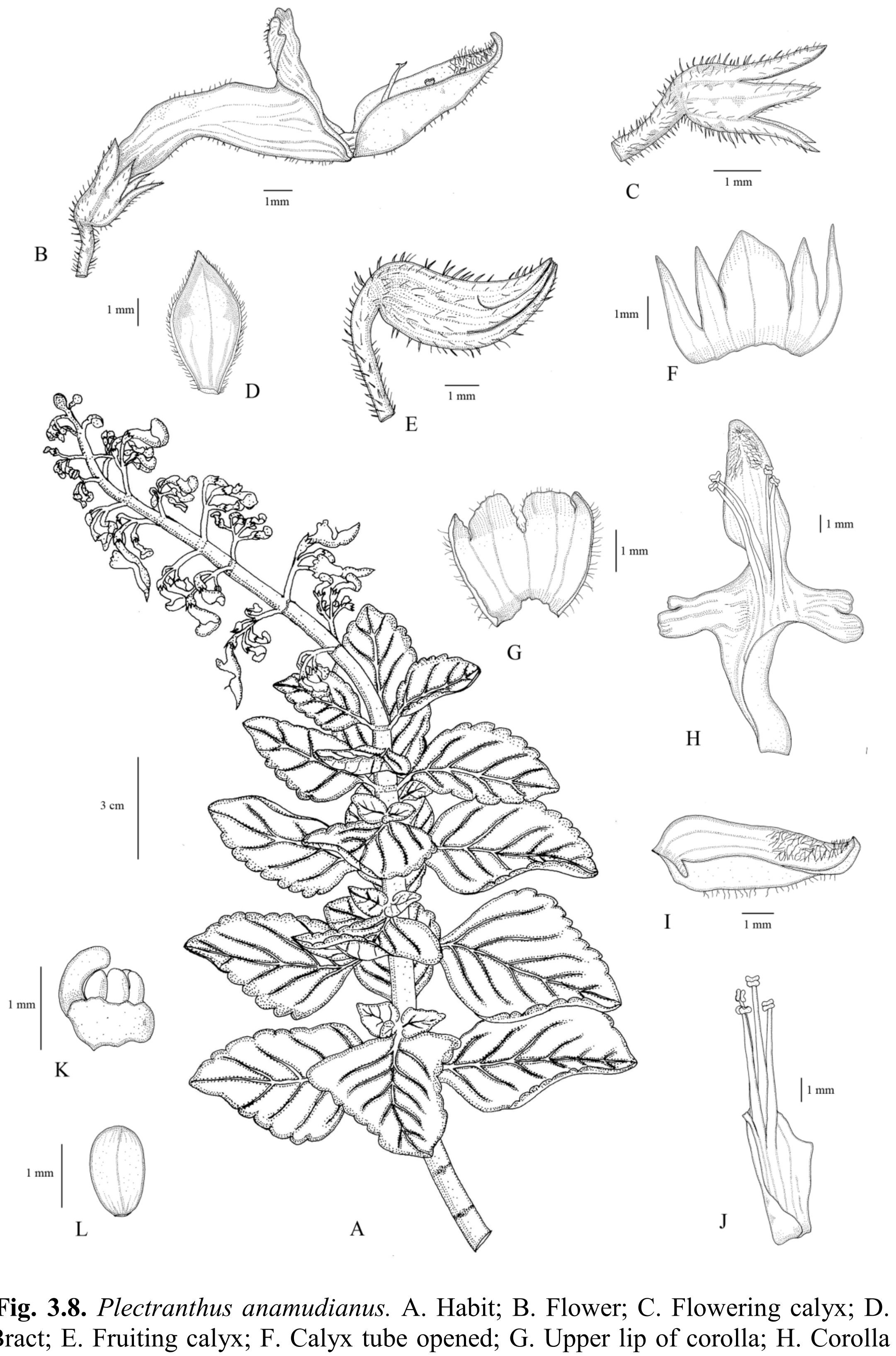


Fig. 3.8. *Plectranthus anamudianus.* A. Habit; B. Flower; C. Flowering calyx; D. Bract; E. Fruiting calyx; F. Calyx tube opened; G. Upper lip of corolla; H. Corolla tube opened; I. Lower lip of corolla; J. Stamen; K. Ovary; L. Mericarp.

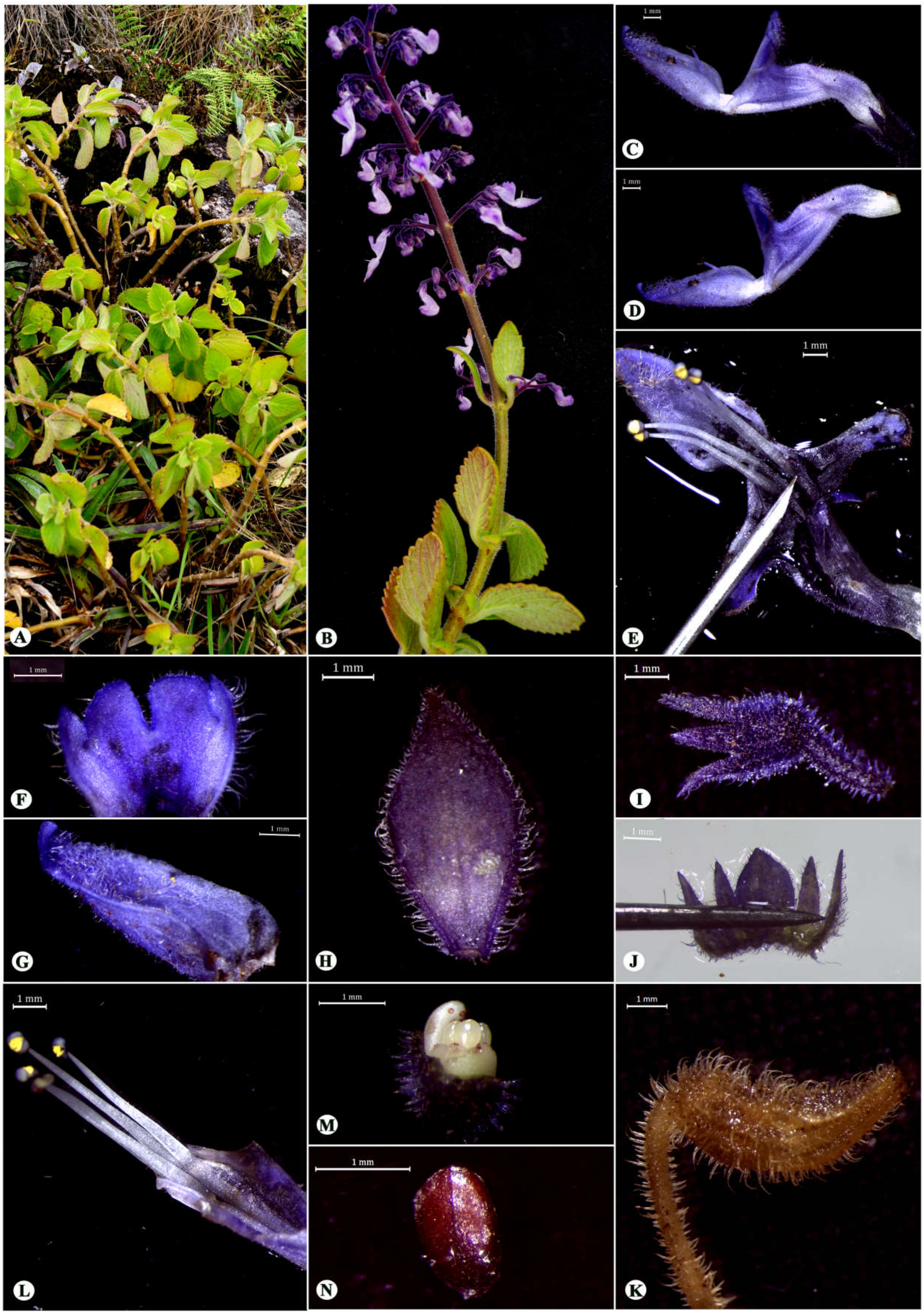


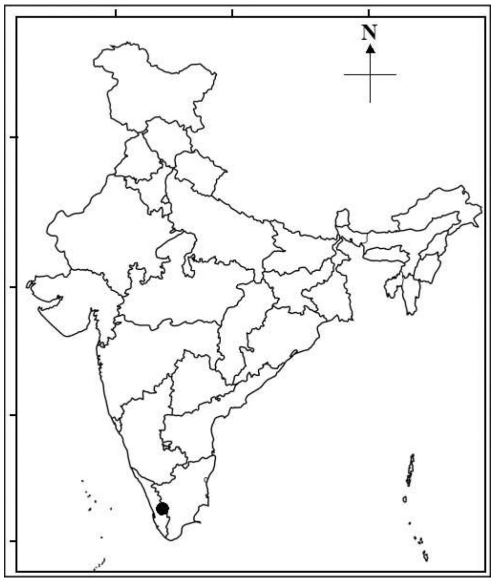
Fig. 3.9. *Plectranthus anamudianus*. A. Habit; B. Leafy twig and verticillaster with 2–4 flowered; C. Flower; D. Corolla; E. Corolla tube opened; F. Corolla upper lip; G. Corolla lower lip; H. Bract; I. Flowering calyx; J. Calyx opened; K. Fruiting calyx; L. Stamen; M. Ovary; N. Mericarp.

fleshy, 0.5–1 cm long, pubescent to pilose. Inflorescence terminal, up to 20 cm long, without basal branches, purplish colored, axis fleshy, puberulous with or without sessile glands; floral nodes 1–2 cm apart, cymes 1–2 cm long, pedunculated, producing lax lateral cincinnal, 5–8-flowered, peduncle 2–4 cm long; bracts early-caducous, rhombic, 4.5–5 × 2.6–3 mm, apex acute, margin ciliate, pubescent below; bracteole absent; flower 10–17 mm long, 7 mm in diameter, pale purple; pedicels slender, 4–5 mm long at anthesis, 5–6 mm in fruit, pubescent. Calyx dark purple, campanulate, ca. 3–4 × 2–3 mm at anthesis, accrescent, recurved and enlarges up to 4–6 × 3–4 mm in fruit, tube 1–3 mm long, 10-nerved, inside glabrous, pubescent with gland-tipped hairs and sessile glands outside; posterior lip broad, ovate, sub-decurrent to tube, apex acute-rounded, margin ciliate, 2 × 2 mm at anthesis, 3 × 2 mm in fruit, inside glabrous, pubescent with gland-tipped hairs and sessile glands outside; teeth of the anterior lip lanceolate, margin ciliate, lateral teeth smaller than median teeth, 1.5 mm long at anthesis, 2.5 mm in fruit, median teeth 2 mm long at anthesis, 4 mm in fruit, pubescent with gland-tipped hairs and sessile glands outside. Corolla pale purple, 13–15 mm long, 7 mm in diameter, pubescent; tube 8–10 mm long, sigmoid below the middle, gradually dilated towards base, widely expanded at throat, glabrous inside; posterior lip 4 lobed, dark purple coloration towards tip, lobes rounded at apex, pubescent, median lobes (1.5 × 1.5 mm) larger than lateral lobes (1 × 1 mm); anterior lip with dark purple coloration towards tip, ovate, boat shaped, 6 × 2 mm, concave, simple long hairs present along inner side of margin, pubescent with orange colored sessile glands outside. Stamens 4, free, attached at the mouth of the corolla tube, posterior pair attached just below anterior but not united, filament of posterior pair 6 mm long, anterior pair 7 mm long, appendages absent, included in anterior corolla lip; anthers bilobed, dorsifixed, ca. 1 mm long, yellowish, dehisces longitudinally. Disc with anterior side enlarged, white, 1 mm long, larger and exceeding ovary, orange colored glands present;

ovary 0.5 mm high; style sigmoid, 1.3 cm long, glabrous; stigma bifid with equal branches. Mericarps elliptic, 1.50–1.54 × 0.95–1.00 mm, brownish, smooth with a reticulate texture formed by polygonal cells, producing mucilage when moistened.

Phenology:—Flowering from October to mid-December, fruiting from December to February.

Etymology:—The species is named after the Anamudi peak of Western Ghats from where the specimens were originally collected (It was collected from the slope of Anamudi).



Habitat and Distribution:—

Plectranthus anamudianus is known from Rajamala, Idukki district, southern Western Ghats. The plants grow on wet rocky surfaces, in an elevation about 1900 m.

Notes:— *P. petricola* is a recently described species collected from Idukki district, Kerala state, India by Mathew *et al.* (2017). The authors compared the new species with *P. anamudianus* and *P. glabratus* and examined only general differences and not the nature of variation within the genus in India. *Plectranthus petricola* is only a sporadic variant form of *P. anamudianus* and their collection localities are also very near. After the critical study of type specimens and protologue of both *P. anamudianus* and *P. petricola*, we could confirm that both are conspecific. Therefore here we treat *P. petricola* as a synonym of *P. anamudianus*.

Additional specimens examined (paratypes):—India. **Kerala**: Idukki district, Munnar, Silent valley, elev. 1830 m, 22 December 2013, *Smitha & Sunojkumar 135445* (CALI!); Idukki district, Rajamala, elev. 1900 m, 10º14’00”N, 77º 04’59”E, 05 November 2015, *Smitha & Sunojkumar 135458* (CALI!).

Conservation status:—*P. anamudianus* species was confined to Anamudi Mountain, which is one of the highest mountains in Western Ghats (India). The species seems to be rare in its habitat. It is known from two different localities in Idukki district in southern Western Ghats. The range of this local endemic species is restricted to two different localities (IUCN Criteria B1a). The *P. anamudianus* is growing on wet rocky surfaces, with an area of occupancy smaller than 10 km^2, and according to field observations it is estimated that the total number of individuals of this endemic species does not exceed 250 in its two different localities. Therefore, we suggest that *P. anamudianus* should be evaluated as critically endangered (CR) according to the IUCN (2012).

3.6.3. Plectranthus barbatus Andrews, Bot. Rep. 9: t. 594b. 1809; Willemse, Blumea 25 (2): 509. 1979; K.M.Matthew, Fl. Tamil Nadu Karnatic 1: 1273. 1983; B.D.Sharma et al., Fl. Karnataka 223. 1984; A.N.Henry et al., Fl. Tamil Nadu 2: 181. 1987; N.P.Singh, Fl. Eastern Karnataka 2: 524. 1988; Lakshmin. & B.D.Sharma, Fl. Nasik Dist. 396. 1991; K.M.Matthew, Fl. Central Tamil Nadu 407. 1991; K.M.Matthew, Fl. Pulney hills 2: 1002. 1999; R.Manik. & Lakshmin., Fl. Rajiv Gandhi National Park 319. 2013.

(Fig. 3.10, 3.11 & 3.12)

Type:—Illustration in Bot. Rep. 9: t. 594. 1809, based on a plant cultivation in England, raised from seed sent from Abyssinia by Lord Valentia (Lectotype illustration!).

var. **barbatus**

≡ *Coleus barbatus* (Andrews) Benth. in Wall., Pl. Asiat. Rar. 2: 15. 1830; Benth. in Labiat. Gen. Spec.: 49. 1832, 711. 1835; in DC., Prodr. 12: 71. 1848; Hook.f., Fl. Brit. India 4: 625. 1885; Trimen, Hanb. Fl. Ceylon 3: 370. 1895; Gamble, Fl. Pres. Madras 2. 1123. 1921; Fyson, Fl. South Indian Hill stations 2: 322. 1932; L.H.Cramer, Kew Bull. 32 (3): 555. 1978; in Dassan. & Fosberg, Rev. Handb. Fl. Ceylon 3: 141. 1981; E.T.Atkinson, Fl. Himalayas 556. 1980; B.D.Neithani, Fl. Chamoli 2: 516. 1985; Manilal, Fl. Silent Valley 217. 1988; H.Collet., Fl. Simlensis 386. 1971; Rama Rao, Fl. Pl. Travancore 322. 1914; Gamble, Fl. Pres. Madras 2: 1124. 1924; N.P.Singh et al., Fl. Bihar Analysis 420. 2001; Lukhoba & A.J.Paton, Kew Bull. 58(4): 914. 2003; Suddee *et al*., Kew Bull. 59(3): 396. 2004; Subba Rao & Kumari, Fl. Visakhapatnam Dist. 2: 68. 2008

Type:— as for *P.barbatus.*

= *Ocimum asperum* Roth, Nov. Pl. Sp.: 268. 1821, as '*Ocymum*'.

Type:—India, Mysore, Nundidroog, *Heyne s.n.* in *Wall. Num. List No.* 2728C (Holotype B, destroyed).

= *Plectranthus asper* (Roth) Spreng., Syst. Veg. 2: 690. 1825.

Type:—as for *O. asperum*.

= *Plectranthus comosus* Sims, Bot. Mag. 49: t. 2318. 1822.

Type:—Illustration in Bot. Mag. 49: t 2318. 1822 (Lectotype).

= *Coleus forskohlii sensu* auctt. Briq. (non *Plectranthus forskohlaei* Willd. 1800) in Engler & Prantl, Nat. Pflanzenfam. 4 (3A): 359. 1897; Mukerjee, Rec. Bot. Surv. India 14 :53. 1940; Raizada & H.O.Saxena, Fl. Mussorie 1: 596. 1978; R.R.Rao & B.A.Razi, Syn. Fl. Mysore 510. 1981; H.J.Chowdhery

& B.M.Madhwa, Fl. Himachal Pradesh Anal. 2: 583. 1984; Bole & J.M.Pathak, Fl Saurashtra 2: 215. 1988; Vajr., Fl. Palghat 374. 1990.

Sub erect or ascending annual or perennial herbs up to 1 m tall. Stems branched, some times rooting at nodes, quadrangular or round-quadrangular, sparsely to densely hirsute with sessile glands. Leaves subfleshy ovate-lanceolate, 60–90 × 25–35 mm, apex acute, base cuneate or attenuate and decurrent on petiole, margin serrate, teeth 19, pilose with sessile glands on both sides, veins prominent beneath, petioles 10–30 mm long, internodes 2 cm. Inflorescence terminal, simple up to 20–35 cm long, axis hirsute with sessile glands, vertcils clearly intrerrupted, 5–25 mm apart, cymes sessile, 3–4 flowered; bracts sessile, caducous, ovate-lanceolate, 8–10 × 5–7 mm, apex acuminate, ciliate, pubescent; pedicils 3–4 mm long, pubescent. Calyx campanulate, 3–5 mm in flowers, 5–7 mm in fruits, dark green coloured; posterior lip ovate, acute or acuminate at apex, margin shortly ciliate, decurrent on tube, shortly pubescent on both sides with sessile glands outside, nerves prominent inside; anterior lip with teeth subequal, lanceolate, tube 10-nerved, pubescent, with sessile glands outside, hairs denser at tube base. Corolla purple, 10–20 mm long; posterior lip sparsely pubescent, with sessile glands outside; median lobes rounded at apex, much larger than the minute acute lateral lobes; anterior lip ovate-oblong, 5–12 mm long, concave, glabrous inside, tube 5–8 mm long, gradually dilated towards base, widely expanded at throat, glabrous inside. Stamens united for about half of their length, included in anterior corolla lip. Style bifid with equal branches; slightly longer than anterior stamens. Disc with anterior side obtuse at apex, exceeding ovary. Mericarps black, globose, 1mm in diameter, smooth, shining.

Phenology:—Throughout the year.

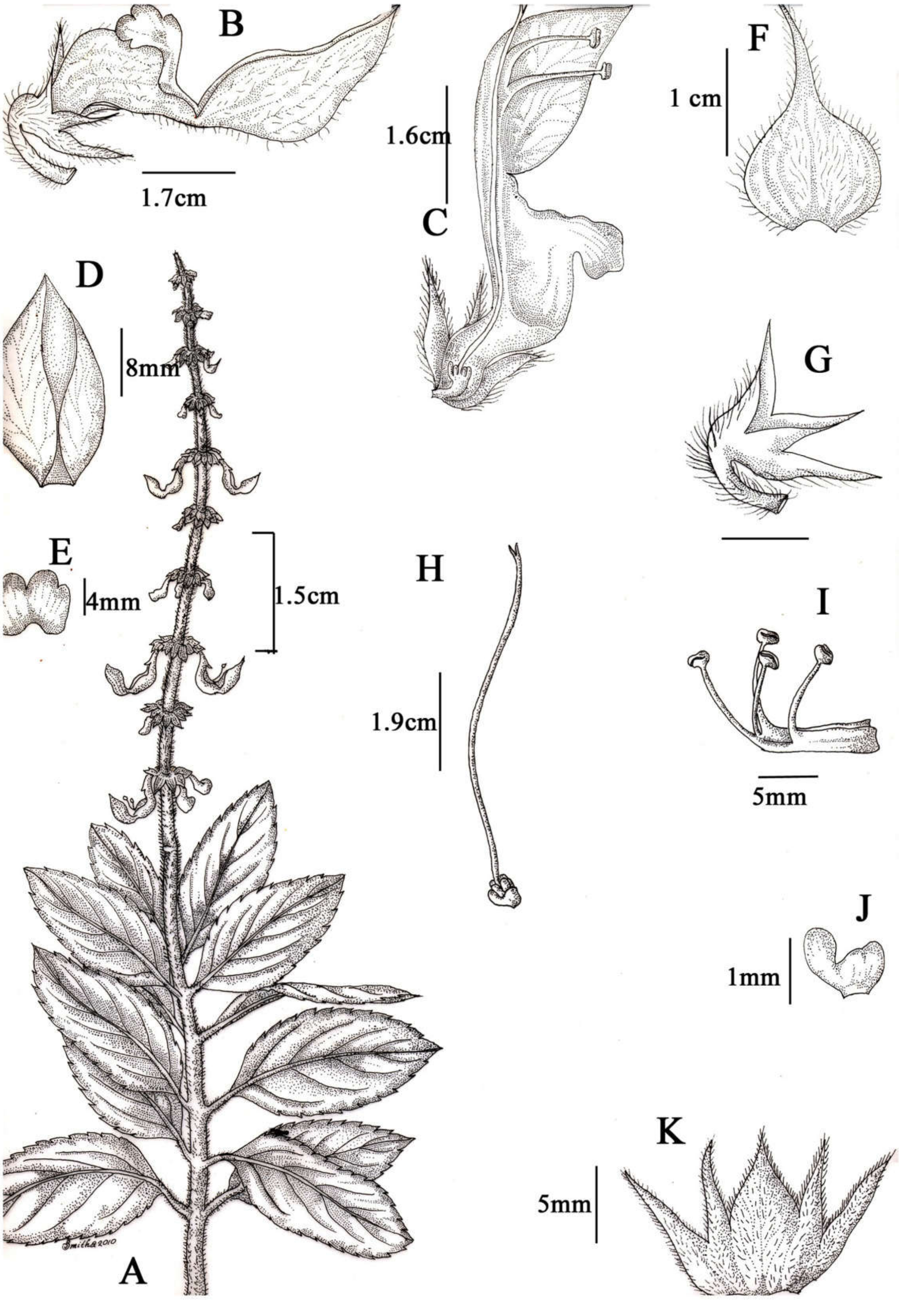


Fig. 3.10. *Plectranthus barbatus*. A. Habit; B. Flower; C. Corolla L.S.; D. Corolla lower lip; E. Corolla upper lip; F. Bract; G. Flowering calyx; H. Gynoecium; I. Stamen; J. Disc; K. Calyx opened.

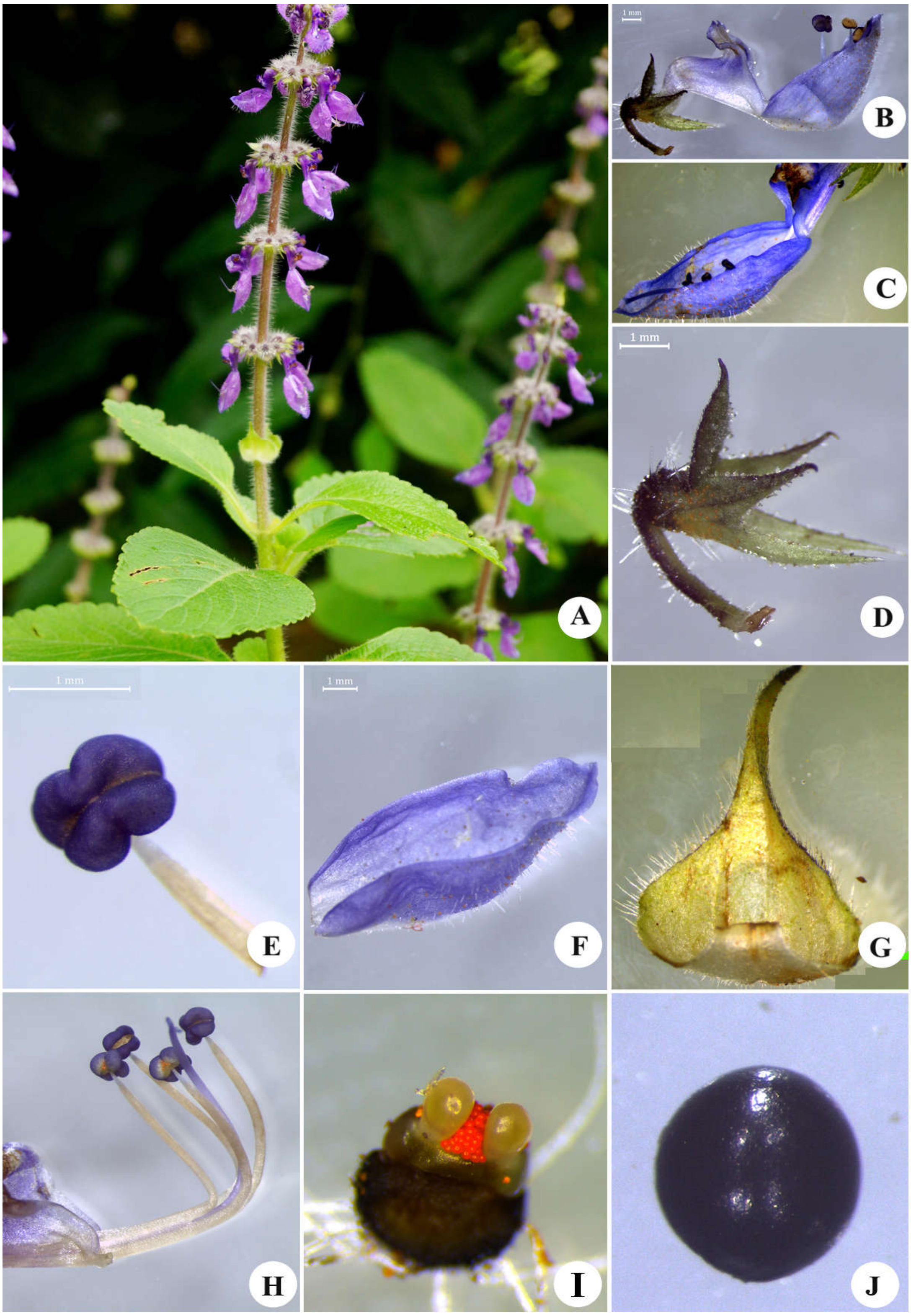
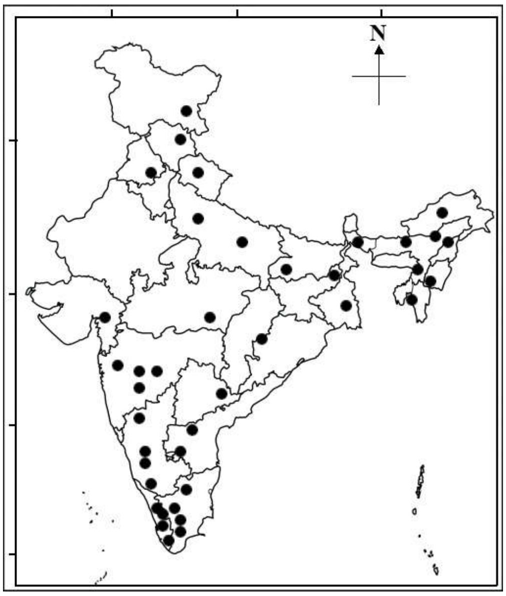


Fig. 3.11. *Plectranthus barbatus*. A. Habit; B. Flower; C. Corolla; D. Flowering calyx; E. Anther; F. Corolla lower lip; G. Bract; H. Stamen; I. Ovary; J. Mericarp.

Fig. 3.12. Lectotype of *Plectranthus barbatus* (Andrews, Bot. Rep. 9: t. 594. 1809)

Habitat and Distribution:— The species grow on rocky surfaces in forest openings at an elevation 500–2100 m. Distributed mainly in Tropical East Africa, West Asia, Nepal, Bhutan, India, Sri Lanka, South China and Thailand.



Notes:—Common name: Indian *Coleus*. In India only the small variety, var. *barbatus* is present. The large variety, var. *grandis* (Cramer) Lukhoba & A.J.Paton, is cultivated and sometimes naturalized in tropical east Africa and Sri Lanka (Lukhoba & Paton 2003).

Uses:—Used to treat illness and various diseases (cardiac troubles) since ancient times. Roots of this species are valued as a source for forskolin (an alkaloid used in the production of a drug for the treatment of glaucoma, congestive cardiomyopathy and asthma). Forskolin also posses positive inotropic and blood pressure lowering activities

Specimens Examined:—India. Andhra Pradesh: Visakapatnam, Sankarimetta, 19 September 1961, *N.P.Balakrishnan 678* (CAL!); **Karnataka:** Banglore District, Banngatta National park, 07 September 1975, *C.Saldanha 18669* (JCB!); 22 August 1976, *C.Saldanha 19080* (JCB!); 20 August 1977, *C.Saldanha 19329* (JCB!); Mysore district, 12 km. from Hunsur, 21 August 1978, *S.R.Ramesh 2234* (JCB!); **Kerala**: Idukki District, Periyar, Mangaladevi, 06 November 1993, *Jomy Augustine 12472* (CALI!); Kanthallur, 26 January 2010, *Smitha & Sunojkumar 124102* (CALI!); Munnar, 13 November 2012, *Smitha & Sunojkumar 135408* (CALI!);

Malappuram District, Kottakkal, 3 March 2010, *Smitha & Sunojkumar 124108* (CALI!); Calicut University Botanical Garden, 16 February 2010, *Smitha & Sunojkumar 12411* (CALI!); Palakkad district, Silent valley, Komenkundu, 18 September 1982, *Prasannakumar 10989* (CALI!); Silent valley, 01 October 2013, *Smitha & Sunojkumar 135436* (CALI!); Thiruvananthapuram district, TBGRI, 20 May 1993, *Mathew Dan 14508* (TBGT!); Thrissur district, 20 January 1992, *Mathew Dan & P.J.Mathew 13436* (TBGT!); Wayanad district, Kalpetta, Myladi, 22 August 2013, *Smitha & Sunojkumar 135415* (CALI!); **Madhya Pradesh:** Bastar district, Jeeram Ghat, 27 August 1959, *K.Subramanyam 8666* (CAL!); **Maharashtra:** Mumbai, Koyana valley 11 July 1956, *B.V.Reddy 5010* (CAL!); Poona, BSI compound, 28 July 1960, *P.J.Cherian 63476* (CAL!); Jalgaon, Patanadevi, Ranlawang, 03 August 2000, *Ragunandan Velankar & Suresh Jagtap 328* (FRLH!); **Tamil Nadu**: Peninsular Indiae Orientalis, *Wight 2100* (CAL!); Shevaroi hills, *Perrottet 64* (CAL!); Coimbatore, Kuridimalai, 16 November 1956, *K.Subramanyam 1346* (CAL!); Coimbatore, Anamalais, 12 September 1961, *J.Joseph 13323* (CAL!); Coimbatore, Udumalped, Amaravathi house, 10 November 1986, *K.M.Mathew 2834* (RHT!); Coimbatore, Mankarai, 06 September 1996, *S.Aroumougame & Ani* (FRLH!); Nilgiri, Coonoor, 29 August 1878, *G.King* (CAL!); August 1883, *Gamble 12334* (CAL!); Willington, 30 August 1883, *Gamble 12495* (CAL!); Pulneys, Pambar peak, 25 June 1897, *A.G.Bourne 129* (CAL!); Kodaikanal, 30 February 1913, *Rev.Aug.Sauliere 1072* (CAL!); Kodaikanal, 15 September 1956, *J.Pallithanam 2155* (RHT!); Kodaikanal, Below Sowripallam, Palni slopes, 22 March 1985, *K.M.Mathew 41218* (RHT!); Kodaikanal, Shembaganur, 28 July 1985, *S.J.Britto 41544* (RHT!); Kodaikanal, Palni hills, Ghat road, 29 November 1985, *K.M.Mathew 43460* (RHT!); Nilgiri, Gudalur, October 1910, *A.Meebold 11730* (CAL!); Kotagiri, 08 August 1910, *C.E.C.Fischer 2094* (CAL!); Nilgiri, near wild and natural resort, 23 September 2006, *K.Ravikumar & R.Murugan 105271* (FRLH!); Nilgiri, Kundra reserve, 31 August 1957, *K.M.Sebastine 3966* (CAL!); Salem, Attur, Nagalur forest, 14 December 1976, *D.I.Arockiasamy 5533* (RHT!); Salem, Yercaud, Majakottai, 29 July 1976, *K.M.Mathew 2834* (RHT!); Kanyakumari, Maruthuvomalai, 18 October 1985, *A.N. Henry & R. Gopalan, 83378* (MH!); Srivilli putur, Sambagatope, 16 July 1993, *CCD-MDU 60175* (FRLH!); Pakkamallai Reserve forest, Gangavaram, 18 September 1993, *J.Den Hollander, P.Blanchflower & C.F.Gostmans 5641* (FRLH!); Pakkamallai Reserve forest, Gangavaram, 26 August 1997, *P.Blanchflower F 5945* (FRLH!); Kanyakumari, 13 November 1997, *Mathew Dan &P.J.Mathew 36211* (TBGT!); Tirunelveli, Naterikal, 13 February 1913, *D.Hooper & M.S.Ramaswami 38567* (CAL!); **Uttarakhand:** Nainital, October 1905, *A.Meebold 2618* (CAL!); Uttarkashi, Ratulisera-Thri path, 08 September 2005, *G.S.Graya 102970* (JCB!).

Conservation status:—Least Concern (LC).

3.6.4. Plectranthus beddomei Raizada, Indian Forester 84: 503. 1958.

(Fig. 3.13 & 3.14)

Type:—India. Tamil Nadu, Courtallum, 1836, *Wight 622* (Holotype K!, K000820175; Isotype K!, K000820174)

= *Plectranthus urticifolius* (Benth.) Hook.f., Fl. Brit. India 4: 622. 1885; Rama Rao, Fl. Plants Travancore 322. 1914; Fyson, Fl. Nilgiri & Pulney Hill tops 1: 322. 1915; Gamble, Fl. Madras 2: 1119. 1921; Mukerjee, Rec. Bot. Surv. India 14(1). 48. 1940; B.D.Sharma et al., Fl. Karanataka Anal. 223. 1984

= *Coleus urticifolius* Benth. in DC., Prodr. 12: 78. 1848; B.D.Sharma et al., Fl. Karanataka Anal. 223. 1984

Erect or prostrate annual herbs, up to 1 m tall. Stem fleshy, winged, greenish purple spotted, branched, quadrangular, glabrous, internodes 2–6 cm long. Leaves simple, membraneous, cordate, 14–26 × 11–25 cm, apex acuminate, base rounded to cuneate, margin crenate, 28–38-toothed, glabrous on both surface, 6–8-nerved, venation eucamptodromous; petioles fleshy, grooved, 2–12 cm long, glabrous. Inflorescence terminal, up to 35 cm long, without basal branches, purplish colored, axis fleshy, puberulous with or without sessile glands; floral nodes 2–4 cm apart, cymes 4–8 cm long, pedunculated, producing lax lateral cincinnal, 10–20-flowered, peduncle 3–5 cm long; bracts caducous, cordate, 3–6 × 2–3 mm, apex acuminate, margin ciliate with glandular tichomes; bracteole absent; flower 18–22 mm long, purple; pedicels slender, 2.5–5 mm long at anthesis, 3–7 mm in fruit, pubescent with glandular trichomes. Calyx dark purple, campanulate, ca. 3–4 × 2–3 mm at anthesis, accrescent, recurved and enlarges to 4–8 × 3–5 mm in fruit, tube 1.5–2.5 mm long, 10-nerved, inside glabrous, pubescent with gland-tipped hairs and sessile glands outside; posterior lip broad, ovate, decurrent to tube, apex rounded, margin entire, ca. 2 × 2 mm at anthesis, ca. 3 × 2 mm in fruit, glabrous inside, pubescent with gland-tipped hairs and sessile glands outside; teeth of the anterior lip lanceolate, margin entire, lateral teeth smaller than median teeth, ca. 1 mm long at anthesis, ca. 3 mm in fruit, median teeth ca. 2 mm long at anthesis, ca. 4 mm in fruit, pubescent with gland-tipped hairs and sessile glands outside. Corolla dark purple, 18–20 mm long, pubescent; tube 10–13 mm long, sigmoid below the middle, gradually dilated towards base, widely expanded at throat, glabrous inside; posterior lip 4 lobed, dark purple, lobes rounded at apex, pubescent, median lobes (ca. 6 × 1 mm) larger than lateral lobes (ca. 5 × 1 mm); anterior lip with dark purple, ovate, boat-shaped,

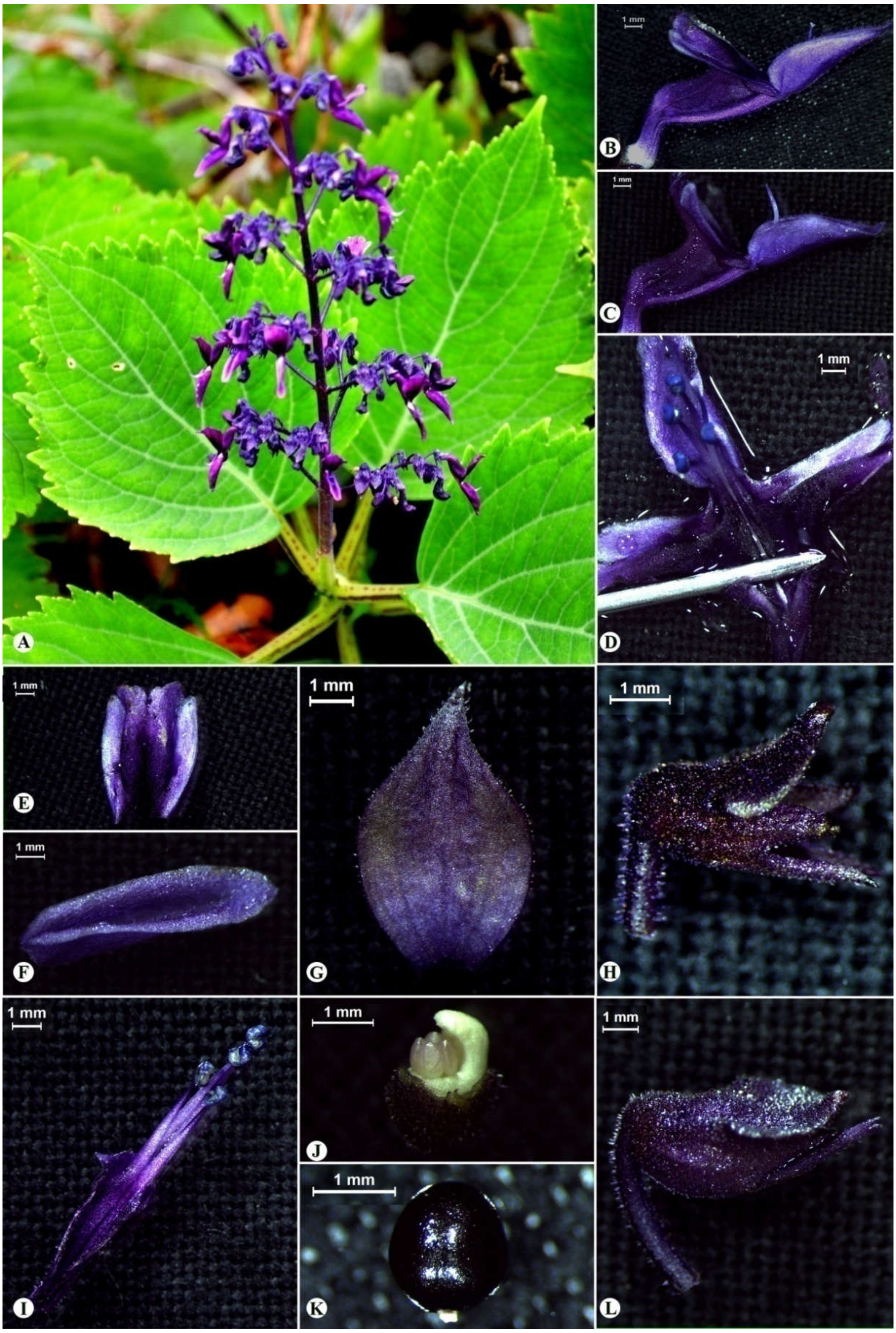


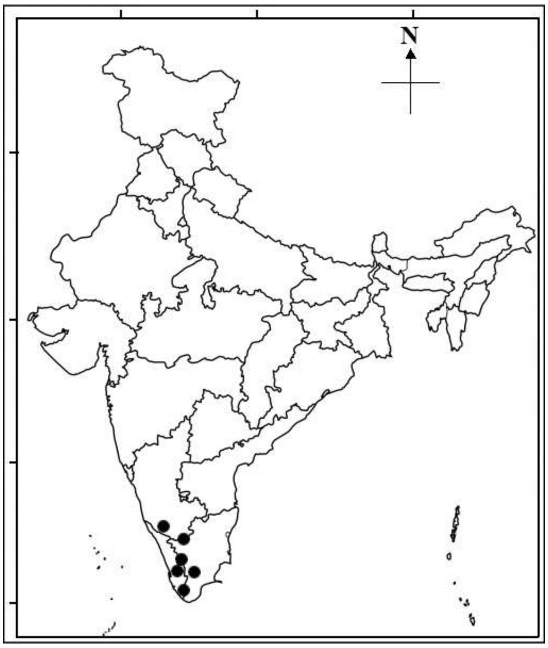
Fig 3.13. *Plectranthus beddomei*. A. Habit; B. Flower; C. Corolla; D. Corolla tube opened; E. Corolla upper lip; F. Corolla lower lip; G. Bract; H. Flowering calyx; I. Stamen; J. Ovary; K. Mericarp; L. Fruiting calyx.

Fig. 3.14. Holotype of *Plectranthus beddomei*. (K000820175, "Reproduced by permission of Board of trustees of Royal Botanic Gardens, Kew").

ca. 8 × 2 mm, concave, simple long hairs present along inner side of margin, pubescent with orange colored sessile glands outside. Stamens 4, free, attached at the mouth of the corolla tube, posterior pair attached just below anterior but not united, filament of posterior pair 5 mm long, anterior pair ca. 6 mm long, appendages absent, included in anterior corolla lip; anthers bilobed, dorsifixed, ca. 2 mm long, yellowish, dehisces longitudinally. Disc with anterior side elongating, white, ca. 1 mm long, larger and exceeding ovary, orange colored glands present; ovary ca. 1 mm high; style sigmoid, ca. 1.5 cm long, glabrous; stigma bifid with unequal branches. Mericarps ovoid, ca. 1.5 × 1 mm, black, shining, smooth, producing mucilage when moistened.

Phenology:— Flowering and fruiting occurs between August and November.

Habitat and Distribution:— Endemic to Western Ghats, grows on wet rocky surfaces



Notes:— *P. beddomei* can be distinguished from other allied species by its woody winged stem, large cordate leaves, large and branched purplish paniculate inflorescence. This species also produce tuberous roots.

Specimens Examined:—India. Kerala: Kottayam district, Vagamon, Kurishumala, 10 October 2013, *Smitha & Sunojkumar 135422* (CALI!); Palakkad district, Silent valley dam site, 04 October 1979, *M.C.Nair 64253* (MH!); Silent valley dam site, 04 October 1979, *M.C.Nair 66253* (MH!); Aruvanpara, 29 September 1983, *T.Sabu 11193* (CALI!); Silent valley, 27 July 1995, T.G.Saji 25809 (TBGT!); Silent valley, 14 September 2012, *Smitha & Sunojkumar 135405* (CALI!); Thiruvananthapuram district, Agasthyamala, 26 August 1963, *A.N.Henry 17329* (MH!); Pongalpara, 12 October 1973, *N.Mohanan 4273* (CALI!); Western slope of Agasthyamala, 06 October 1973, *J.Joseph 44599* (MH!); Forest near Bonacod, 21 August 1975, *J.Joseph 46469* (MH!); Pongalpara, 14 October 1988, *N.Mohanan 4273* (TBGT!); Pongalpara, 25 August 1990, *N.Mohanan 10039* (TBGT!); Wayanad district, Suchipara water falls, 23 August 2013, *Smitha & Sunojkumar 135417* (CALI!); **Tamil Nadu**, Kanyakumari, upper Kothayar dam, 01 September 1981, *K.M.Mathew 17758* (RHT!); Tirunelveli, way to Manjanamparai, 04 September 1963, *A.N.Henry 17448* (MH!)

Conservation status:—Near Threatened (NT)

3.6.5. Plectranthus bishopianus Gamble, Bull. Misc. Inform. Kew 265. 1924; Gamble, Fl. Madras 2. 1120. 1921

Type**:**— India. Tamil Nadu: Pulneys, shola forest at Pillar rocks, 20 May 1901, *A. G. Bourne & E. G. Bourne 1398* (Lectotype designated by Mathew (1993), K!; K000794273)

(Fig. 3.15 & 3.16)

Erect or ascending perennial under shrubs, up to 150 cm tall. Stem woody, light green, branched, quadrangular to cylindrical, glabrous; internodes 2–4 cm long. Leaves simple, membraneous, ovate, 5–9 × 4–6 cm, apex acute, base truncate to slightly cuneate, margin crenate, purplish coloration on lower side, 12–14-nerved, venation eucamptodromous; petioles fleshy, 1–4 cm long, glabrous, slightly purplish. Inflorescence terminal, up to 25 cm long, with basal branches, purplish colored, axis fleshy, pubescent with glandular hairs; floral nodes 1–2 cm apart; cymes 6–8 cm long, pedunculate, producing lax lateral cincinnae, 12–14-flowered; peduncle 2–4 cm long; bracts caducous, ovate to cordate, 2–3 × 3–4 mm, apex acute to acuminate, margin ciliate, with

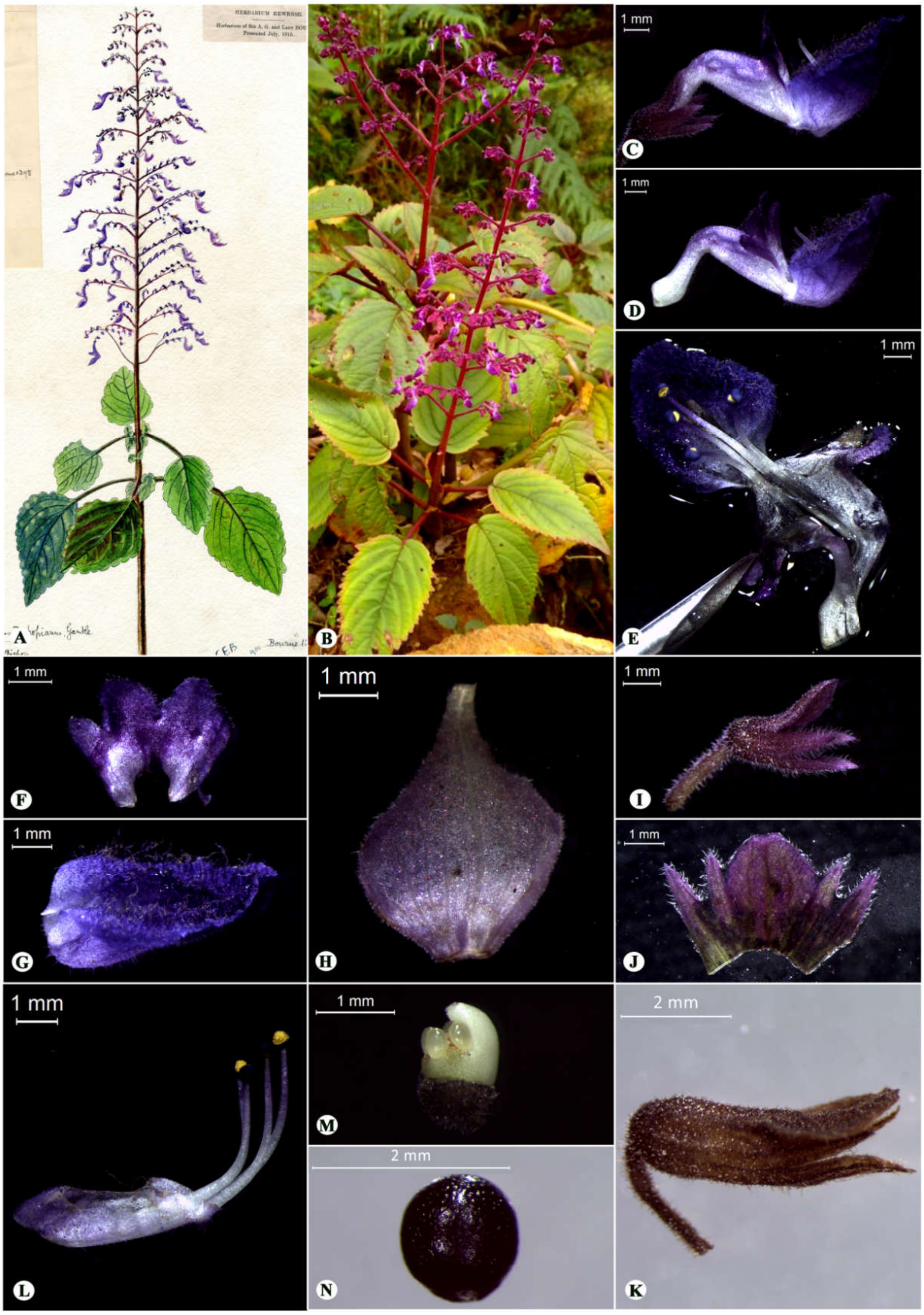
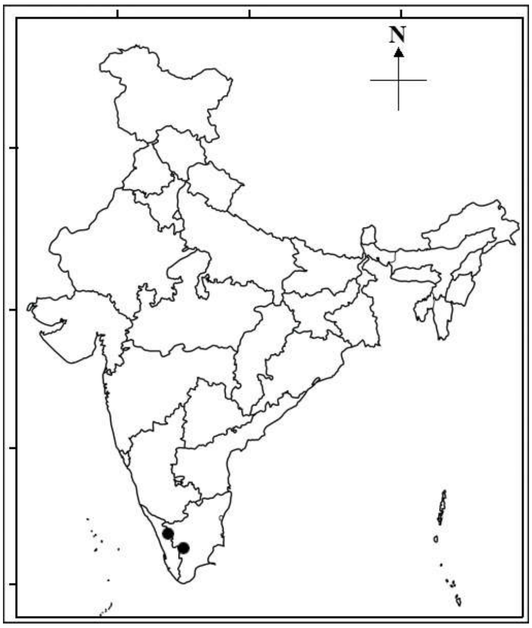


Fig 3.15. *Plectranthus bishopianus*. A. Drawing in Kew collection by Mrs. Bishop; B. Habit; C. Flower; D. Corolla; E. Corolla tube opened; F. Corolla upper lip; G Corolla lower lip; H. Bract; I. Flowering calyx; J. Calyx opened; K. Fruiting calyx; L. Stamen; M. Ovary; N. Mericarp.

Fig. 3.16. Lectotype of *Plectranthus bishopianus*. (K000794273, "Reproduced by permission of Board of trustees of Royal Botanic Gardens, Kew").

orange-colored sessile glands; flower 10–12 mm long, pale purple with dark purplish coloration on upper and lower lips; pedicels slender, 1.5–2 mm long at anthesis, 2–2.3 mm in fruit, pubescent with white glands. Calyx purple, campanulate, 3–3.5 × 2–2.5 mm at anthesis, accrescent and enlarges up to 4–5 × 2–3 mm in fruit with throat open and teeth not pressing together; tube straight, 1–3 mm long, 10-nerved, inside glabrous, pubescent with gland-tipped hairs and sessile glands outside; posterior lip broad, ovate, sub-decurrent to tube, apex acute–obtuse, margin slightly ciliate, equal to anterior lateral teeth; teeth of the anterior lip lanceolate, margin slightly ciliate, lateral and median teeth equal, ca. 2 mm long at anthesis, ca. 3 mm in fruit, pubescent with gland-tipped hairs and sessile glands outside. Corolla pale purple with dark purplish coloration on upper and lower lips, 9–11 mm long, 4–5 mm in diameter, pubescent; tube 5–7 mm long, sigmoid below the middle, gradually dilated toward base, widely expanded at throat, glabrous inside; posterior lip 4-lobed, dark purple, lobes rounded at apex, pubescent, median lobes (2 × 1.5 mm) larger than lateral lobes (1.5 × 1 mm); anterior lip dark purple, ovate, boat shaped, 5 × 2.5 mm, concave, simple long hairs present along inner side of margin, pubescent with orangecolored sessile glands outside. Stamens 4, free, attached at the mouth of the corolla tube; posterior pair attached just below anterior but not united, filament of posterior pair ca. 4 mm long; filament of the anterior pair ca. 5 mm long, slightly exerted from anterior corolla lip; anthers bilobed, dorsifixed, ca. 0.5 mm long, yellowish, dehisces longitudinally. Disk with anterior side enlarged, white, ca. 1 mm long, larger and exceeding ovary; ovary ca. 0.5 mm high; style sigmoid, ca. 1 cm long, glabrous; stigma bifid with unequal branches. Mericarps subprolate, 1.21–1.24 × 1.01–1.03 mm, black, smooth isodiametric cells with anticlinal walls straight, channeled and the curvature of the outer periclinal cell wall convex, producing mucilage when moistened.

Phenology:— Flowering and fruiting occur between January and May.



Habitat and Distribution:— *Plectranthus bishopianus* is a rare species endemic to Western Ghats. Presently, it is known from Aranamala of Wayanad District. The species was found growing on wet rocky surfaces.

Notes:— *Plectranthus bishopianus* has recently been treated as a synonym of *Plectranthus deccanicus*. However, a detailed study of the type materials, recently collected specimens, as well as SEM analysis of pollen and mericarp of both species suggest that *P. bishopianus* is a distinct species. The specific status of *P. bishopianus* is thus reinstated and it can be easily distinguished from *P. deccanicus* by the nature of stem, leaf size and shape, cyme length, number of flowers per cyme, the structure of flowering and fruiting calyx and mericarp surface.

Additional specimens examined:— India. Tamil Nadu: Pulneys, shola forest (Montane evergreen forest) at Pillar Rocks, 27 June 1899, *A. G. Bourne & E. G. Bourne 1329* (K!); Kerala: Wayand district, Meppady, Aranamala, 25 January 2016, *Smitha & Sunojkumar 135465* (CALI!)

Conservation status:— The type specimen of *P. bishopianus* was collected from Pillar Rocks in Pulney hills in 1901. Except for the present collection from Aranamala in Wayand District, this species has not been reported by any published floral surveys. We have explored the entire area of the type locality (2012–2017), which is now a tourist site and no specimens could be located. In the recent collection, very few mature plants (less than 30) were recorded in Aranamala. This species was found in a single location and the place is subject to disruptive activities of local people and tourists. Apart from this, cardamom and tea plantations cause severe threat to the wild habitat in Aranamala and the extent of occurrence for *P. bishopianus* is now estimated to be less than 100 km^2. Therefore, we suggest that *P. bishopianus* should be re-evaluated as critically endangered, CR [B1a, b (ii, iii), B2a, b (ii, iii, iv, v) + D] according to the IUCN (2012) categories and criteria.

3.6.6. Plectranthus bourneae Gamble, Bull. Misc. Inform. Kew 264. 1924; Gamble, Fl. Madras 2. 1120. 1921; Fyson, Fl. South Indian Hill stations 2: 322. 1932; B.D.Sharma, Fl. Nilgiri Dist. 231. 1975; A.N.Henry et al., Fl Tamil Nadu 2: 181. 1987; K.M.Matthew, Fl. Pulney hills 2: 1002. 1999 **(Fig. 3.17 & 3.18)**

Type:— India. Tamil Nadu: Pulneys, Coelogyne rock, Poombarai road 16 May 1901, *A. G. Bourne & E. G Bourne 2028* (Lectotype designated here, K!).

Erect or ascending perennial subshrub, up to 1 m tall. Stem woody, light green, branched, cylindrical, scarcely pubescent with simple white hairs; internodes 1–2 cm long. Leaves simple, fleshy, smooth, orbicular, 2.0–3.5 × 2–3 cm, acute to obtuse at apex, truncate at base, with margin crenate at the upper part and entire towards base, 10–14-toothed; upper surface pubescent with simple white hairs; lower surface pubescent along veins only, and with sessile glands; margin pubescent; veins 6–8, eucamptodromous; petioles fleshy, 1–2 cm long, pubescent with white hairs. Inflorescence terminal, up to 25 cm long, without basal branches, purplish; axis fleshy, puberulous with or without sessile glands; floral nodes 1 cm apart; cymes 1.5–4.0 cm long, pedunculated, producing lax lateral cincinna, 10–12-flowered; peduncle 1.5–2.5 cm long; bracts early-caducous, cordate, 4.0 × 2.5 mm, acute to acuminate at apex, ciliate along margin, pubescent below; bracteole absent; pedicels slender, 2–3 mm long at anthesis, 4–5 mm in fruit, pubescent. Calyx dark purple, campanulate, ca 2–3 × 1.5–2.0 mm at anthesis, accrescent, recurved and enlarging to 4–5 × 2.0–2.5 mm in fruit; tube 1–2 mm long, 10-nerved, pubescent with sessile glands outside; posterior lip broad, cordate, sub-decurrent to tube, acute at apex, with ciliate margin, 2 × 2 mm at anthesis, 2 × 2 mm in fruit, glabrous inside, pubescent with gland-tipped hairs and sessile glands outside; teeth of the anterior lip lanceolate, with ciliate margin, lateral teeth equal in length with median teeth, 2 × 1 mm, pubescent with sessile glands outside. Flower 10–13 mm long, 4–5 mm in diameter, pale purple; corolla pale purple, 10–12 mm long, 6 mm in diameter, pubescent; tube 5–6 mm long, sigmoid below the middle, gradually dilated towards base, widely expanded at throat, glabrous inside; posterior lip 4-lobed, dark purple, with lobes rounded at apex, pubescent, its median lobes (2.0 × 1.5 mm) larger than the lateral lobes (1.5 × 1.0 mm); anterior lip dark purple, ovate, boat-shaped, 6–4 mm, obtuse at apex, concave, with simple long hairs present along the inner side of margin, pubescent with orange colored sessile glands outside. Stamens 4, free, attached at the mouth of the corolla tube; posterior pair attached just below the anterior but not united; filament of posterior pair 2.5 mm long, that of anterior pair 3 mm long, without appendages, slightly exerted from anterior corolla lip; anthers bilobed, dorsi-fixed, ca 0.5 mm long, yellowish, longitudinally dehiscing. Disc with anterior side enlarged, white, 1 mm long, larger and exceeding ovary, with orange glands; ovary 0.5 mm high, with short simple hairs; style sigmoid, 8 mm long, glabrous; stigma bifid with equal branches. Mericarps spheroidal, 1.17–1.19 × 1.05–1.07 mm, brownish, its surface comprised of isodiametric cells with anticlinal walls straight, channeled and the curvature of the outer periclinal cell wall convex, producing mucilage when moistened.

Phenology:— Flowering and fruiting occurs between December and May.

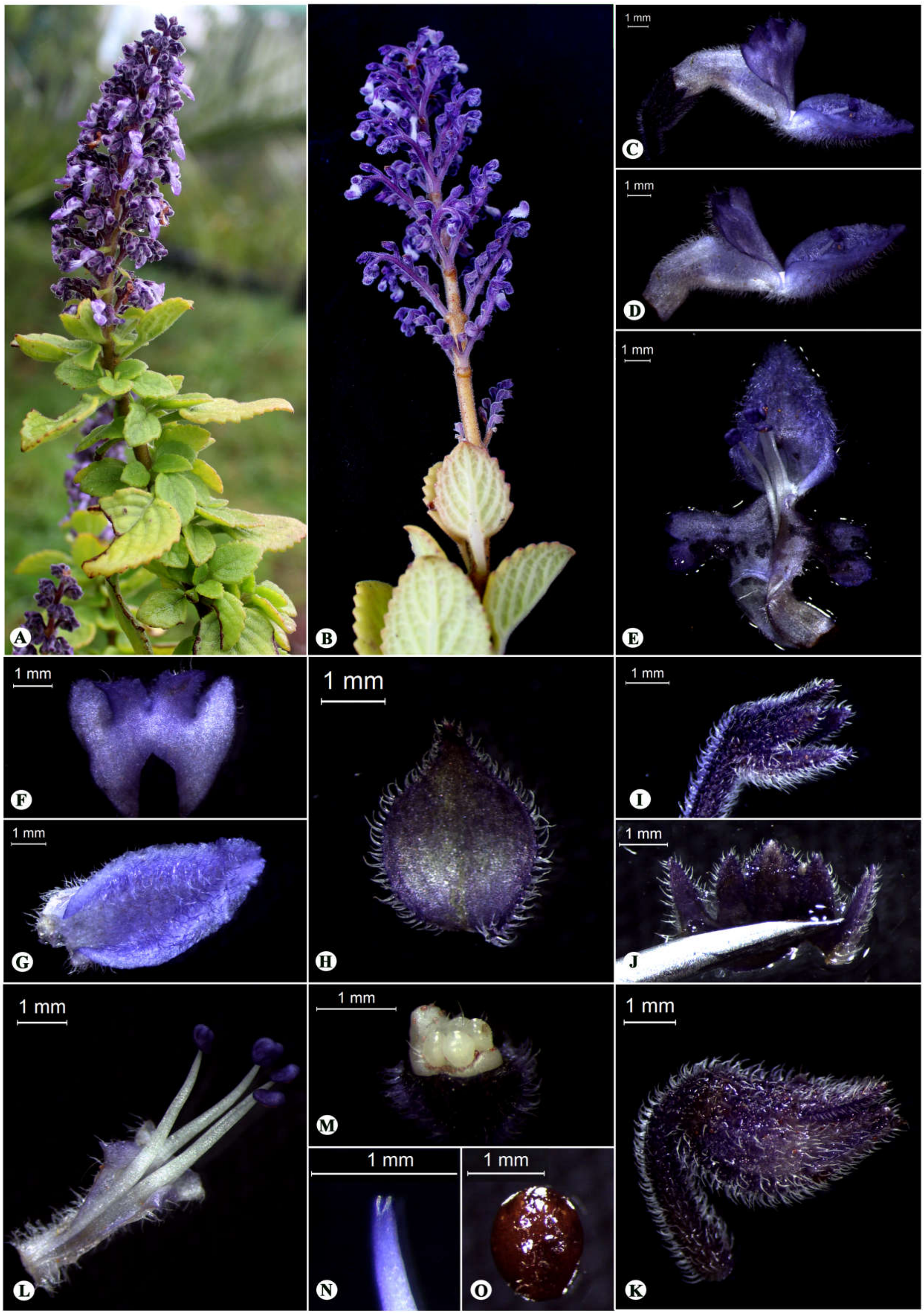
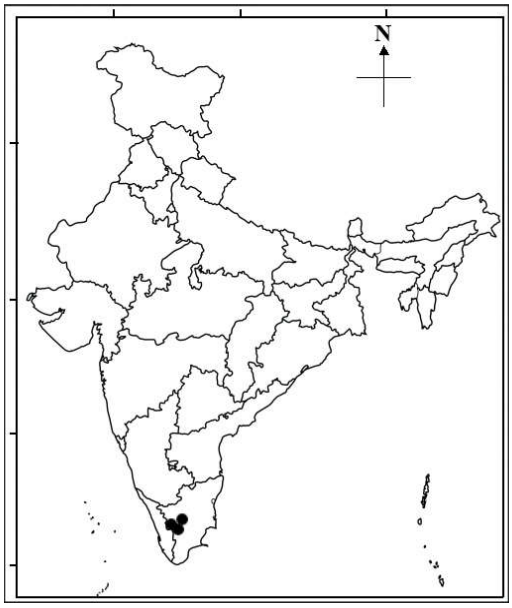


Fig. 3.17. *Plectranthus bourneae*. A. & B. Leafy twig and verticillaster; C. Flower; D. Corolla; E. Corolla tube opened; F. Corolla upper lip; G Corolla lower lip; H. Bract; I. Flowering calyx; J. Calyx opened; K. Fruiting calyx; L. Stamen; M. Ovary; N. Stigma; O. Mericarp.

Fig. 3.18. Lectotype of *Plectranthus bourneae*. (K000820152, "Reproduced by permission of Board of trustees of Royal Botanic Gardens, Kew").

Habitat and Distribution:—*Plectranthus bourneae* is a rare species endemic to Western Ghats. It is known from only few localities in Pulney hills. The plants grow on wet rocky surfaces, at an elevation about 1920 m a.s.l.



Notes:— Syntypes of *Plectranthus bourneae* consists of Gamble's and A. G. Bourne & E. G Bourne's specimens from different localities. Amount of variation noticed on the cited syntypes and those observed on fresh specimens enabled us to treat both collections under different species. Following Gamble, we treated A. G. Bourne & E. G Bourne's collection as *P. bourneae* and a lectotype is designated. Gamble's specimen having ovate leaves, compact inflorescence, elliptic bracts and glabrous ovules are treated as new species under the name *P. gamblei*.

Additional specimens examined:— **India**. **Tamil Nadu**: Pulneys, Coelogyne rock, Poombarai road, 6 July 1898, *Bourne 1308* (K!); Pulneys, Coelogyne rock, Poombarai road, 17 December 1898, *Bourne 1308** (K!); Pulneys, near sonerila rock, Pambar stream, 28 June 1899, *Bourne 1331* (K!); Pulneys, Coelogyne rock, Poombarai road, 25 May 1899, *Bourne 1338** (K!); Pulneys, Pambar ravine, 28 May 1901, *Bourne 1367* (K!); Pulneys, Pillar rock, Kodaikanal, 19 May 1901, *Bourne 1393* (K!); Pulneys, below Coelogyne rock, Poombarai road, 5 June 1901, *Bourne 1503* (K!); Kodaikanal, Grand cascade, 29 April 1986, *Mathew 44694* (RHT); Kodaikanal, Poombarai, 9 April 1987, *Mathew & Charles 49132* (RHT); Kodaikanal, Kodai to Berijam road 16 th km, 17 December 1989, *Perianayagam 53970* (RHT); Kodaikanal, Pambar ravine, 3 March 1990, *Mathew 54154* (RHT); Pambar ravine, 3 March 1990, *Mathew 54157* (RHT); Pambar shola, 9 February 1997, *Mathew & Tanya Balcar 55120* (RHT); Poombarai, Bourne's rock, 21 January 2017, *Smitha & Sunojkumar 135474* (CALI!).

Conservation status :— *Plectranthus bourneae* is confined to Pulney Hills which covers a total area of 3350 km2 in Kodaikanal Taluk of Western Ghats (India). As per the available information from literature and herbarium sources, it species has been collected from four different areas in Pulney Hills. When we made our own recent collection, very few mature plants (less than 200) were noticed in a fragmented population in Poombarai which is a tourist place that is highly threatened due to the construction of roads and buildings. Therefore P. bourneeae should be considered 'Endangered' (EN, B1a, b (ii, iii) + D) according to the IUCN (2012) categories and criteria.

3.6.7. Plectranthus caninus Roth, Nov. Pl. Sp. 279. 1821; Keng in Steenis, Fl. Malesia 8(3): 392. 1978; Ramaswamy & Razi, Fl. Banglore 510. 1973; K.M.Matthew, Fl. Tamil Nadu Karnatic 1: 1273. 1983; B.D.Sharma *et al.*, Fl. Karnataka 223. 1984; A.N.Henry, Fl. Tamil Nadu 2: 181. 1987; N.P.Singh., Fl. Eastern Karnataka, 2: 524. 1988; K.M.Mathew, Excurs. Fl. Cent. Tamil Nadu 408. 1991; Lakshmin. & B.D.Sharma, Fl. Nasik Dist. 396. 1991; K.M.Matthew, Fl. Pulney hills 2: 1002. 1999. **(Fig. 3.19)**

Type:— India, Heyne s.n. in *Wall. Cat*. 2729 C (holotype B, destroyed; Lectotype K-W, K000820142!, designated here).

≡ *Coleus caninus* (Roth) Vatke, Linnaea 37 (3): 318. 1872; R.R.Rao & Razi, syn. Fl. Mysore 510. 1981; Bole & J.M.Pathak, Fl Sourashtra 2: 215. 1988

= *Majana canina* (Roth) Kuntze, Revis. Gen. Pl. 2: 524. 1891.

= *Ocimum monadelphum* Roth, Nov. Pl. Sp. 267. 1821, as ' *Ocymum*'.

Type:— INDIA, Heyne s.n. (holotype B, destroyed); India, Herb. Ham. In *Wall. Cat*. 2729B, with '*Plectranthus monadelphus*'(Lectotype K, K000820142!, designated here).

= *Coleus heynei* Benth., Labiat. Gen. Spec. 50. 1832; Benth in DC., Prodr. 12. 71. 1848.

Type:— as for *O. monadelphum*.

= *Coleus spicatus* Benth. in Wall., Pl. Asiat. Rar. 2: 15. 1830; Benth., Lab. Gen. Sp. 49. 1832; Benth. in DC., Prodr. 12: 71. 1848; Hook.f., Fl. Brit. India 4: 624. 1885; Gamble, Fl. Madras 2. 1123. 1921; Mujkerjee, Rec. Bot. Surv. India 14: 52. 1940.

Type:— India, Herb. Wigt in *Wall. Cat*. 2729A (Lectotype K, K000820141!, designated here).

=*Plectranthus monadelphus* Roxb. [Hort. Beng. 45. 1814, *nom. nud*.], Fl. Ind. 3: 22. 1832.

Type:— Roxburgh's illustration No. 1459.

Erect or ascending annual, aromatic herbs, up to 50 cm tall. Stems succulent, branched, quadrangular to cylindrical, softly pubescent with white hairs, internodes 3–4 cm long. Leaves simple, fleshy, smooth, obovate, 2–3.5 × 1.5–3 cm, apex obtuse, base cuneate, margin slightly crenate, 4–6 pairs of teeth, pubescent to puberulous with sessile glands on both surfaces, venation eucamptodromous; petioles slender, 0.5–2 cm long, pubescent. Inflorescence terminal, simple, spike-like, adjacent verticils touching, rarely separated below, up to ca. 15 cm long, cymes sessile, 3-flowered, peduncle 1–3 cm long; bracts caducous, broadly ovate, ca. 8 × 8 mm, apex acuminate, margin ciliate, pubescent along margin; bracteole absent; flower 13–16 mm long, ca. 5 mm in diameter, purple; pedicels slender, 2–3 mm long at anthesis, 3–4 mm in fruit, pubescent. Calyx green, campanulate, 3–4 × 2–3 mm at anthesis, accrescent, enlarges up to 4–5 × 4–5 mm in fruit, tube 1–1.5 mm long, 10-

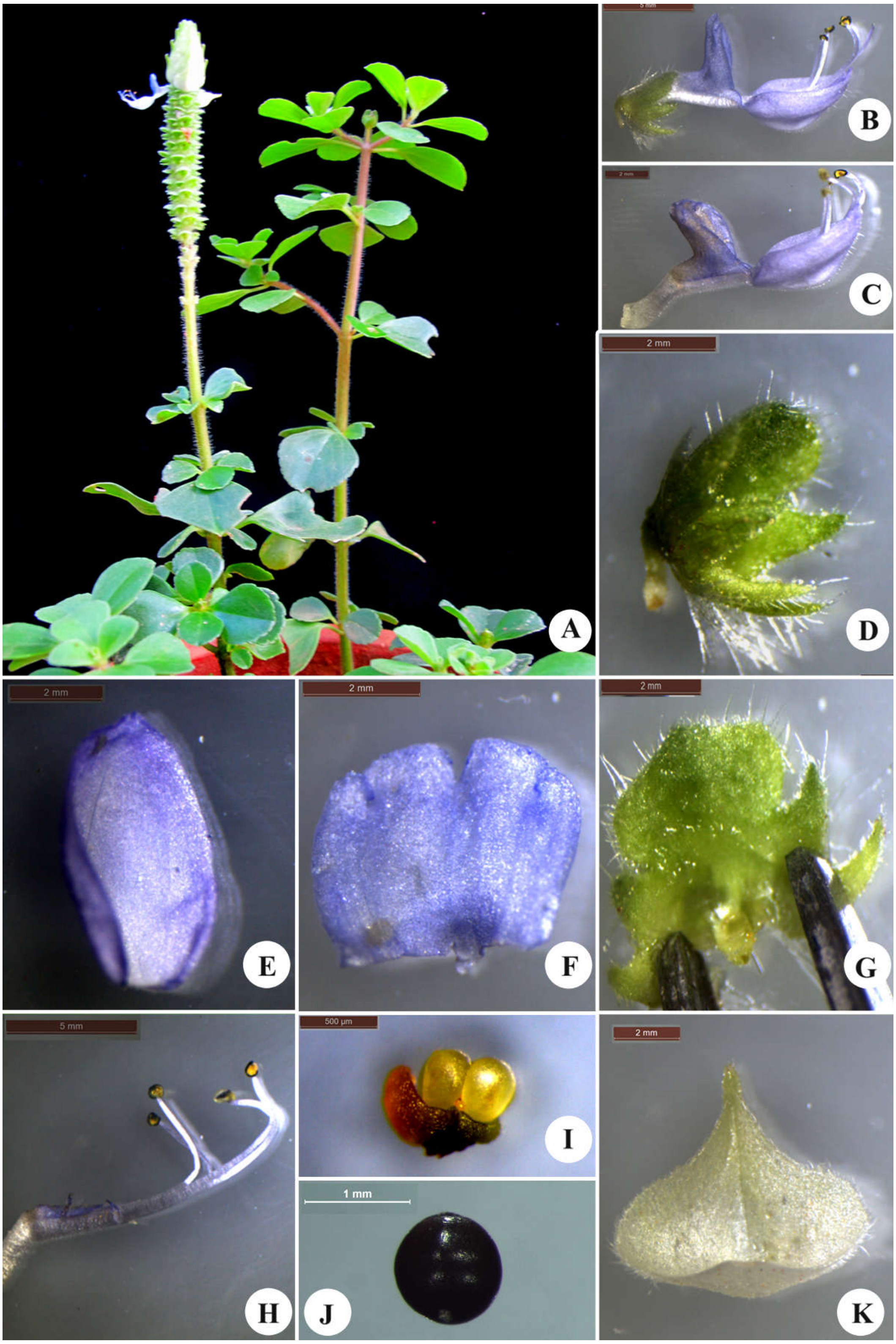
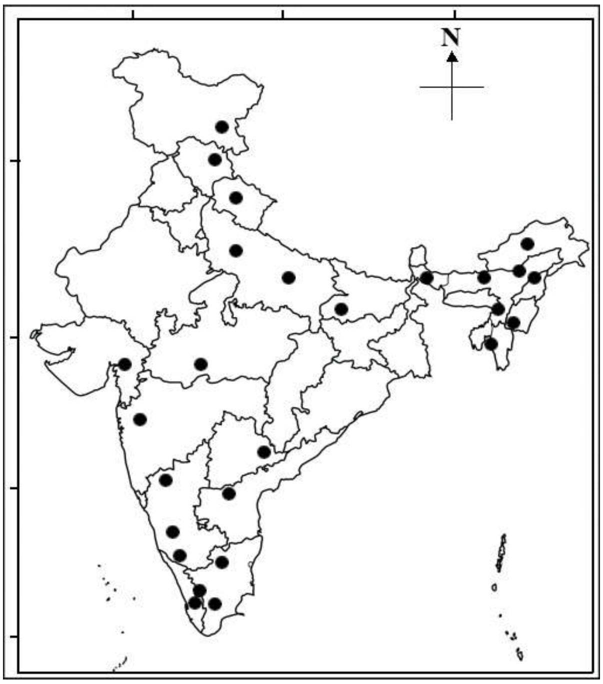


Fig. 3.19. *Plectranthus caninus*. A. Habit; B. Flower; C. Corolla; D. Flowering calyx; E. Corolla lower lip; F. Corolla upper lip; G. Calyx opened; H. Stamen; I. Ovary; J. Mericarp; K. Bract.

nerved, pubescent, with sessile glands outside, hairs denser at tube base, with a ring of dense white hairs inside throat; posterior lip broadly obovate, slightly decurrent on tube, apex acute, margin ciliate, ca. 3 × 4 mm at anthesis, ca. 3.5 × 5 mm in fruit, inside glabrous, pubescent with sessile glands outside; anterior lip 4-lobed equal in length, slightly smaller than posterior, lateral teeth (ca. 1 × 2 mm) triangular to ovate, midian teeth (ca. 0.5 × 2 mm) lanceolate, all teeth with margin shortly ciliate, pubescent with sessile glands outside. Corolla purple, 11–13 mm long, pubescent; tube 4–5 mm long, sigmoid below the middle, gradually dilated towards base, widely expanded at throat, glabrous inside; posterior lip 4-lobed, dark purple, lobes rounded at apex, pubescent, median lobes (ca. 2 × 1 mm) larger than lateral lobes (ca. 1 × 1 mm); anterior lip ovate, boat shaped, ca. 6 × 4 mm, concave, glabrous inside, pubescent with orange sessile glands outside. Stamens 4, united for half of their length, appendages absent, exserted beyond anterior corolla lip; anthers bilobed, dorsifixed, yellowish, dehisces longitudinally. Disc with anterior side enlarged, white, ca. 1 mm long, not exceeding ovary, orange coloured glands present; ovary ca. 1 mm high; style sigmoid, ca. 1.5 mm long, glabrous; stigma bifid with unequal branches. Mericarps spherical, ca. 1 × 1 mm, black, smooth, shining, producing mucilage when moistened.



Phenology:—Flowering and fruiting occurs between December and February.

Habitat and Distribution:— Distributed mainly in Tropical Africa, India and Burma. Sometimes cultivated. Found mostly in scrub forest, rocky places etc.

Notes:—*P. caninus* is characterized by its high aromaticity with a smell of camphor. This species can be easily distinguished by its small obovate leaves and spike-like inflorescence.

Specimens Examined:—India. Peninsula Indiae Orientalis, *Wight 2103* (CAL!); **Andhra Pradesh**: Cuddapah district, Nagarjunasagar, 13 December 1959, *K.M.Sebastine 9749* (MH!); Cuddapah district, February 1883, *J.S.Gamble 11055* (CAL!); Nalconda district, 13 December 1959, *K.M.Sebastine 9749* (CAL!); **Karnataka:** Chikmagalur district, Bababudan hills, 26 December 1893, *Talbot 3256* (CAL!); Chikmagalur, near Birur, 16 December 1978, *S.R.Ramesh & P.Prakash 5446* (JCB!); Hassan district, Mysore, Belur, November 1908, *A.Meebold 10336* (CAL!); Belavathally state forest, 19 December 1968, *C.J.Saldanha 12007* (JCB!); Arkalgud, 8 December 1969, *C.J.Saldanha 15732* (JCB!); Mysore, Aloka near Yelwal, 21 January 1970, *R.Raghavendra Rao 329* (JCB!); Bourdalboore state forest, 26 December 1978, *C.J.Saldanha, P.Prakash & S.B.Manohar 5465* (JCB!); Mandya district, Adichunchanagiri, 18 December 1978, *K.P.Sreenath & K.R.Keshavamurthy 5044* (JCB!); Bellur-Nagamangala road, 7 January 1979, *K.R.Keshavamurthy 5044* (JCB!); Biligere, 20 December 1980, *C.J.Saldanh & S.R.Ramesh 1241*4 (JCB!); Bandipur, Gopalaswami hill, 4 February 1979, *P.Prakash & K.P.Sreenath 5731* (JCB!); Bellary district, near Gondabommanahalli, 17 January 1979, *S.B.Manohar & B.R.Ramesh 583*5 (JCB!); Chiribi reserve forest, 09 January 1980, *S.B.Manohar & S.R.Ramesh 10684* (JCB!); **Kerala**: Idukki district, Chinnar, 14 February 2001, *P.Prajeesha 72965* (CALI!); Chinnar, 14 February 2001, *T.Sujitha 73975* (CALI!); Chinnar, 14 February 2001, *V.Smitha 45543* (CALI!); Idukki district, Marayur, 13 November 2012, *Smitha & Sunojkumar 135409* (CALI!); Chinnar, 03 January 2014, *Smitha & Sunojkumar 135446* (CALI!); **Tamil Nadu**: Coimbatore district, Nellimalai R.F., 22 May 1962, *K.Ramamurthy 14058* (MH!); Maruthumalai, 29 December 1956, *K.M.Sebastine 1878* (CAL!); Maruthumalai, 29 December 1956, *K.M.Sebastine 1878* (MH!); Kuridimalai, 23 February 1957, *K.Subramanyam 2437* (MH!); Coimbatore, Udumaiped, Amaravathi house, 10 November 1986, *K.M.Mathew 47242* (RHT!); Kollegal, 10 February 1930, *Y.Narayanaswamy 19779* (MH!); Cowvery hills, 20 June 1932, *V.Ramaswami 376* (RHT!); Kotagiri, 06 January 1957, *K.Subramanyam 1970* (CAL!); Kodaikanal Ghat road, 25 February 1959, *J.Pallithanam JP 4597* (RHT!); Sirumalais, 05 February 1959, *J.Pallithanam JP 4312* (RHT!); Narthamalai, 09 January 1969, *K.M.Mathew 9642* (RHT!); Madurai distrct, way to Kambam, 22 February 1978, *M.Chandrabose 54230* (MH!); Madurai district, way to Kambam, 22 February 1978, *M.Chandrabose 54230* (CAL!); Salem, Mettur, 21 December 1976, *K.M.Mathew & V.Alphonse Raj 6015* (RHT!); Sankagiri hill, 09 December 1978, *K.M.Mathew 19928* (RHT!); Rasipuram, 05 July 1979, *P.Permal 23498* (RHT!); south Arccot, Vrindachalam, 01 January 1980, K.M.Mathew 26249 (RHT!); Dharmapuri, Denkanikotta, 28 October 1981, *K.M.Mathew, S.J.Britto & N.Rani 28474* (RHT!); Madurai, Kodaikanal, Kilanavayal-Manjampetti hill track, 05 February 1986, *K.M.Mathew & N.Rajendran 44037* (RHT!); Anna, Kodaikanal, Palamalai, 03 December 1987, *K.M.Mathew 51850* (RHT!); Thiruvannamalai, Javadi hills, 05 January 2002, *K.M.Mathew 73746* (RHT!);

Conservation status:—Near Threatened (NT)

3.6.8. ***Plectranthus deccanicus*** Briq., Annuaire Conserv. Jard. Bot. Genève 2: 234 (1898); A.N.Henry et al., Fl Tamil Nadu 2: 181. 1987; K.M.Matthew, Fl. Pulney hills 2: 1002. 1999 **(Fig. 3.20 & 3.21)**

Type:—India, Deccan peninsula, Pulneys, *Wight Cat 2514* (Holotype: K; K000820137); (Isotype: K; K000820138).

=*Plectranthus fruticosus* (Wight ex Benth.) Hook.f., Fl. Brit. Ind. 4. 623. 1885; Gamble, Fl. Madras 2. 1120. 1921

=*Coleus fruticosus* Wight ex Benth. in A.P.de Candolle, Prodr. 12: 78. 1848; Rama Rao, Fl. Plants Travancore 322. 1914

Erect or ascending perennial shrubs, up to 250 cm tall. Stem woody, green with purple dots, branched, quadrangular, white tomentose with simple white hairs, ring of white hairs at nodes; internodes 7–9 cm long. Leaves simple, membraneous, smooth, cordate, 4–14 × 3–13 cm, apex acute, base deeply cordate, margin doubly crenate, 28–42-toothed on both sides, upper surface pubescent with simple hairs, lower surface white tomentose, margin pubescent, 6–8-nerved, venation eucamptodromous; petioles fleshy, 1–4 cm long, white tomentose. Inflorescence terminal, up to 30 cm long, sometimes basally branched, dense, purplish, axis fleshy, puberulous with or without sessile glands; floral nodes 1–2 cm apart; cymes 4–6 cm long, pedunculate, producing lateral cincinnae, 20–24-flowered, compact; peduncle 2–3 cm long; bracts early caducous, ovate, 4–5 × 1–2 mm, apex acuminate, margin ciliate, pubescent below; flower 16–18 mm long, with glandular and non-glandular hairs; pedicels slender, 2–3 mm long at anthesis, 3–4 mm in fruit, pubescent. Calyx dark purple, campanulate, 2–3 × 1–2 mm at anthesis, accrescent, recurved and enlarges up to 2.5–3.5 × 2.5–3 mm in fruit, inside glabrous, pubescent with gland-tipped hairs and sessile glands outside and with posterior and anterior lips closing together; tube recurved, 1–1.5 mm long, enlarged to 3 mm in fruit; lips closed, 10-nerved, inside glabrous, pubescent with gland-tipped hairs and sessile glands outside; posterior lip broad, cordate, decurrent to tube, apex acuminate, margin ciliate, always longer than anterior lateral teeth; teeth of the anterior lip lanceolate, margin ciliate, lateral teeth smaller than median teeth, ca. 1.5 mm long at anthesis, ca. 2 mm in fruit, median teeth ca. 2 mm long at anthesis, ca. 3 mm in fruit. Corolla purple,

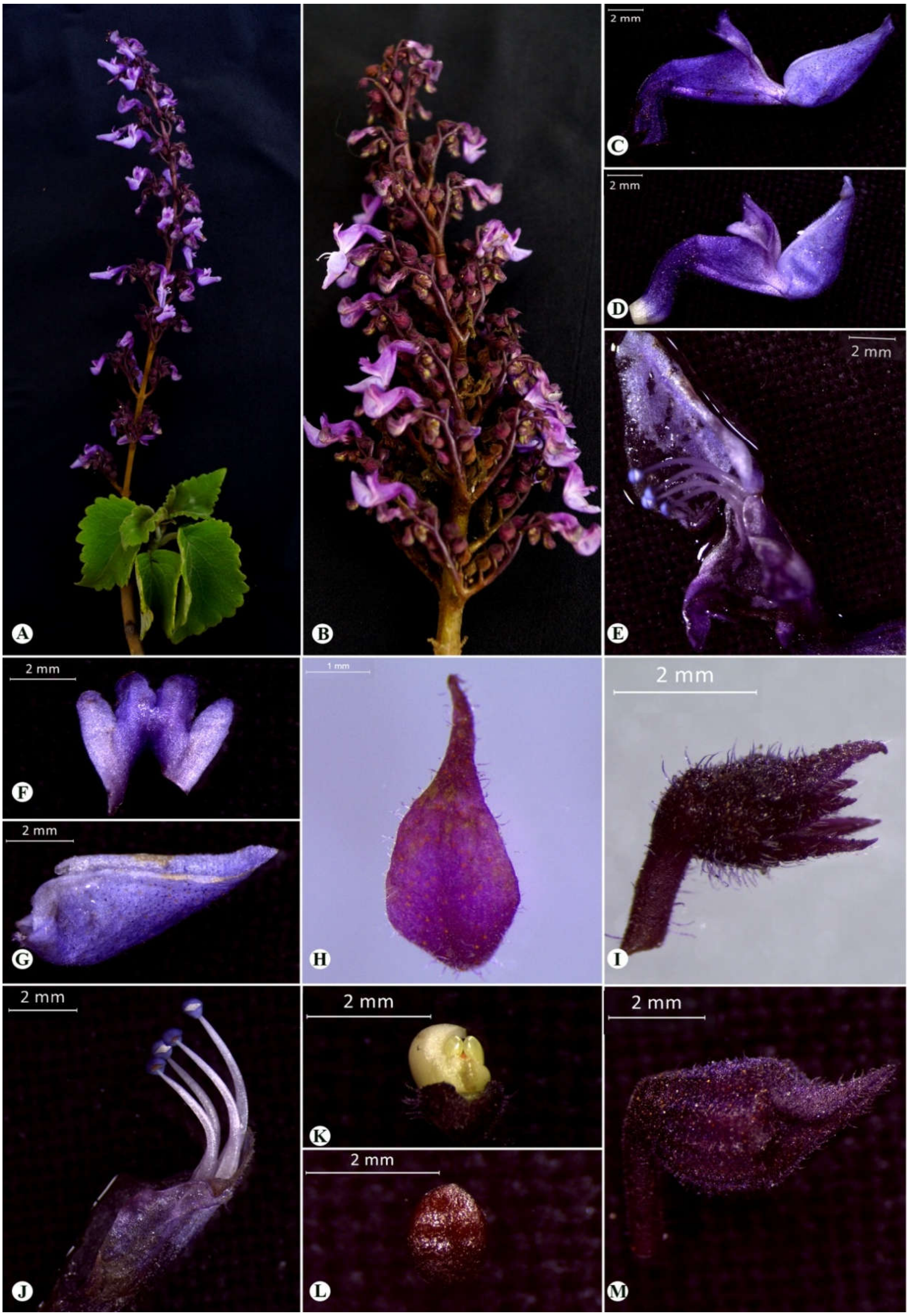
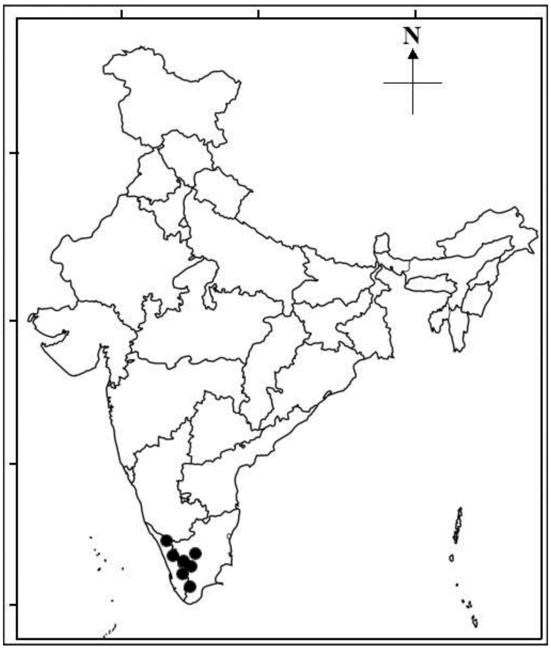


Fig. 3.20. *Plectranthus deccanicus*. A. Vegetative shoot and inflorescence; B. Inflorescence; C. Flower; D. Corolla; E. Corolla tube opened; F. Corolla upper lip opened; G. Corolla lower lip in profile; H. Inflorescence Bract; I. Flowering calyx; J. Stamen; K. Ovary; L. Mericarp; M. Fruiting calyx.

Fig. 3.21. Lectotype of *Plectranthus deccanicus*. (K000820137, "Reproduced by permission of Board of trustees of Royal Botanic Gardens, Kew").

15–16 mm long, ca. 7 mm in diameter, pubescent; tube 8–10 mm long, sigmoid below the middle, gradually dilated toward base, widely expanded at throat, glabrous inside; posterior lip 4-lobed, pale purple coloration toward tip, lobes rounded at apex, pubescent, median lobes (2 × 1.5 mm) larger than lateral lobes (1.5 × 1 mm); anterior lip single, ovate, boat shaped, 8 × 7 mm, concave, simple small hairs present along inner side of margin, pubescent with orange-colored sessile glands outside. Stamens 4, free, attached at the mouth of the corolla tube; posterior pair attached just below anterior but not united, filament of posterior pair ca. 4 mm long; filament of anterior pair ca. 5 mm long, appendages absent on both filaments, included in anterior corolla lip; anthers bilobed, dorsifixed, ca. 0.5 mm long, yellowish, dehisces longitudinally. Disk with anterior side enlarged, white, ca. 1 mm long, larger and exceeding ovary, orange-colored glands present; ovary ca. 0.5 mm high; style sigmoid, ca. 1.5 cm long, glabrous; stigma bifid with unequal branches. Mericarps prolate, 1.45–1.50 × 1.14–1.23 mm, brown, rough with small cellular projections and isodiametric cells with anticlinal walls straight, channeled and the curvature of the outer periclinal cell wall convex, producing mucilage when moistened.

Phenology:—Flowering and fruiting occurs between February and July.



Habitat and Distribution:— *Plectranthus deccanicus* is a rare species endemic to Western Ghats. This large woody shrub is sometimes planted as hedges. In wild, we observed the species growing on margins of shola forest (montane evergreen forest).

Notes:— There are two sheets of

Wight 2514 with same number and locality at K. Hence they are deposited in the same herbarium these two sheets are considered as isotypes (ICN 2012). Therefore one sheet (K000820137!) is cited as the holotype as the specimen is clearly marked as Herbarium Benthamianum and there is a reference to the protologue written on the label. The second one (K000820138!) is an isotype as there is no reference to Bentham on the specimen.

Additional specimens examined:—INDIA. **Tamil Nadu**: Dindigal district, Kodaikanal, Pulney, July 1899, *A. G. Bourne 1143* (CAL!); 1 July 1901, *A. G. Bourne 2035* (CAL!); Shembaganur, 26 March 1913, *Rev. Aug. Saulieres 306* (CAL!); Kukkal, 03 May 1984, *K. M. Mathew 41304* (RHT!); Bombay shola, 30 May 1984, *K. M. Matthew & S. J. Britto 40115* (RHT!); Pambar shola, 01 March 1986, *K. M. Matthew 44322* (RHT!); Shembaganur, 02 March 1986, *K. M. Matthew 44352* (RHT!); Tandigudi, 27 April 1986, *K. M. Matthew 44583* (RHT!); Shembaganur, 13 May 1986, *K. M. Matthew 44979* (RHT!); Samarkadu, 02 March 1987, *K. M. Matthew & N. Rajendran 48757* (RHT!); Pulney hills, Mangalamkombu, 06 March 1987, *K. M. Matthew & N. Rajendran 48514* (RHT!); Shembaganur, 07 March 1987, *K. M. Matthew & N. Rajendran 48538* (RHT!); Kodaikanal, Pulney hills, below Mungickal church, 21 March 1987, *K. M. Matthew 48639* (RHT!); Kukkal, 06 April 1987, *K. M. Matthew & M. Charles 48898* (RHT!); Pulney hills, Tandigudi slopes, 12 April 1987, *K. M. Matthew 49216* (RHT!); Palney ghat road, 15 May 1987, *K. M. Matthew & N. Rajendran 49473* (RHT!); Kukkal, 20 May 1987, *K. M. Matthew & M. Charles 49602* (RHT!); Kukkal shola, 01 May 1988, *K. M. Matthew 52803* (RHT!); 20 December 1988, *S. Sudheesan 625* (CAL!); Pozhachikadu, 3 February 1990, *K. Ravikumar 92506* (MH!); Sirumalai, 23 February 2014, *Smitha & Sunojkumar 135449* (CALI!); **Kerala**: Idukki district, Pambadumpara to Munnar road side, 14 April 1960, *K. Subramanyam 10230* (MH!); Munnar, 27 March 2016, *Smitha & Sunojkumar 135467* (CALI!).

Conservational status:—Least Concern (LC).

3.6.9. Plectranthus gamblei Smitha & Sunojk. (in press)

(Fig. 3.22 & 3.23)

Type:—India. Tamil Nadu, Coonoor, August 1883, *Gamble 12263* (Holotype: K000820169! in K) (Isotype: K000820170! in K)

Erect or ascending perennial subshrub, up to 2 m tall, aromatic. Stem fleshy-woody, branched, rounded at base becoming quadrangular towards apex, glabrous towards base but tomentose with white hairs towards apex; internodes 1.5–3.0 cm long. Leaves simple, fleshy, ovate, 2.5–6.0 cm × 2–5 cm, acute at apex, cuneate at base, with margins crenate at the upper part and entire towards base, 20–22-toothed, upper surface pubescent with simple white hairs, lower surface pubescent along veins only, with black sessile glands beneath; veins 8–12, eucamptodromous, more conspicuous beneath; petioles fleshy, 0.5–1.5 cm long, more tomentose on upper part with white hairs. Inflorescence terminal, up to 12 cm long, without basal branches, pale green; axis fleshy, villous with white hairs, with or without sessile black glands; cymes compact, producing lateral cincinna, 1.5–2.0 cm long, 8–10-flowered, densely villous with white hairs; peduncles 1–2 cm long; bracts caduceus after anthesis, elliptic, 6 × 2 mm, acuminate at apex, ciliate along margin, pubescent below; bracteoles absent.; pedicels slender, 3 mm long at anthesis, elongating to 4 mm in fruit, villous. Calyx pale green, campanulate, ca 2–3 × 1–2 mm at anthesis, accrescent, recurved and enlarged to 3–4 × 2.0–2.5 mm in fruit; tube 1–2 mm long, 10-nerved, pubescent with dense white hairs and orange glands outside; posterior lip ovate, continuous with the tube, acute at apex, with ciliate margin, 1.2 × 1 mm at anthesis, 2 × 1 mm in fruit, villous; anterior lip lanceolate, acuminate at apex, with ciliate margin, median and lateral lobes equal, 1.2 mm long at anthesis, 2 mm in fruit, villous. Flower 10–11 mm long, 5 mm in diameter, pale white with upper lip pink; corolla 1 cm long, pubescent with white hairs; tube 5 mm long, sigmoid below the middle, gradually dilated towards base, widely expanded at throat, glabrous inside; posterior lip 4-lobed, pink, ovate with unequal lobes; median lobes (3 × 3 mm), longer than lateral lobes (1 × 1 mm), outside villous with white

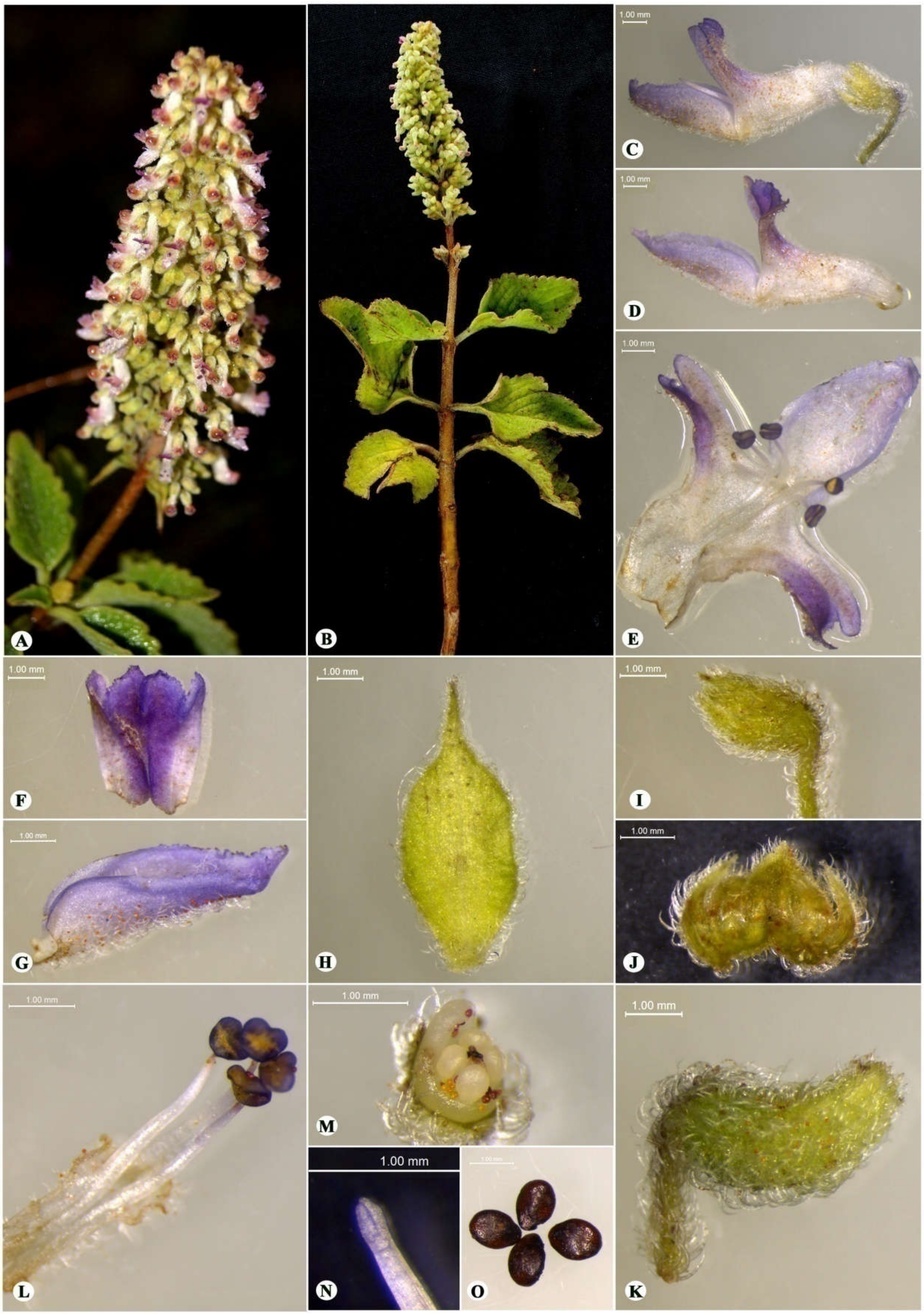
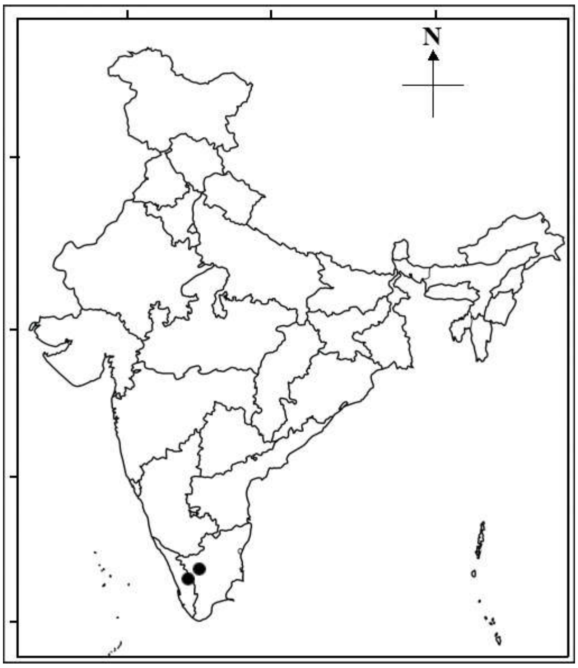


Fig. 3.22. *Plectranthus gamblei*. A. & B. Leafy twig and verticillaster; C. Flower; D. Corolla; E. Corolla tube opened; F. Corolla upper lip; G Corolla lower lip; H. Bract; I. Flowering calyx; J. Calyx opened; K. Fruiting calyx; L. Stamen; M. Ovary; N. Stigma; O. Mericarp.

Fig. 3.23. Lectotype of *Plectranthus gamblei*. (K000820169, "Reproduced by permission of Board of trustees of Royal Botanic Gardens, Kew").

hairs, orange gland dotted, inside glabrous; anterior lip pale with tip pink, 4 × 3 mm, acute at apex, with entire margin, with simple long hairs along inner side of margin. Stamens 4, free, attached at the mouth of the corolla tube; posterior pair attached just below the anterior but not united; filament of posterior pair 2.5 mm long, that of anteriorpair 3 mm long, without appendages, inserted in anterior corolla lip; anthers bi-lobed, dorsi-fixed, ca 0.5 mm, violet, longitudinally dehiscent. Disc with anterior lobe enlarged, white, 1 mm, larger and exceeding ovary, with orange colored glands; ovary 0.5 mm long, with orange coloured glands; style sigmoid, 0.8–1.0 cm long, glabrous; stigma bifid with unequal branches, upper lobe 0.1 mm, lower lobe 0.05 mm, glabrous. Mericarps prolate, 1.25–1.27 × 0.91–0.98 mm, black, their surface comprised of isodiametric cells with anticlinal walls straight, channeled and the curvature of the outer periclinal cell wall convex, producing mucilage when moistened.

Phenology:—Flowering and fruiting occurs between October and February.



|**Etymology**:—The species is named after J. S. Gamble, who first collected the species from Coonoor, India.

Habitat and Distribution:—*Plectranthus gamblei* is a rare species endemic to Western Ghats. It is collected from the core area of Silent Valley national park after Gamble’s collection (1883). The plants grew attached to wet rocky surfaces, at an elevation about 2000 m a.s.l.

Additional specimens examined:— **India. Kerala**: Palakkad district, Silent Valley, Mullan para, elev. 1830 m, 30 October 2013, *Smitha & Sunojkumar 135434* (CALI!)

Conservation status:— The type specimen of the Western Ghat endemic species *P. gamblei* was collected from Coonoor in Nilgiris district. After the type collection made in 1883, the species has never been recollected there. As part of the present study we have explored the entire area and no such plants could be found. Our new collection is from Mullan para which is a hillock in the core area of Silent Valley national park in the nearby Palakkad district. Less than 30 mature individuals along with few saplings were noticed in Mullan para forming a single fragmented population. Using IUCN (2012) criteria D, it has been categorized as a 'Critically Endangered' (CR) species.

3.6.10. Plectranthus glabratus (Benth.) Alston in Trimen, Hand-Book. Fl. Ceylon 6. Suppl., 236. 1931; L.H.Cramer in Dassan. & Fosberg, Rev. Handb. Fl. Ceylon 3: 135. 1981; B.D.Sharma et al., Fl. Karanataka 223. 1984

(Fig. 3.24 & 3.25)

≡ *Coleus glabratus* Benth., Lab. Gen. Spec.: 58. 1832, 711. 1835; in DC., Prod. 12: 78. 1848;

Type:—India, Peninsula India orientalis, Madura, Herb. *Wight s.n*. (Holotype K!)

= *Coleus paniculatus* Benth. in Wall., Pl. As. Rar. 2: 16. 1830: Benth., Lab. Gen. Spec. 59. 1832; in DC., Prodr. 12 :79. 1848.

Type:— India, Dindigul, Herb. *Wight* in *Wall. Cat*. 2734 (Holotype K!)

= *Coleus wightii* Benth., Lab. Gen. Spec.: 58. 1832; in DC., Prodr. 12: 78. 1848.

Type:— India, Nilgiris, *Wight s.n.* (Holotype K!)

= *Plectranthus coleoides* Benth. in DC. Prod. 12: 64. 1848; Hook.f., Fl. Brit. India 4: 622. 1885; Trimen, Hanb. Fl. Ceylon 3: 370. 1895; Rama Rao, Fl.

Plants Travancore 322. 1914; Fyson, Fl. Nilgiri & Pulney. 1: 323. 1915; Gamble, Fl. Pres. Madras 2. 1119. 1921; Fyson., Fl. South Indian Hill Stations, 2: 404. 1932; Mukerjee, Rec. Bot. Surv. India 14: 48. 1940; B.D.Sharma., Fl. Nilgiri 232. 1975; K.M.Matthew, Fl.Tamil Nadu Karnatic 1: 1273. 1983; A.N.Henry et al., Fl. Tamil Nadu 2: 181. 1987; K.M.Matthew, An Excur. Fl. Central Tamil Nadu, 408. 1991 & Fl. Pulney hills 2: 1002. 1999

Type:—India, Nilgiris, *Perrottet* s.n. (Holotype G-DC!)

= *Plectranthus bernadii* Doan, Fl. Indo-Chine 4: 949. 1936, *nom inval*.

= *Plectranthus bishopianus sensu* Karupp. & Rajasek., Curr. Sci. 295. 2009, *non* Gamble.

Erect or ascending annual undershrubs, up to 2 m tall. Stems woody, light green with brown spots, branched, quadrangular to cylindrical, almost glabrous, internodes 6–12 cm long. Leaves simple, membraneous to fleshy, smooth, cordate, 5–12 × 5–11 cm, apex acute, base rounded to cordate, margin mainly crenate, often double crenated, 24–30 pairs of teeth, upper surface pubescent with simple hairs, lower surface pubescent along veins only, with sessile glands beneath, margin pubescent, with 6–8 lateral veins from leaf base, venation eucamptodromous; petioles slender, 2–13 cm long, puberulous and vedged. Inflorescence terminal, up to ca. 35 cm long, branched at inflorescence base, purplish coloured, axis slender, pubescent with gland-tipped hairs; floral nodes 1.5–2.5 cm apart, distant, cymes 2–4 cm long, pedunculate, producing lax lateral cincinni, 10–14-flowered, peduncle 4–5 cm long; bracts early-caducous, ovate, 3 × 1 mm, apex acuminate, margin ciliate, pubescent through margin; bracteole absent; flower 10–13 mm long, ca. 5 mm in diameter, pale purple; pedicels slender, 2–3 mm long at anthesis, 3–4 mm in fruit, pubescent. Calyx light green to purple, campanulate, 2–3 × 2–3 mm at anthesis, accrescent, enlarges up to 5–7 × 3–4 mm in fruit, tube 2–5 mm long, 10-nerved, inside glabrous, pubescent with gland-tipped hairs and sessile glands outside; posterior lip cordate, decurrent to tube, apex obtuse, margin ciliate, ca. 2 × 2 mm at anthesis, ca. 3 × 3 mm in fruit, inside glabrous,

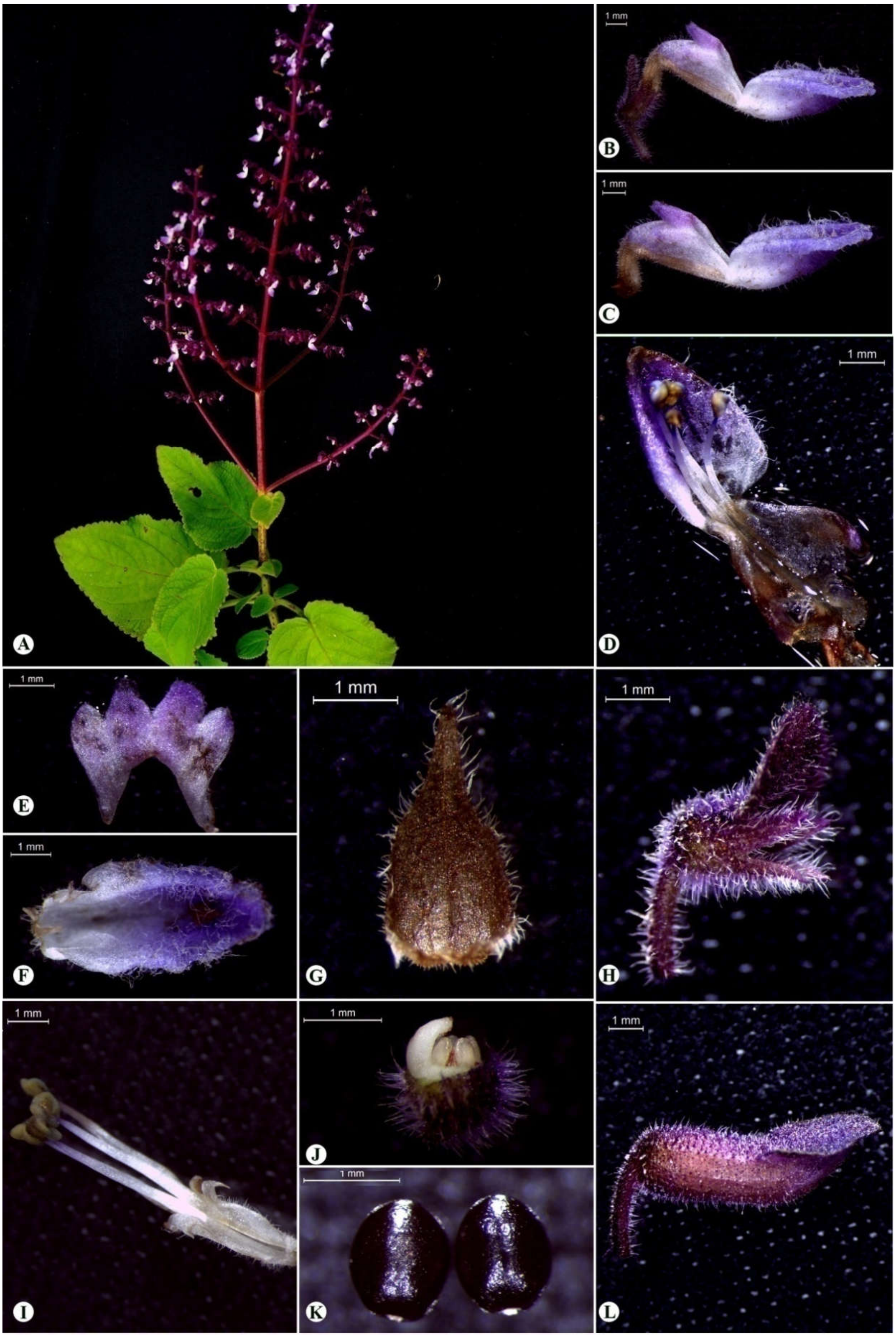
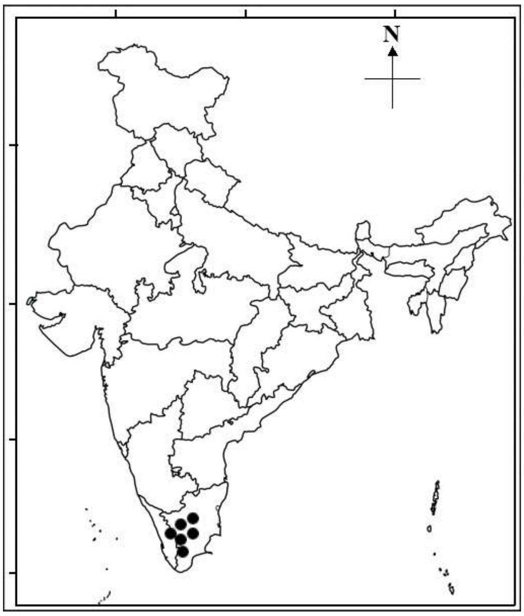


Fig. 3.24. *Plectranthus glabratus*. A. Habit; B. Flower; C. Corolla; D. Corolla tube opened; E. Corolla upper lip; F. Corolla lower lip; G. Bract; H. Flowering calyx; I. Stamen; J. Ovary; K. Mericarp; L. Fruiting calyx.

Fig. 3.25. Holotype of *Plectranthus glabratus*. (K000820128, "Reproduced by permission of Board of trustees of Royal Botanic Gardens, Kew").

pubescent with gland-tipped hairs and sessile glands outside; anterior lip teeth lanceolate, margin ciliate, 4 almost equal, ca. 1.2 × 0.5 mm at anthesis, ca. 2 × 1 mm in fruit, pubescent with gland-tipped hairs and sessile glands outside. Corolla pale purple, 9–11 mm long, ca. 5 mm in diameter, pubescent; tube 5–6 mm long, sigmoid below the middle, gradually dilated towards base, widely expanded at throat, glabrous inside; posterior lip 4-lobed, dark purple coloration towards tip, lobes rounded at apex, pubescent, median lobes (ca. 1.2 × 1 mm) larger than lateral lobes (ca. 1 × 0.8 mm); anterior lip with dark purple coloration towards lower side, ovate, boat shaped, ca. 6 × 5 mm, concave, simple long hairs present along innerside of margin, pubescent with orange coloured sessile glands outside. Stamens 4, free, attached at the mouth of corolla tube, posterior pair attached just below anterior but not united, filament of posterior pair 4 mm long, anterior pair ca. 5 mm long, appendages absent, anterior side purple, included in anterior corolla lip; anthers bilobed, dorsifixed, ca. 0.5 mm long, yellowish, dehisces longitudinally. Disc with anterior side enlarged, white, 1 mm long, larger and exceeding ovary, orange coloured glands present; ovary ca. 0.5 mm high; style sigmoid, ca. 9 mm long, glabrous; stigma bifid with equal branches. Mericarps ovate, ca 1 × 1 mm, black, smooth, shining, producing mucilage when moistened.



Phenology:— Flowering and fruiting occurs between October and March

Distribution:—India, Sri Lanka

Habitat and Ecology:— The plants grows attached with wet rocky surfaces or in moist soils at an elevation about 1600 m.

Notes:— It is a woody undershrubs with large fleshy leaves. *P. glabratus* can be easily distinguished from allied species in having large puplish basally branched inflorescence, broad posterior lip of the calyx which is always larger than anterior lips and, straight and enlarged fruiting calyx tube

Specimens Examined:—India. Tamil Nadu: Coimbatore, Ponnachi shola, 05 December 1905, *C.E.C.Fisher 689* (CAL!); Nilgiri, Coonoor, 13 March 1870, *C.B.Clarke 10755* (CAL!); Ooty, February 1883, *J.S.Gamble 12640* (CAL!); Nilgiris, October 1884, *J.S.Gamble 14883* (CAL!); Coonoor, January 1899, *Prain s. n.* (CAL!); Coonoor, Nilgiri, 08 January 1910, *C.E.C.Fisher 1577* (CAL!); Ooty, October 1910, *A.Meebold 11879* (CAL!); Kotagiri, Kilthattapallam, 06 January 1957, *K.Subramanyam 1988* (CAL!); Coonoor, upper Tiger Shola, 19 January 1957, *K.M.Sebastine 2072* (CAL!); Coonoor, Lamb's rock, 06 December 1957, *K.M.Sebastine 4783* (CAL!); Ooty to Coonoor road side, 03 January 2016, *Smitha & Sunojkumar 135461* (CALI!); Coonoor, Lamb's rock, 03 January 2016, *Smitha & Sunojkumar 135462* (CALI!); Salem, Balmadies estate, 20 December 1958, *K.Subramanyam 7559* (MH!); Kodanad R.F., Shola near view point, 12 November 1970, *E.Vajravelu 36863* (MH!); On the way to Anaikatty, 27 November 1970, *G.V.SubbaRao 37377* (MH!); Kalhatti falls, 29 November 1971, *N.C.Rathakrishnan 39070* (MH!); Bokkapuram, 21 November 1971, *N.C.Rathakrishnan 38959* (MH!); Kinna Kurai, 2 January 1971, *B.V.Shetty 37648* (MH!); Pakkasura hilla, 02 December 1972, *E.Vajravelu 43179* (MH!); Madanad, 23 January 1972, *E.Vajravelu 39583* (MH!); Salem, Namakkal, Kolli hills, way to Tiffin shed, 05 February 1979, *P.Perumal & C. Mohanan 21490* (RHT!); Salem, Omallur, Servarayan, 12 January 1980, *K.M.Mathew 25789*; Kanyakumari, way to Muthukuzhivayal, 28 September 1980, *A.N.Henry 68836* (CAL!); Madurai, Kodaikanal shola below Vembadi peak, 19 November 1985, *K.M.Mathew 42762* (RHT!); Kodaikanal, Palni hills, Kukkal shola, 04 February 1986, *K.M.Mathew & N.Rajendran 44007* (RHT!); Kodaikanal, Palni hills, Kukkal shola, 08 April 1987, *K.M.Mathew & M.Charles 49073* (RHT!); Kodaikanal, Katthirikkiodai, 18 April 1988, *K.M.Mathew 52758* (RHT!); Salem, Kolli hills, Perumakoil Cholai, 14 February 1995, *M.B.Viswanathan 17094* (JCB!)

3.6.11. Plectranthus hadiensis (Forssk.) Schweinf. ex Sprenger, Wiener III. Gart.-Zeitung 19: 2 (1894).

=*Plectranthus hadiensis var. tomentosus* (Benth.) Codd., Fl. South Africa 28: 153. 1985

=*Plectranthus zeylanicus* Benth., Lab. Gen. Sp. 36. 1832; Benth. in DC., Prodr. 12: 66. 1848; Thwaites., Enum. Pl. Zeyl. 238. 1860; Trimen., Handb. Fl. Ceylon 3. 371. 1885; Hook.f., Fl. Brit. India 4: 622. 1885; Abeywick, Ceylon. J. Sci. Biol. Sci. 2 (2): 219. 1959; Sasidh., Fl. Pl. Kerala. 374. 2004.

Type:—Ceylon, *Macrae* s.n. (Holotype, K!)

=*Coleus zeylanicus* (Benth.) L.H.Cramer in Kew Bull. 32 (3): 555. 1978; in Dassan. Revis. Handb. Fl. Ceylon 3. 150. 1981 (homotypic synonym)

Erect or ascending annual herbs up to 1 m tall, strongly aromatic. Stem fleshy, quadrangular, rooting at lower nodes, branched above, pale pink in upper parts, internodes 3–10 cm long. Leaves broadly ovate to suborbicular, 3–12.5 cm, apex obtuse, base truncate, margin serrate, teeth up to 35, nerves prominent beneath, venation eucamptodrous; petiole ca. 4 cm long, pubescent. Inflorescence terminal panicles, 12–42 cm long, verticils lax, panicles slender, hirtellous with gland-tipped hairs; bracts sublunar, ca. 5 × 7 mm, concave, subacute, pedicels 2–3 mm long, hirtellous. Calyx 1 mm long, ca. 2 mm in fruit, tube ca. 1.5 mm long, 10-nerved, dotted with oil glands; posterior lip broadly ovate, ca. 2 × 2.5 mm, abruptly acute, subdecurrent on tube, deflexed over mouth of calyx after anthesis; anterior lip ca. 2.5 mm long, lateral lobes triangular to ovate, median ones lanceolate, longer than laterals, acuminate. Corolla 8–10 mm long, pale blue, tube 4–5 mm long, finely pubescent with gland-tipped hairs, whitish; posterior lip ca. 4 mm long, shallowly lobed, dotted at back with oil globules; anterior lip orbicular, 4–5 mm long, finely pubescent. Style glabrous.

Phenology:— Flowering and fruiting occur between May and October.

Habitat and Distribution:—Cultivated as a medicinal herb, sometimes naturalized. Distributed in Arabian Peninsula, Egypt to Southern Africa, India, Maldives and Sri Lanka

Notes:—Leaves are aromatic and the whole plant is used in dyspepsia, indigestion, dysentry, vomiting, thirst, fever, dermititis, ulcers and bleeding disorders.

Specimens Examined:—India. Karnataka. Hassargatta, IIHR campus, 18 April 2001, *K.Ravikumar 58356* (JCB!); **Kerala**: Pathanamthitta district, Erumely, Peerumedu, Nallathany, 01 January 1993, *T.A.Panicker 15068* (JCB!); Malappuram district, Calicut University Botanical Garden, 23 May 2010, *Smitha & Sunojkumar 124110* (CALI!); Wayanad district, way to Kanthanpara, 23 August 2013, *Smitha & Sunojkumar 135416* (CALI!); **Tamil Nadu**. Namakkal, Kolli hills, 07 July 2005, *K.Ravikumar & R.Vijaya Sankar 52194* (JCB!)

3.6.12. Plectranthus malabaricus (Benth.) R.H.Willemse, Blumea 25: 2. 509. 1979. B.D.Sharma et al., Fl. Karnataka 224. 1984; A.N.Henry, Fl. Tamil Nadu 2: 182. 198 V.S.Ramach. & V.J.Nair., Fl. Cannanore 370. 1988; Vajr., Fl. Palghat 375. 1990; M.Mohanan & A.N.Henry, Fl. Thiruvananthapuram 369. 1994; K.M.Matthew, Fl. Pulney hills 2: 1002. 1999; Sasidh., Fl. Pl. Kerala 373. 2004. **(Fig. 3.26, 3.27, 3.28 & 3.29)**

Type:—India, Travancore, Herb. *Wight* in *Wall. Cat 2735* (Holotype K!)

≡ *Coleus malabaricus* Benth. in Wall. Pl. As. Rar. 2: 16. 1831; Benth., Lab. Gen. Sp. 47. 1832; Benth., in DC. Prodr. 12: 76. 1848; Thw. Enum., Pl. zeyl. 238. 1860; Hook.f., Fl. Brit. India 3: 626. 1885; Trimen., Handb. Fl. Ceylon 3: 276. 1895; Rama Rao, Fl. Pl. Travancore 322. 1914; Gamble, Fl. Madras 2.

1123.1921; Mukerjee, Rec. Bot. Surv. India 14(1).: 55. 1940; Abeywick, Ceyl. J. Sci., Biol. Sci. 2 (2): 219. 1959; L.H.Cramer, Kew Bull. 32 (3): 555. 1978; in Dassan. & Fosberg, Rev. Handb. Fl. Ceylon 3: 145. 1981; Manilal, Fl. Silent valley 218. 1988; Vajr., Fl. Palghat 375. 1990; Sivar. & P.Mathew, Fl. Nilambur 545. 1996.

Type:—S.coll. in Wall., Num. List 2735A, 1817. Travancore, India (holotype K-WALL.)

= *Coleus macrei* Benth., Lab. Gen. Sp. 58. 1832; Benth. in DC., Prod. 12: 77. 1848.

Type:—Macrae Lindl., s.n., Ceylon, in Hb. Bentham (holotype, K).

= *Coleus walkeri* Benth. in DC., Prod. 12: 77. 1848.

Type:—Walker s.n., Ceylon, in Hb. Benth. (holotype, K).

= *Plectranthus idukkianus* J.Mathew, Yohannan & B.J.Conn, Telopea 20: 181. 2017 ***syn. nov.***

Type:—INDIA. Kerala: Idukki District, 10 km away from Kuttikkanam, Panchalimedu Hills, 14 December 2015, *J. Mathew 4821* (Holotype: TBGT!, isotype: MSSRF!).

= *Plectranthus saxorum* J.Mathew, Yohannan & B.J.Conn, Telopea 20: 185. 2017 ***syn. nov***

Type:—India. Kerala: Kozhikode District, Vellarimala, 10 km away from Muthappanpuzha, REC para, 30 January 2015, *J. Mathew 4911* (Holotype: TBGT!, isotype: MSSRF!).

Erect or prostrate, highly variable, perennial herbs, up to 150 cm tall. Stem woody, light green, branched, quadrangular, glabrous with purple spots or tomentose or highly villous, sometimes along margins or ring of hairs at

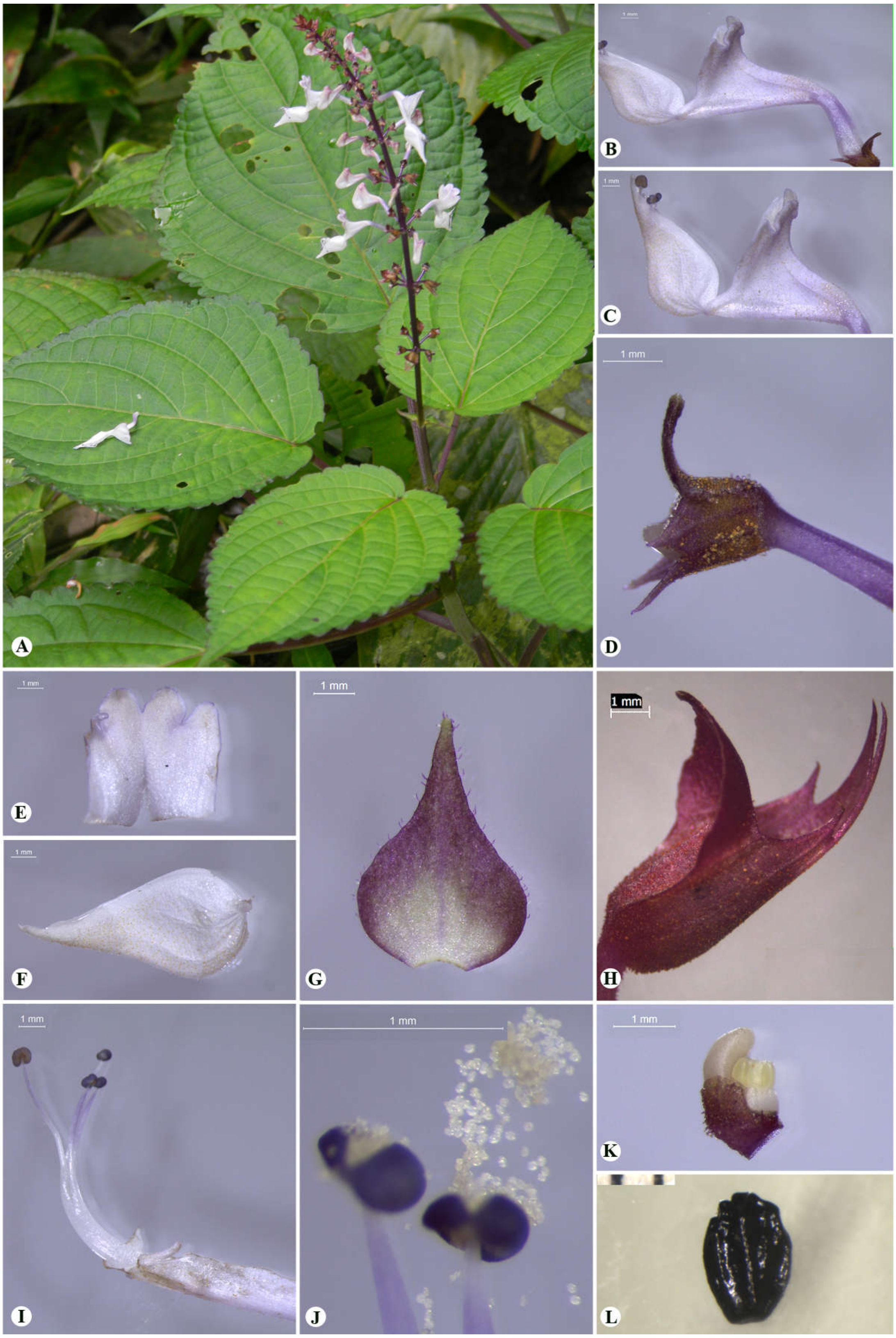


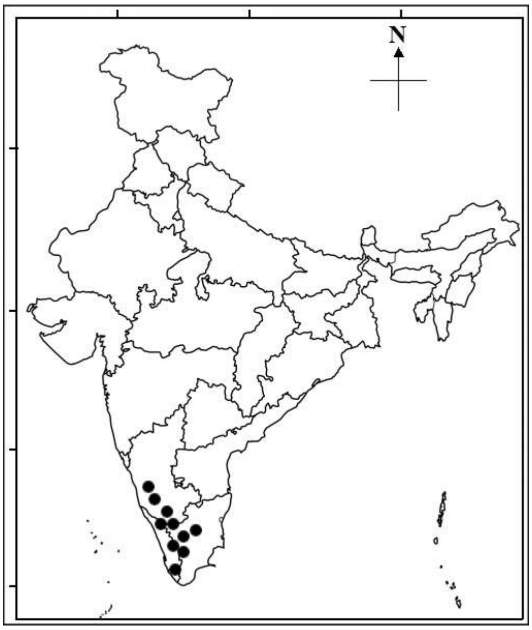
Fig 3.26. *Plectranthus malabaricus*. A. Habit; B. Flower; C. Corolla; D. Flowering calyx; E. Corolla upper lip; F. Corolla lower lip.

Fig. 3.27. Holotype of *Plectranthus malabaricus*. (K000820119, "Reproduced by permission of Board of trustees of Royal Botanic Gardens, Kew").

nodes, internodes 2–6 cm long. Leaves simple, membraneous, smooth, ovate or rounded or cordate, 8–25 × 5–17 cm, apex acuminate, base rounded or cordate or truncate, margin mainly crenate, 40–70-toothed, upper surface glabrous or pubescent with simple hairs, lower surface sometimes purplish, pubescent along veins only, with sessile glands beneath, margin pubescent, 6–8-nerved, venation eucamptodromous; petioles fleshy, 4–16 cm long, pubescent to pilose. Inflorescence terminal, up to 40 cm long, sometimes with basal branches, light green to purplish colored, axis fleshy, pubescent with or without sessile glands; floral nodes 1–2 cm apart, cymes 1–4 cm long, pedunculated, producing lax lateral cincinnal, 5–10-flowered, peduncle 2–5 cm long; bracts caducous, cordate, 5–7 × 3–5 mm, apex acuminate, margin ciliate, pubescent through margin only; bracteole absent; flower 15–25 mm long, 1 mm in diameter, pale purple; pedicels slender, 2–3 mm long at anthesis, 4–5 mm in fruit, pubescent. Calyx light green to dark purple, campanulate, ca. 3–4 × 2–3 mm at anthesis, accrescent, recurved and enlarges up to 7–9 × 5–6 mm in fruit, tube 2–4 mm long, 10-nerved, inside glabrous, pubescent with gland-tipped hairs and sessile glands outside; posterior lip broad, ovate, decurrent to tube, apex acute with a swollen tip, margin entire, ca. 2 × 2 mm at anthesis, ca. 5 × 4 mm in fruit, inside glabrous, pubescent with gland-tipped hairs and sessile glands outside; teeth of the anterior lip lanceolate, margin entire, lateral teeth much smaller than median teeth, 1 mm long at anthesis, ca. 2 mm in fruit, median teeth ca. 2 mm long at anthesis, ca. 4 mm in fruit, pubescent with gland-tipped hairs and sessile glands outside. Corolla pale purple, 13–22 mm long, ca. 7 mm in diameter, pubescent; tube 10–12 mm long, sigmoid below the middle, gradually dilated towards base, widely expanded at throat, glabrous inside; posterior lip 4-lobed, dark purple colored, lobes rounded at apex, pubescent, median lobes (ca. 2.5 × 2.5 mm) larger than lateral lobes (ca. 1.5 × 1.5 mm); anterior lip with pale purple colored, ovate, boat shaped, ca. 6 × 2 mm, concave, glabrous inside, pubescent with orange colored sessile glands outside. Stamens 4, united for about half their length, filament of posterior pair ca. 5 mm long, anterior pair ca. 7 mm long, appendages absent, included in anterior corolla lip; anthers bilobed, dorsifixed, ca. 0.5 mm long, dehisces longitudinally. Disc with anterior side enlarged, white, ca. 2 mm long, larger and exceeding ovary, orange colored glands present; ovary ca. 1 mm high; style sigmoid, 1.3–1.7 cm long, glabrous; stigma bifid with equal branches. Mericarps ovate, 1.5–3 × 1–2 mm, black, rough, producing mucilage when moistened.

Phenology:— Flowering and fruiting occur between July and January

Habitat and Distribution:—In shola forest (Montane evergreen forest) in shade areas. Distributed only in Southern India and Sri Lanka.



Notes:— *P. malabaricus* is a highly polymorphic species which exhibit a vast range of variation. We could collect more than eight different accessions of this species from different localities of Western Ghats (Fig. 28 & 29). All these accessions show differences vegetatively but floral characters are same. Apart from morphological study, molecular analysis was also conducted with three choloplast genes (*trnL* intron, *trnL-F* intergene spacer and *rps 16*). In this analysis, all the eight accessions form polytomy and we couldn't came up with any more conclusion than to decide it is a polymorphic form. Thus it is evident that more markers are needed to find out the status of this complex. Of these eight accessions, now, two of them were published (Mathew et al. 2017) as new species. All the characters used to delimit these two accessions as species are variable vegetative characters and this lead us to treat these two species as synonyms under *P. malabaricus*

Fig. 3.28. Different accessions of *P. malabaricus.* A. Thusharagiri; B. Kodajadhri; C. Thollayiram forest; D. Kurichermala.

Fig. 3.29. Different accessions of *P. malabaricus.* A. Vagamon 1; B. Vagamon 2; C. Sholayar; D. Parambikulam.

Specimens Examined:—India. Peninsula Indiae Orientalis, *Wight 2104* (CAL!); **Karnataka:** Shimoga, Agumbe, 17 October 1960, *C.J.Saldanha 6082* (JCB!); Agumbe, Vanakabbe falls, 16 May 1960, *R.S.Raghavan 62554* (CAL!); Agumbe, Ghat road, 30 August 1965, *R.S.Raghavan 90309* (CAL!); Banglore, Bisile Ghat, 01 October 1967, *C.J.Saldanha 1188* (JCB!); Chikmagalur, Bagavathi-Gangamala, 08 October 1979, *C.J.Saldanha 9710* (JCB!); Shimoga, Kodachadri, 07 April 1979, *C.J.Saldanha, K.R.Keshavamurthy & S.R.Ramesh 6839* (JCB!); Chikmagalore, Sringeri, Kudremukh, 07 July 1996, *G.S.Goraya, K.Ravikumar & P.S.Udayan 06146* (FRLH!); Kodachadri, 04 January 2013, *Smitha & Sunojkumar 135413* (CALI!); Kodachadri, 11 November 2013, *Smitha & Sunojkumar 135438* (CALI!); **Kerala**: Brahmagiri shoals, 06 December 1907, *C.E.C.Fischer 259* (CAL!); Peerumedu, December 1910, *A.Meebold 13891* (CAL!); Idukki district, Devicolam, Kandaloor forest, 24 January 1964, *K.M.Sebastine 18451* (MH!); Pathanamthitta district, Pamba, 01 October 1976, *K.Vivekananthan 48363* (CAL!); Kollam district, Moozhiar, 03 September 1977, *N.C.Nair 50853* (CAL!); Palakkad district, Kumattanthode, 06 October 1979, *N.C.Nair 64338* (CAL!); Idukki district, Kalvery mount, 11 November 1981, *C.N.Mohanan 72459* (CAL!); Kasaragod district, Konnakadu, 30 September 1982, *R.Ansari 74*388 (CAL!); Palakkad district, Silent valley, Dam site, 02 July 1982, *Prasannakumar 10937* (CALI!); Malappuram district, Nilambur, Thampumala, 13 November 1983, *Philip Mathew 33628*; Idukki district, Kulamavu, 23 September 1984, *C.N.Mohanan 80156* (MH!); Pathanamthitta district, Elamannoor, 02 February 1986, *C.Anilkumar 184* (TBGT!); Thiruvanthapuram, Bonacord, 21 December 1987, *N.Mohanan 9070* (TBGT!): Thiruvananthapuram district, Athirumala, 12 October 1988, *N.Mohanan 4230* (TBGT!); Periyar, Pachakkanam, 06 September 1993, *Jomy Augustine 12318* (CALI!); Idukki district, Walara, 02 December 1993, *A.E.S.Khan, S.Binu & E.S.Santhoshkumar 19106* (FRLH!); Eravikulam, 24

November 1994, *K.Swarupanandan 10706* (FRLH!); Palakkad district, Silent Valley, 29 September 1994, *N.Sasidharan 912* (FRLH!); Thiruvanathapuram district, Agasthyamala, Peppara, 06 September 1994, *N.Mohanan & K.T.Shaju 16006* (FRLH!); Palakkad district, Silent Valley-campshed, 20 August 1995, *Saji & Madhu 25819* (TBGT!); Thiruvananthapuram district, Idinjar, 23 November 1995, *P.Deepthi Das 26452* (TBGT!); Kozhikode district, Kakkayam, Kurisadi, 29 August 1997, *R.Rajesh 34795* (TBGT!); Wayand district, Chembra, 18 March 2012, *Smitha & Sunojkumar 135401* (CALI!); Thollayiram, 27 April 2012, *Smitha & Sunojkumar 135402* (CALI!); Kurichermala, 01 September 2012, *Smitha & Sunojkumar 135403* (CALI!); Palakkad district, Silent valley, 14 September 2012, *Smitha & Sunojkumar 135406* (CALI!); Kozhikode district, Thusharagiri, 26 November 2012, *Smitha & Sunojkumar 135410* (CALI!); Kollam district, Shendurney, 08 September 2012, *Smitha & Sunojkumar 135411* (CALI!); Thrissur district, Parambikulam, Karimala hills, 26 September 2013, *Smitha & Sunojkumar 135418* (CALI!); Kottayam district, Way to Vagamon, 09 October 2013, *Smitha & Sunojkumar 135419* (CALI!); Kottayam district, Way to Vagamon, 09 October 2013, *Smitha & Sunojkumar 135420* (CALI!); Wayanad district, Kurichermala, 28 October 2013, *Smitha & Sunojkumar 135431* (CALI!); Sholayar, 13 December 2013, *Smitha & Sunojkumar 135441* (CALI!); **Tamil Nadu**: Nilgiris, 1884, *J.S.Gamble 14865* (CAL!); Nilgiris, June 1884, *J.S.Gamble 14247* (CAL!); Pulneys, 06 July 1898, *Bourne 558* (CAL!); Tirunelveli, Kakachi, 12 October 1957, *K.M.Sebastine 4421* (CAL!); Tirunelveli, way to Agasthyamalai, 26 May 1963, *A.N.Henry, 16298* (CAL!); Kodaikanal, Berijam-Kodai, 22 September 1970, *K.M.Mathew 12726* (RHT!); Kanyakumari, Balamore to MK Vayal, 26 August 1976, *A.N.Henry, 47532* (CAL!); Tirunelveli, Ambasamudram, 31 December 1977, *K.M.Mathew 15667* (RHT!); Tirunelveli, Kakkachi, 03 September 1981, *K.M.Mathew 17856* (RHT!); Kodaikanal, Berijam Shola, 24 July 1984, *K.M.Mathew 40491*

(RHT!); Berijam-Kodai, 13 August 1985, *K.M.Mathew 41996* (RHT!); Berijam, 28 July 1986, *K.M.Mathew & M.Charles 45983* (RHT!); Korappur, 09 September 1986, *K.M.Mathew 46788* (RHT!); Kodaikanal, Blackburne shola, 10 August 1987, *K.M.Mathew, K.T.Mathew 50030* (RHT!); Tirunelveli, Kannikatty R.F., 15 September 1988. *R.Gopalan 86053* (MH!); Theni, Kalian kutta, 31 March 1991, *R.Gopalan 86053* (MH!); Dindigal, Berijam, 26 February 1994, *V.S.Ramachandran 1600* (FRLH!); Nilgiris, Naduvattam, 26 November 2004, *K.Ravikumar & R.Vijya Sankar 53357* (FRLH!)

Conservation status:—Near Threatened (NT)

3.6.13. Plectranthus mollis (Aiton) Spreng., Syst. Veg. 2: 690. 1825; Benth., Lab. Gen. Spec.: 35. 1832, 711. 1835; Santapau, Fl. Khandala 16 (1): 216. 1967; Ramaswamy & Razi, Fl. Bangalore 509. 1973; B.D.Sharma, Fl. Nilgiri 232. 1975; C.J.Saldanha & Nicolson, Fl. Hassan Dist. 506. 1976; E.T.Atkinson, Fl. Himalayas 556. 1980; R.R.Rao & Razi, A Synoptic Fl. Mysore Dist, 514. 1981; K.M.Matthew, Fl. Tamil Nadu Karnatic 1: 1273. 1983; B.D.Sharma *et al.*, Fl. Karnataka Anal. 224. 1984; H.J.Chowdhery & B.M.Madhwa, Fl. Himachal Pradesh Analysis 2: 583. 1984; A.K.Mukh., Fl. Pachmarhi & Bori Reserves 253. 1984; D.M.Verma et al., Fl. Raipur, Durg & Rajnandgaon 308. 1985; R.S.Rao, Fl. Goa, Diu, Damon, Dadra & Nagar Haveli 2: 349. 1986; A.N.Henry *et al.*, Fl. Tamil Nadu, 2: 182. 1987; N.P.Singh, Fl. Easern Karnataka 2: 524. 1988; K.M.Mathew, Excur. Fl. Central Tamil Nadu, 408. 1991; B.V.Shetty &V.Singh, Fl. Rajasthan 2: 704. 1991; Lakshmin. & B.D.Sharma, Fl. Nasik Dist. 396. 1991; Kothari & Moorthy, Fl. Raigad Dist. 325. 1993; D.Deshp. et al., Fl. Mahabaleshwar and Adjoinings 2: 480. 1995; P.K.Battacharya & K.Sarkar, Fl. West Champaran Dist. 313. 1998; K.M.Matthew, Fl. Pulney hills 2: 1002. 1999; S.K.Murthi & Panigrahi, Fl. Bilaspur Dist. 2: 493. 1999; N.P.Singh et al., Fl. Bihar Analysis 420. 2001; N.Mohanan & Sivad., Fl. Agasthyamala 534. 2002; An.Kumar, Fl. Indravati Tiger Reserve, Chattisgarh 241. 2003; K.G.Bhat, Fl. Udupi 519.

2003; N.D.Paria & S.P.Chattopadhyay, Fl. Hazaribagh Dist. 2: 706. 2005; T.S Nayar *et al*., Fl. Pl. Kerala Handb. 2006; Subba Rao & Kumari, Fl. Visakhapatnam Dist. 2: 84. 2008; R.Manik. & Lakshmin., Fl. Rajiv Gandhi National Park 319. 2013. **(Fig. 3.30)**

≡ *Ocimum molli* Aiton in Hort. Kew. 2. 322. 1789.

Type:— Cultivated, native of the East Indies. Introduced by Sir Joseph Banks in 1781 (Holotype BM!).

= *Ocimum mayporense* Roth, Nov. Pl. Sp.: 271. 1821, as ' Ocymum'.

Type:—India *Heyne* s.n. in Wall. Cat. 2736C (Holotype B, destroyed; Lectotype K, K000820183!, designated here)

= *Plectranthus mayporense* (Roth) Spreng., Syst. Veg. 2: 691. 1825.

Type:—as for O. *mayporense.*

=*Plectranthus incanus* Link., Enum. Hort. Berol. Alt. 2: 120. 1822; Hook.f., Fl. Brit. India 4: 621. 1885; Rama Rao., Haines, Forest Fl. Chota Nagpur 491. 1910; Fl. Pl. Travancore, 22.1914; Gamble, Fl. Pres. Madras 2. 1119. 1921; Mukerjee, Rec. Bot. Surv. India 14: 47. 1940; H.Collet., Fl. Simlensis 386. 1971; B.D.Neithani, Fl. Chamoli 2: 516. 1985

=*Plectranthus divaricatus* Weinm., Syll. Pl. Soc. Ratisb, 1: 68. 1824.

=*Plectranthus cordifolius* D.Don., Prod. Fl. Nepal 116. 1825; Benth. In Wall., Pl. As. Rar. 2: 16. 1830; Benth., Lab. Gen. Spec.: 35. 1832, 709. 1835; in DC., Prod. 12: 66. 1848.

Type:—Nepal, *Wall. Cat*. 2736A (K!, Neotype chosen by Suddee *et al.* 2004)

=*Plectranthus secundus* Roxb. [Hort. Beng.: 45. 1814, nom. nud.], Fl. India 3: 20. 1832, *nom Illeg*.

Erect or ascending annual herbs up to 1 m tall. Stems branched, quadrangular, aromatic, not much fleshy, shortly pubescent, nodes somewhat enlarged, green in colour with violet dots, internodal length 5–7 cm long. Leaves simple, membraneous, smooth, cordate, 8–12 × 9–4 cm, apex acuminate, base cordate, margin crenate, double serration present, 44–52 teeth present, lamina green colour on upper side and pale green colour on lower side, glabrous above and green gland-dotted beneath, 5 prominent veins from leaf base; petioles slender, 4–12 cm long, with upper part violet coloured and lower side pale green in colour. Inflorescence terminal, up to 25 cm long, simple or branched at inflorescence base, axis slender, shortly pubescent, verticils 10–15 mm apart, clearly interrepted, cymes 3 flowered on each side,; peduncle ca. 2 cm long; bracts persistent, obovate, 4–6 × 4–6 mm, green in colour, apex acuminate, margin entire, pubescent on margin only; pedicels slender, 4–7 mm long at anthesis, 7–10 mm long in fruit. Calyx campanulate, 4–6 mm long at anthesis, 6–9 mm long in fruit, 5 mm in diameter, tube 5 mm long; posterior lip broad, ovate, 2–3 cm broad, apex rounded, margin entire; anterior lip with teeth lanceolate, 4 lobed, lateral teeth smaller than median two, lateral teeth ca. 2 mm long, median teeth 3–4 mm long, tube 10-nerved, shortly pubescent on nerves, often swollen at the middle because of the large nutlets. Corolla light blue, ca. 1 cm long, ca. 5 mm in diameter, posterior lip 4-lobed, lobes rounded at apex, pubescent with sessile glands on back, median lobes larger than lateral lobes; anterior lip boat-shaped, ovate longer than posterior lip, 5–7 mm long, concave, glabrous inside; tube 3–5 mm long, sigmoid below the middle, gradually dilated towards base, widely expanded at throat, pubescent outside. Stamens 4, posterior pair attached just below anterior pair but not united, included in anterior corolla lip, filament size of posterior pair ca. 3 mm, anterior pair ca. 4 mm, appendages absent; anthers bithecous, dorsifixed, ca. 1 mm in size. Style ca. 6 mm long, glabrous; stigma bifid, equal in length. Disc with anterior side enlarged; ovary 0.1 mm,

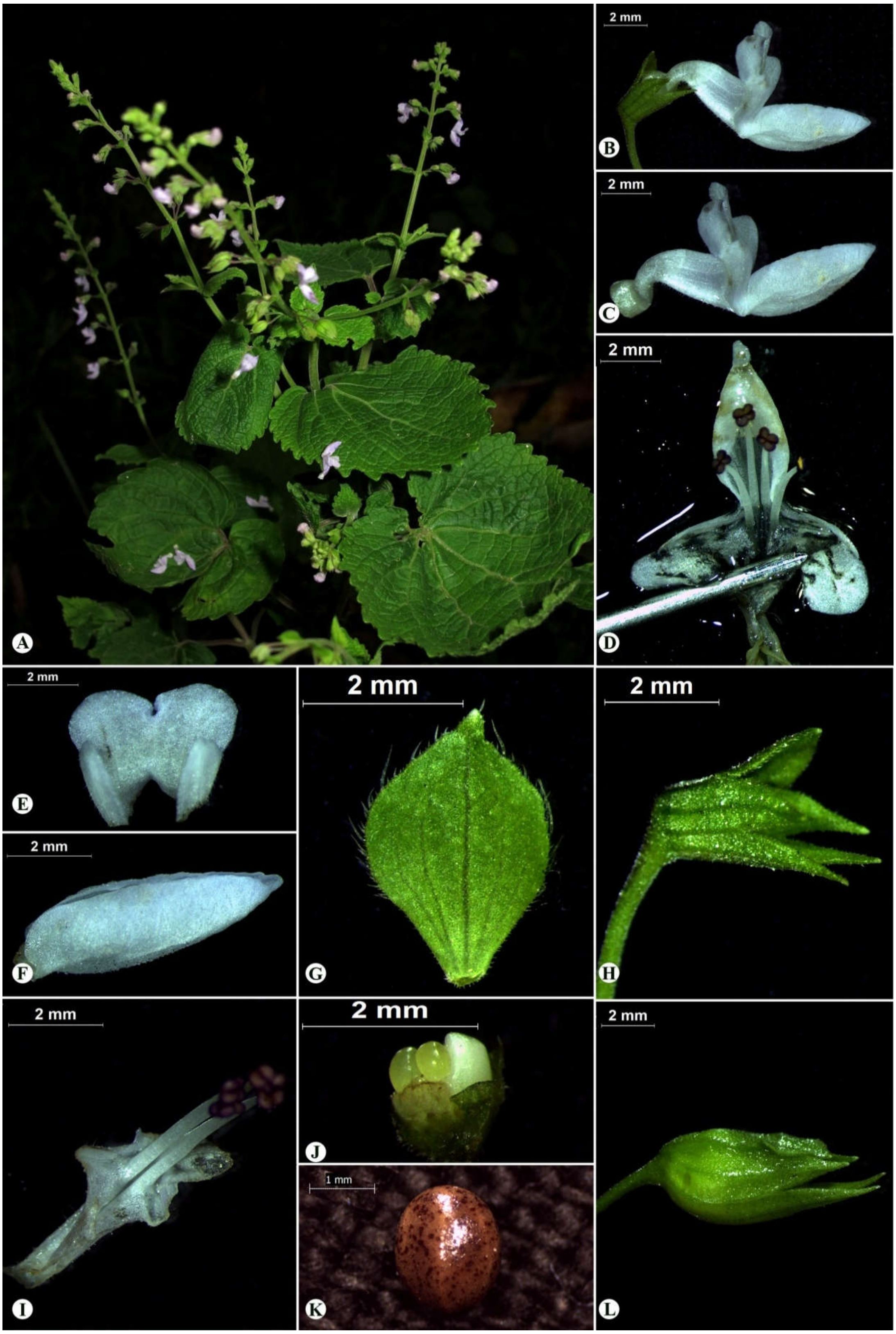
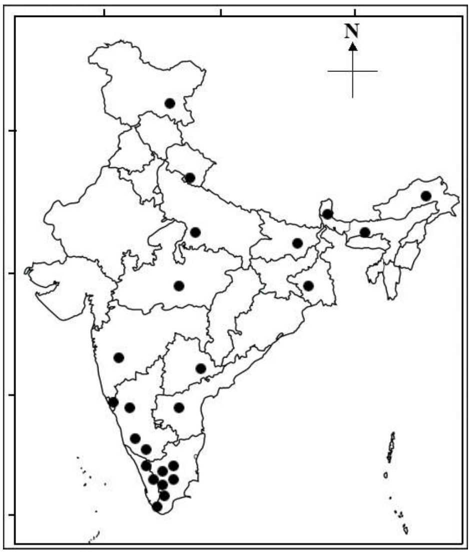


Fig. 3.30. *Plectranthus mollis*. A. Habit; B. Flower; C. Corolla; D. Corolla tube opened; E. Corolla upper lip; F. Corolla lower lip; G. Bract; H. Flowering calyx; I. Stamen; J. Ovary; K. Mericarp; L. Fruiting calyx.

glabrous. Mericarps light brown coloured with scattered black spots, ovoid, 2 mm long, smooth, not producing mucilage when wet.

Phenology:— Flowering and fruiting occur between July and December.



Distribution:—India, Nepal, Burma

Habitat and Ecology:—In shady areas along paths or riverbanks in forest.

Notes:—*P. mollis* is easily recognized by the cordate leaves, the persistent bracts, the swelling of the mature fruiting calyx tube caused by the large nutlets, and the black spots on mericarp.

Specimens Examined:— India: Peninsula Indiae Orientalis, *Wight 2092* (CAL!); **Andhra Pradesh:** Chittoor, 11 October 1958, *K.Subramanyam 6886* (CAL!); Medak, 23 September 1958, *K.M.Sebastine 6666* (CAL!); Visakapatnam, Araku valley, 24 August 1960, *N.P.Balakrishnan 10834* (CAL!); Visakapatnam, Araku valley, 15 September 1961, *N.P.Balakrishnan 557* (CAL!); **Bihar:** Raneli, Jagannath nagar, 14 October 1966, *R.N.Banerjee 221* (CAL!); Hazaribad, 05 September 1986, *S.P.Chattopadhyay 3* (CAL!); **Karnataka:** North Kanara, 10 August 1888, *W.A.Talbot 1706* (CAL!); Mysore, *A.Meebold 10617* (CAL!); Banglore, September 1910, *A.Meebold 11373* (CAL!); South Kanara, Charmadi village, 27 October 1960, *C.J.Saldanha CS 6229* (JCB!); Nandi, 22 August 1964, *C.J.Saldanha CS 8933A* (JCB!); Hassan district, Mysore, Bagi-Belur road, 23 August 1969, *C.J.Saldanha 14648* (JCB!); Hassan district, Mysore, Outskirts of Hassan town, 19 September 1969, *C.J.Saldanha 15120* (JCB!); Hari halli, 20 August 1969, *C.J.Saldanha 14537* (JCB!); Hassan district, near Belupet, 20 August 1970, *C.J.Saldanha & T.P.Ramamurthy HFP 525* (JCB!); Hassan, 24 September 1971, *C.J.Saldanha HFP 2168* (JCB!); Mysore, Chamundi hills, 24 October 1971, *R.Raghavendra Rao 1464* (JCB!); Dharwar, 24 October 1978, Mysore, Biligiri Rangan hills, 07 September 1978, *S.R.Ramesh KFP 2636* (JCB!); *C.J.Saldanha & P.Prakash KFP 3417* (JCB!); Chickmagalur, Bababudan hills, 27 September 1979, *C.J.Saldanha KFP 9563* (JCB!); Chickmagalur, Gangegiri road, 24 October 1980, *C.J.Saldanha 12000* (JCB!); Shimoga, Ayanur Ripponpet, 26 September 1980, *B.R.Ramesh KFP 12337* (JCB!); Mysore, Yelandur, 06 August 1994, *C.G.Kushalappa 03526* (FRLH!); **Kerala:** Attapadi valley, Edavani, 22 October 1910, *C.E.C.Fischer 2348* (CAL!); Santhanpara, December 1910, *A.Meebold 13456* (CAL!); Tavancore, Puliyara, 08 September 1913, *M.Rama Rao 1719* (CAL!); Wayanad district, Nilgiri, 21 September 1920, *C.E.C.Fischer 4490* (CAL!); Sulthan Bathery**,** 28 October 1973, *J.L.Ellis 19917* (MH!); Neykuppa, 28 August 2001, *Betty 10411* (FRLH!); Wayanad district, Muthanga, 09 October 2012, *Smitha & Sunojkumar 135404* (CALI!); Muthanga, Ponkuzhi, 21 August 2013, *Smitha & Sunojkumar 135414* (CALI!); **Madhya Pradesh**: West Khandesh-Ahrani Plateau, 02 October 1909, *I.H.Burkill 33255* (CAL!); Gubbulpore, 26 September 1959, *K.M.Sebastine 8949* (CAL!); Bastar, Abujh, 30 September 1985, *G.P.Roy 42613* (CAL!); **Maharashtra**: Poona, Tittalwadi, College of Science, 31 May 1887, *Krishna 126* (CAL!); Bombay, Ghat after Khed, 09 September 1956, *G.S.Puri 6773* (CAL!); Poona, Saswad, 02 October 1957, *S.D.Mahajan 26902* (CAL!); Khandala, near railway station, 15 September 1957, *S.D.Mahajan 16744* (CAL!); Nagpur, Ambala Talao, Ramtek, 02 October 1962, *U.R.Nofday 153* (CAL!); Nuvum, 15 September 1965, *John Cheriyan 106165* (CAL!); **Tamil Nadu**: Kodanad, September 1885, *J.S.Gamble 16828* (CAL!); Sirumalais, 21 September 1955, *Pallithanam TP855* (RHT!); Sirumalais, 05 November 1958, *Pallithanam TP3614* (RHT!); Sirumalais, 28 August 1959, *Pallithanam TP4879* (RHT!); Northern Hay R.F, 15 August 1970, *B.D.Sharma 35504* (MH!); Conoor upper Tiger Shola, 19 January 1972, *E.Vajravelu 39640* (MH!); Gudalur, Devarshola forest, 18 November 1972, *E. Vajaravelu 42814* (MH!); Gudalur – Cherambadi, 22 July 1972, *E.Vajravelu 41760* (MH!); Kargudi, 29 October

1972, K. *Vivekananthan 43103* (MH!); Nagalur, Periakalrayan, 28 August 1976, *D.I.Arockiaswamy 3690* (RHT!); Madurai, Thandigudi, 22 October 1977, *M.Chandrabose 51627* (CAL!); Salem, Servarayan hills, Manjakuttai, 17 December 1980, *K.M.Mathew, J.B.Britto & N.Rani 28098* (RHT!); Kodaikanal, Thandiankudisai, 14 August 1986, *K.M.Mathew & M.Charles 46153* (RHT!); Kodaikanal, Law's Ghat, 02 November 1987, *K.M.Mathew 50978* (RHT!); Coimbatore, Topslip, Ulandy, 29 April 1994, *V.S.Ramachandran 17487* (JCB!); Thiruvannamalai, Thenmalai, 31 November 1996, *K.Ravikumar 6073* (FRLH!); Thiruvannamalai, Polur, Santhavasal R.F., 09 December 1997, *R.Vijaya Sankar 30386* (JCB!); Namkkal, Kollimalai, 26 September 1999, *A.Giriraj F7250* (FRLH!); Salem, Servarayan hills, 18 December 2000, *K.M.Mathew & N.Baskaran 62461* (RHT!); Mudumalai, 23 September 2006, *K.Ravikumar & R.Murugan 105281* (JCB!); **West Bengal**: Nimiaghat, Parasnath hill, 08 October 1855, *S.K.Mukerjee 3870* (CAL!)

Conservational status:—Least Concern (LC).

3.6.14. Plectranthus montanus Benth. in Wall., P1. Asiat. Rar. 2:17. 1830; Benth., Labiat. Gen. Sp.: 44. 1832; in DC., Prodr. 12: 60. 1848; Suddee *et al.*, Kew Bull. 59 (2): 315. 2004; Smitha & Sunojk., Phytotaxa 302 (3): 290. 2017. **(Fig. 3.31 & 3.32)**

Type:—India, Peninsula India orientalis (Deccan peninsula, exact locality unknown) Herb. Wight in *Wall. Cat 2747B* (Lectotype K!)

= *P. cylindraceus* Hochst. ex Benth. in DC., Prodr. 12: 60 (1848); Baker in Fl. Trop. Afr. 5: 414 (1900); Codd, Bothalia 11: 385 (1975); Suddee *et al.*, Kew Bull. 59 (2): 315. 2004

Type:—Ethiopia, Ad rupes prope Gapdia in Samea, 29 Sept. 1838, Schimper 1113 [holotype K! (Herbarium Hookerianum); isotypes BM, G, K! (Herbarium Benthamianum), P).

= *P. marrubioides* Hochst. ex Benth. in DC., Prodr. 12: 60 (1848); Baker in Fl. Trop. Afr. 5: 414 (1900).

Type:—Ethiopia, Samen, Schimper sect. 3, n. 1925 [holotype K! (Herbarium Hookerianum); isotypes BM, K! (Herbarium Benthamianum), G, P].

= *P. fischeri* Gurke, Bot.Jahrb. Syst. 19: 200 (1894); Baker in Fl. Trop. Afr. 5: 404 (1900).

Type:—Tanzania, Kilimandcharo, 1200 m, 4 July 1893, Volkens 518 (syntype B, destroyed); Massaihochland, Fischer ser. 1 n. 77 (syntype B, destroyed; isosyntype HBG!), Fischer ser. 2 n. 501 (syntype B, destroyed).

= *Geniosporum lasiostachyum* Briq., Bot. Jahrb. Syst. 19: 164 (1900); Baker in Fl. Trop. Afr. 5: 351 (1900).

Type:—Angola, Huilla, Welwitsch 5489 (holotype K!; isotypes BM!, LISC!).

= *P. moschosmoides* Baker in Fl. Trop. Afr. 5: 414 (1900).

Type:—Angola, Huilla, Welwitsch 5489 (holotype K!; isotypes BM!, LISC!).

= *Germanea cylindracea* (Hochst. ex Benth.) Hiern, Cat. Afr.1 . Welw. 1:861 (1900).

Type:—as for P cylindraceus.

= *G. fissum* S. Moore, J. Bot. 39: 263 (1901).

Type:— Kenya, Dadaro, 1110 m, Lord Delamere s.n. (holotype BM!).

= *P densiflorus* T. Cooke, Bull. Misc. Inform., Kew 1909: 378 (1909).

Type:—Natal, near the Mooi R., 900 - 1200 m, April 1891, Wood 4475 (holotype K!; isotypes GRA, NH, SAM).

= *P villosus* T. Cooke, Bull. Misc. Inform., Kew 1909: 378 (1909).

Type:—Natal, Entumeni, 600-900 m, 13 April 1888, Wood 3955 (holotype K!; isotype HN).

= *P spiciformis* R. A. Dyer in Fl. P1. Africa 24: t. 946 (1944).

Type:—Transvaal, Hammanskraal, Mogg in National Herbarium, Pretoria, 27138 (holotype PRE).

= *Coleus subbaraoi* Kumari et Malathi, Fl. Visakhapatnam Dist. 2: 68. 2008; Smitha & Sunojk., Phytotaxa 302 (3): 290. 2017.

Type**:**—India: Andhra Pradesh, Visakapatnam District, Kappakonda, 24 December 1967, *Subba Rao 29637* (Holotype CAL, isotypes MH!)

Erect or ascending annual, aromatic herbs, up to 60 cm tall. Stem woody, green, branched, quadrangular to cylindrical, scarcely pubescent with simple white hairs, internodes 0.5–1 cm long. Leaves simple, fleshy, smooth, obovate, 0.5–5 × 0.5–3 cm, apex acute to obtuse, base cuneate, margin serrate and entire towards base, 8–12 teeth, upper surface pubescent with simple hairs, lower surface pubescent with sessile glands; petioles 0.3–0.5 cm long or absent; Inflorescence both terminal and axillary, spike-like, adjascent verticils rarely separated, up to 10 cm long, branched, purplish coloured, axis fleshy, puberulous with or without sessile glands; cymes sessile, 3–6-flowered, peduncle 0.5–1 cm long; bracts persistant, cordate, 2–3 × 2–3 mm, apex acute, margin ciliate, villous; bracteole absent; flower 5–6 mm long, ca. 2.5 mm in diameter, dark violet; pedicels slender, 1–2 mm long at anthesis, 2–3 mm in fruit, pubescent. Calyx purple, campanulate, 1–1.5 × 1–1.5 mm at anthesis, campanulate, enlarges up to 1.8–2 × 1.6–1.8 mm in fruit, tube 1–3 mm long, inside glabrous, villous with gland-tipped hairs and sessile glands outside; posterior lip ovate-lanceolate, continous with the tube, apex acute-rounded, margin ciliate, ca. 0.8 × 0.8 mm at anthesis, ca. 1 × 1 mm in fruit, inside glabrous, pubescent with gland-tipped hairs and sessile glands outside; anterior lip teeth lanceolate, margin ciliate, lateral teeth and median teeth equal in length, ca. 0.5 × 0.5 mm long at anthesis, ca. 0.7 × 0.7 mm in fruit,

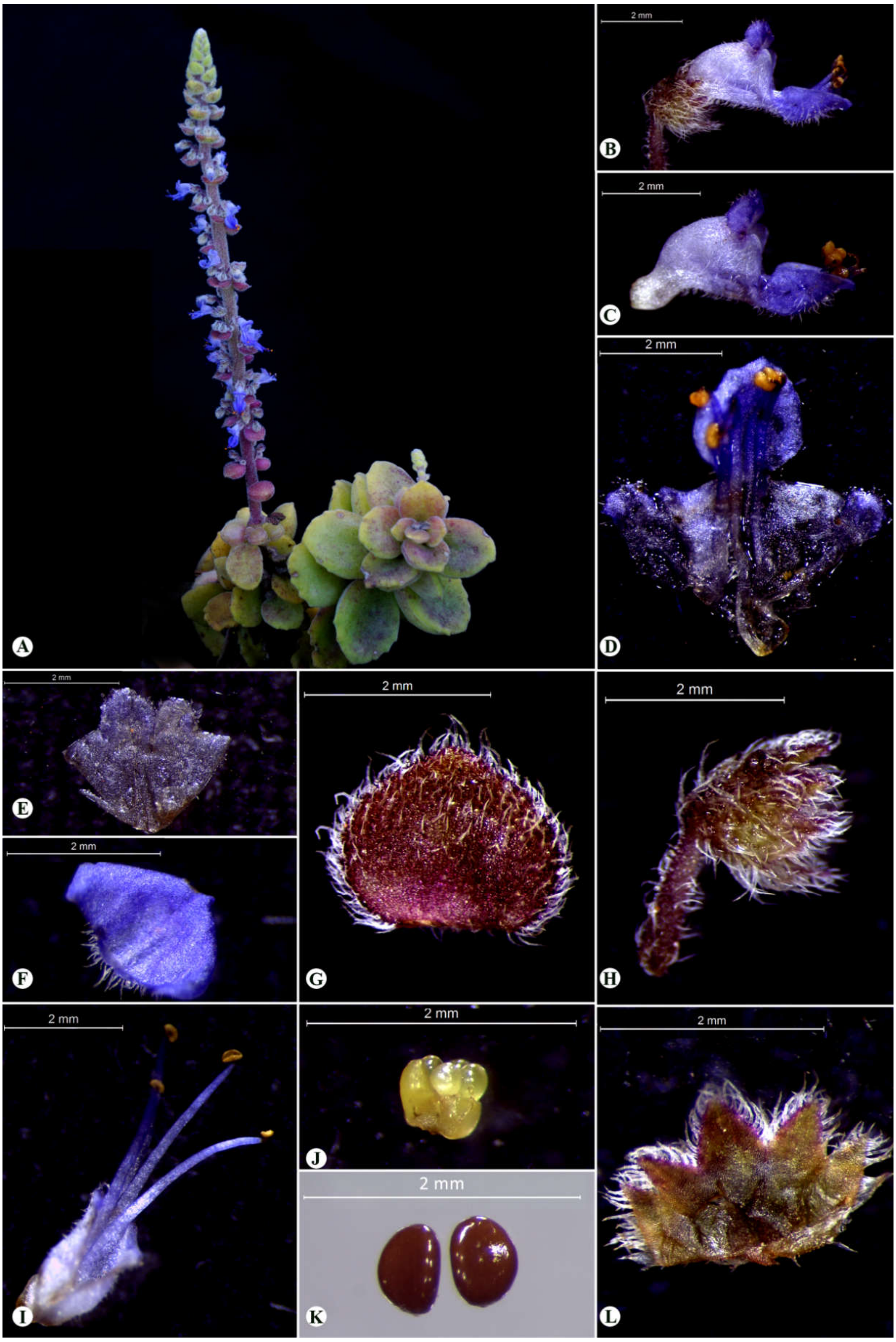
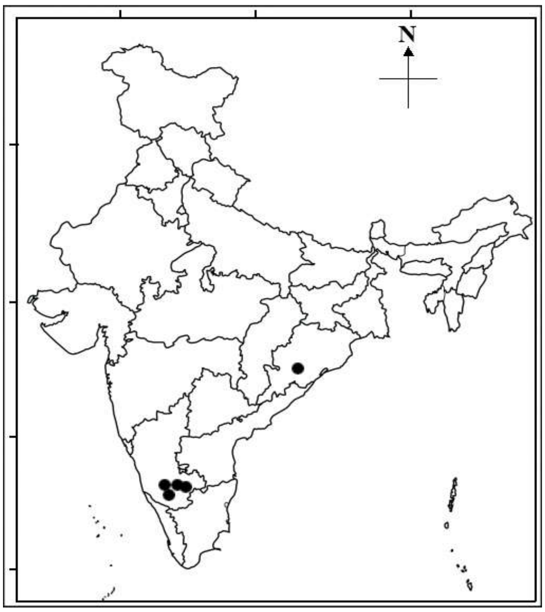


Fig. 3.31. *Plectranthus montanus*. A. Habit; B. Flower; C. Corolla; D. Corolla tube opened; E. Corolla posterior lip; F. Corolla anterior lip; G. Bract; H. Flowering calyx; I. Stamen; J. Ovary; K. Mericarp; L. Calyx opened.

Fig. 3.32. Lectotype of *Plectranthus montanus*. (K000820120, "Reproduced by permission of Board of trustees of Royal Botanic Gardens, Kew").

villous with gland-tipped hairs and sessile glands outside. Corolla violet, 4–4.5 mm long, 2–2.2 mm in diameter, pubescent; tube 2–2.5 mm long, sigmoid below the middle, gradually dilated towards base, widely expanded at throat, glabrous inside; posterior lip 4-lobed, dark violet, lobes rounded at apex, pubescent, median lobes (ca. 1 × 1 mm) larger than lateral lobes (ca. 0.5 × 0.5 mm); anterior lip with dark violet, ovate, boat shaped, ca. 2 × 1.5 mm, concave, glabrous inside, pubescent with orange coloured sessile glands outside. Stamens 4, free, attached at the mouth of the corolla tube, posterior pair attached just below anterior but not united, filament of posterior pair ca. 2.5 mm long, anterior pair ca. 3 mm long, appendages absent, exerted from anterior corolla lip; anthers bilobed, dorsifixed, yellowish, dehisces longitudinally. Disc with anterior side enlarged, white, ca. 0.3 mm long, larger and exceeding ovary; ovary ca. 0.2 mm high; style sigmoid, 5 mm long, glabrous; stigma bifid with equal branches. Mericarps elliptic, ca 0.8 × 0.5 mm, brownish, smooth, producing mucilage when moistened.

Phenology:—Flowering and fruiting was observed during December to February.



Distribution:—This species is reported from India (Deccan Peninsula), Somaliland, Ethiopia, Sudan, Angola, Transvaal, Swaziland, Natal and South Africa (Suddee & Paton 2004). It is a widespread species in Africa but an extremely rare species in India. The type specimens of *P. montanus* was made from Deccan Peninsula in south India and Subba Rao's collection represents an extended distribution of this species in Eastern Ghats phytogeographical region of India.

Notes:—*P. montanus* is a well known and widespread species in Africa and least known from India. Before the work of Suddee & Paton (2004), this species is known as *P. cylindraceus* in Africa. *P. montanus* was first described by Bentham (1830) based on a fruiting specimens collected from the Deccan Peninsula, India (Herb. Wight in Wall. Cat. 2747B K). He gave '?'after the generic name (P.? montanus) and also stated '*corollam non vidi*'. In later works Bentham (1832, 1848), a further specimen, also fruiting, from the Wallich Herbarium was cited (Herb. Rottler in Wall. Cat 2747A, Nundydroog, Deccan Peninsula). Bentham (1848) also mentioned *P. cylindraceus* based on a specimen which is flowering (Schimper), and stated, *'fructiferum non vidi'*. He also discussed the similarity of this species to *P. montanus*. Hooker (1885) placed *P. montanus* as a doubtful species and states that the specimen was very imperfect and have no corolla. After examining types of both names as well as additional specimens, Suddee & Paton (2004) came to a confirmation that both clearly belong to the same species. Based on these findings, they gave priority to *P. montanus* and lectotypified the name.

Subba Rao had collected this species from two different places namely Kappakonda (*Subba Rao* 29637 Holotype CAL!, Isotypes MH!) and Cherukonda (*Subba Rao* 29732 Paratypes MH!) of Vishakapatnam district of Andhra Pradesh state in 1967 and 1968 respectively and misidentified as a new species *Coleus subbaraoi* Kumari et Malathi (2008: 68). The authors compared this species with *P. amboinicus* (Lour) Spreng. (1825: 690), a frequently occurring one. And from this comparison it is clear that they are unaware of the species *P. montanus*, probably due to lack of enough specimens of this species in Indian herbaria. After critical study of type specimens and protologue of both *Coleus subbaraoi* and *P. montanus*, we could confirm that both are conspecific. Therefore we treated *Coleus subbaraoi* as a synonym of *P. montanus* (Smitha and Sunolkumar 2017).

Specimens Examined:—India. **Karnataka**: Mysuru district, Santapura, *Meebold 13738* (CAL!); Banglore district, Banglore to Nandi hills road, 20 January 1973, *Burtt, Townsend & Saldanha 18348* (K!); Chikmagalur district, Bababudangiri, 15 January 2016, *Smitha & Sunojkumar135464* (CALI!). Orissa: Koraput district, Turia Konda, 13 October 1950, *Mooney 4144* (K!).

Conservation status:—Near Threatened (NT)

3.6.15. Plectranthus rotundifolius (Poir.) Spreng., Syst. Veg. 2: 690. 1825; Benth., Lab. Gen. Sp.: 34. 1832, 711. 1835; in DC., Prodr. 12: 65. 1848; Keng in Steenis, Fl. Males. 8 (3): 388. 1978; Willemse, Blumea 25 (2): 509. 1979. **(Fig. 3.33)**

≡ *Germanea rotundifolia* Poir. in Lam., Encyl. Suppl. 2: 763 .1812

Type:— Mauritius, *Commerson* s.n. (Holotype P!)

= *Coleus rotundifolius* (Poir.) A.Chev. & E.Perrot., Veg. Util. Afr. Trop. Franc. 1: 101, 119. 1905; Cramer, Kew. Bull. 32 (3): 555. 1978; L.H.Cramer in Dassan. & Fosberg, Revis. Handb. Fl. Ceylon 3: 139. 1981; K.G.Bhat, Fl. Udupi 519. 2003; G.S.Giri et al., Fl. Arunachal Pradesh 2: 278. 2008

Type:—as for *G. rotundifolia*.

= *Solenostemon rotundifolius* (Poir) J.K.Morton, J. Linn. Soc., Bot. 58: 272. 1962.

Type:—as for *Germania rotundifolia*.

= *Plectranthus tuberosus* Blume, Bijdr: 838. 1826.

Type:—Java, *Blume* s.n. (Holotype L!)

= *Coleus tuberosus* (Blume) Benth., Lab. Gen. Sp. 59. 1832; in DC., Prodr. 12. 79. 1848;

Type:— as for *P. tuberosus.*

= *Coleus rugosus* Benth. in Wall., Pl. As. Rar. 2: 15. 1830.

Type:— India, Madras, Palamcotta, Herb. Madras, with 'Dracocephalum rugosum' MSS., *Wall. Cat*. 2760 (Syntypes K!)

= *Coleus parviflorus* Benth. in DC., Prodr. 12: 72. 1848; Hook.f., Fl. Brit. India 4: 625. 1885; Rama Rao, Fl. Pl. Travancore 322. 1914; Mukerjee., Rec. Bot. Surv. India 14: 54. 1940.

Type:—South India, Quilon and Panpanassum, *Wight* 2512 (Holotype K!)

Erect or ascending perennial herbs up to 60 cm tall with tuberous roots. Stem annual, sometimes rooting at nodes, succulent, branched, round-quadrangular, pubescent. Leaves fleshy, ovate or orbicular 30–70 × 30–50 mm, apex acute, base attenuate, margin crenate, teeth 11, glabrous to puberulous on both sides with sessile glands beneath, veins conspicuous beneath, petioles 2–5 cm long, pubescent, internodes 5–7 cm long. Inflorescence terminal, simple, 10–15 cm long, axis pubescent, verticils 5–10 mm apart, peduncle ca. 6 cm long, pedicel ca. 3 mm long; bracts sessile, flat, caducous, ovate up to 2 mm long, ciliate at margin, pubescent. Calyx campanulate, 3–5 mm long, usually purple when dry; posterior lip ovate or ovate-oblong, twice as long as lateral lobe of anterior lip, acute at apex, slightly puberulous inside, pubescent with sessile glands outside, margin sometimes ciliate, slightly decurrent on tube; anterior lip with median teeth united more than half of their length, shortly bifid with acute teeth at apex, tube 10-nerved, pubescent with sessile glands outside. Corolla whitish-purple, 5–7 mm long, 2-lipped; posterior lip pubescent with sessile glands at back, two median lobes broadly ovate, rounded at apex,

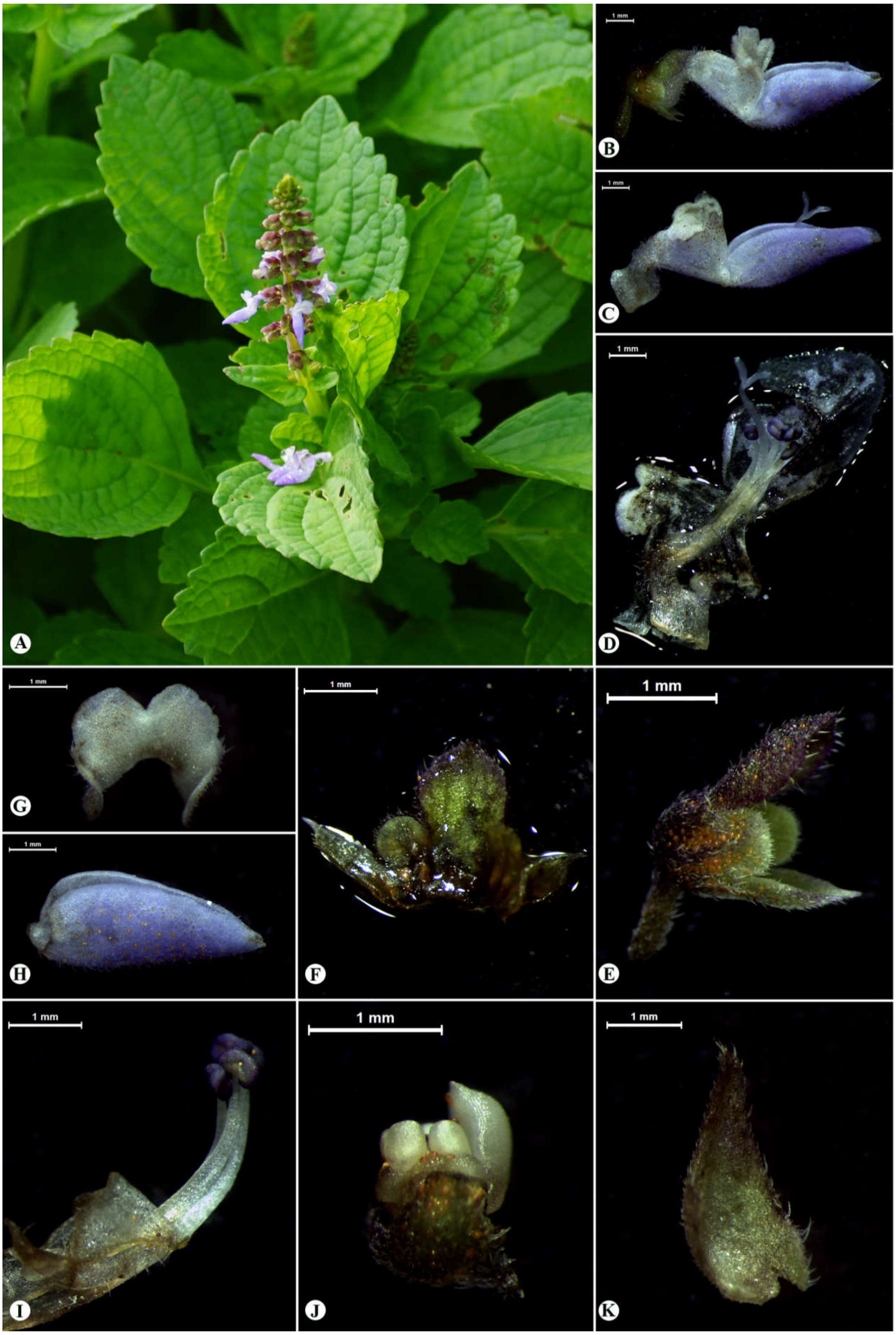


Fig. 3.33. *Plectranthus rotundifolius*. A. Habit; B. Flower; C. Corolla; D. Corolla tube opened; E. Flowering calyx; F. Bract; G. Corolla posterior lip; H. Corolla anterior lip; I. Stamen; J. Ovary; K. Bract.

larger than the acute ovate lateral lobes; anterior lip ovate-oblong, 3–4 mm long, glabrous inside, tube 4–5 mm long, slightly dilated at base, widely expanded at throat, pubescent with sessile glands outside. Stamens 4, united at base, included in anterior corolla lip. Style bifid with subequal flabellate branches, exceeding stamens but not exceeding anterior corolla lip. Disc with anterior side thick, obtuse or truncate at apex, twice as long as ovary.

Phenology:— Flowering and fruiting occur between October and December.

Habitat and Distribution:—Widely cultivated in the tropics for its edible tubers. Distributed in Tropical Africa, India, Sri Lanka, Thailand, Vietnam, Phili-ppines, Malaysia & Indonesia

Notes:—Common name: Koorka (Mal.)

Specimens Examined:—India. Assam: Sadiya, 23 November 1911, *I.H.Burkill 35780* (CAL!); **Kerala**: Calicut district, Thamarassery, 15 February 2010, *Smitha & Sunojkumar 124106* (CALI!); Tamil Nadu: Tirunelveli district, Kannikatti, 08 February 1913, *D.Hooper & M.S.Ramaswamy 39416* (CAL!)

3.6.16. Plectranthus sahyadricus Smitha & Sunojk., Phytotaxa 345 (2): 165. 2018

(Fig. 3.34)

Type:—India. Kerala: Idukki district, Munnar, Lockhart Gap view point, elev. 1600 m, 21 September 2015, *Smitha & Sunojkumar 135456* (holotype CALI!, isotypes CALI!).

Erect annual herbs, up to 60 cm tall. Stem fleshy, light green with purple spots, branches quadrangular, winged, glabrous, internodes 2–4 cm, a ring of hairs at young nodes. Leaves membraneous, cordate, 6–13 × 3–11 cm, apex acuminate, base rounded to cordate, margin mainly crenate, sometimes doubly crenate, 13–30-pairs of tooth, upper surface glabrous, lower surface slightly pubescent along veins, 6–8-nerved, venation eucamptodromous; petioles fleshy, ridged, 5–9 cm long, light purple, upper side slightly pubescent. Inflorescence terminal, up to 20 cm long, without basal branches, light green colored, axis fleshy, pubescent with simple hairs; floral nodes 1–2 cm apart, cymes 1–4 cm long, pedunculate, producing lax lateral cincinnal, 5–10-flowered, peduncle 2–4 cm long; bracts caducous, cordate, 4–5 × 2.5–3 mm, apex acuminate, margin ciliate, pubescent along margins; bracteole absent; flower 8–10 mm long, off-white; pedicels slender, ca. 2 mm long at anthesis, ca. 3 mm in fruit, pubescent. Calyx green, campanulate, 2.5–3.5 × 2–3 mm at anthesis, enlarges up to 4–5 × 3–4 mm in fruit, tube 1–2 mm long, 10-nerved, inside glabrous, pubescent with sessile glands outside; posterior lip broad, ovate, decurrent to tube, apex acute-rounded, margin ciliate, ca. 2 × 2 mm at anthesis, ca. 3 × 2 mm in fruit, inside glabrous, pubescent with sessile glands outside; teeth of the anterior lip lanceolate, margin ciliate, lateral teeth smaller than median teeth, ca. 2 mm long at anthesis, ca. 2.5 mm in fruit, median teeth ca. 2.5 mm long at anthesis, ca. 3 mm in fruit, pubescent with sessile glands outside. Corolla off-white, 7–9 mm long, ca. 4 mm in diameter, pubescent; tube 5–7 mm long, sigmoid below the middle, gradually dilated towards base, widely expanded at throat, long white hairs inside; posterior lip 4-lobed, lobes rounded at apex, pubescent, median lobes (ca. 1 × 1 mm) larger than lateral lobes (ca. 0.5 × 0.5 mm); anterior lip ovate, not fully opened, form an inverted dome over mouth to partially close opening, ca. 3 × 2 mm, long hairs along inner margin, pubescent with sessile glands outside. Stamens free, anterior pair attached at the mouth of corolla tube, posterior pair attached just below

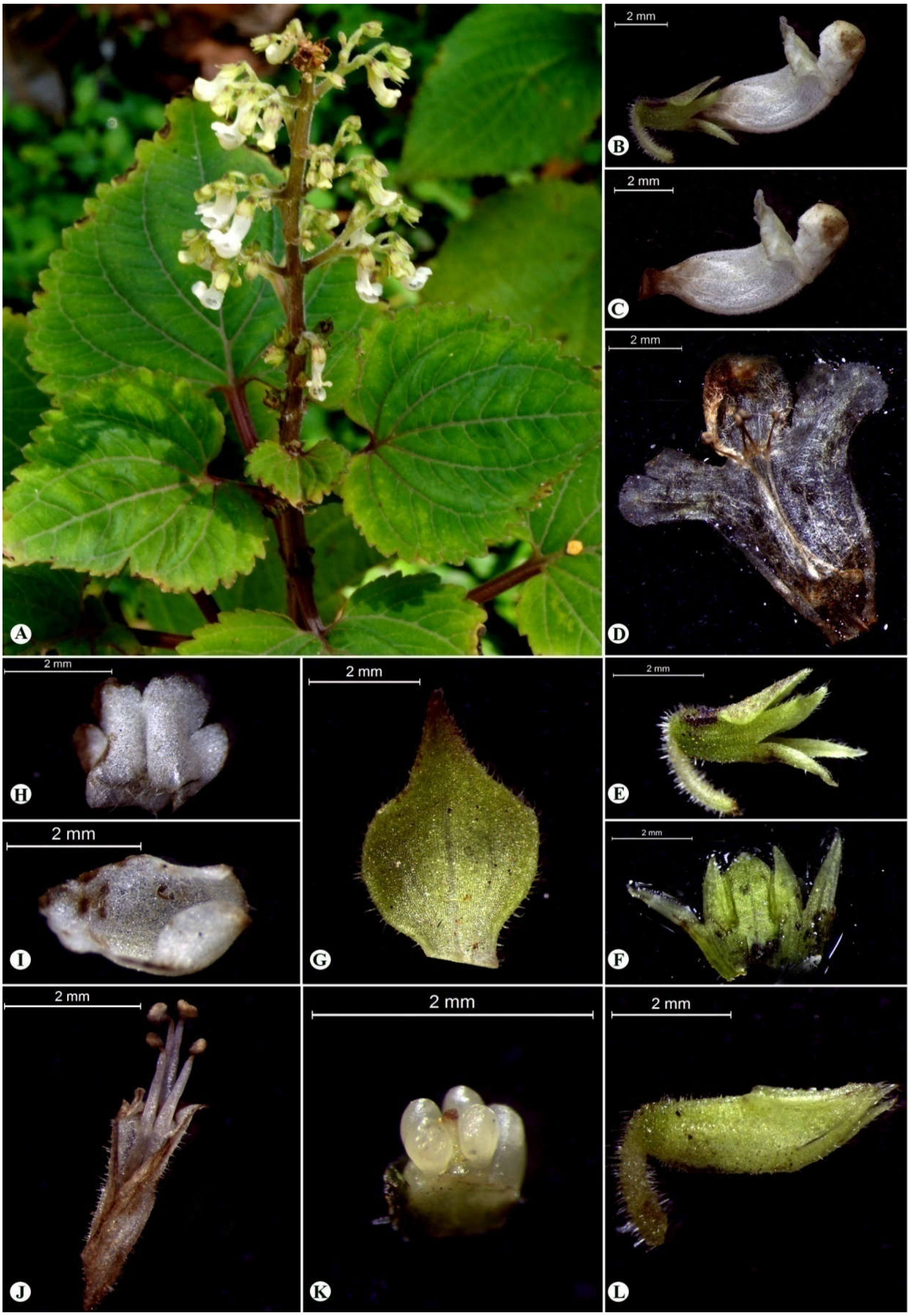


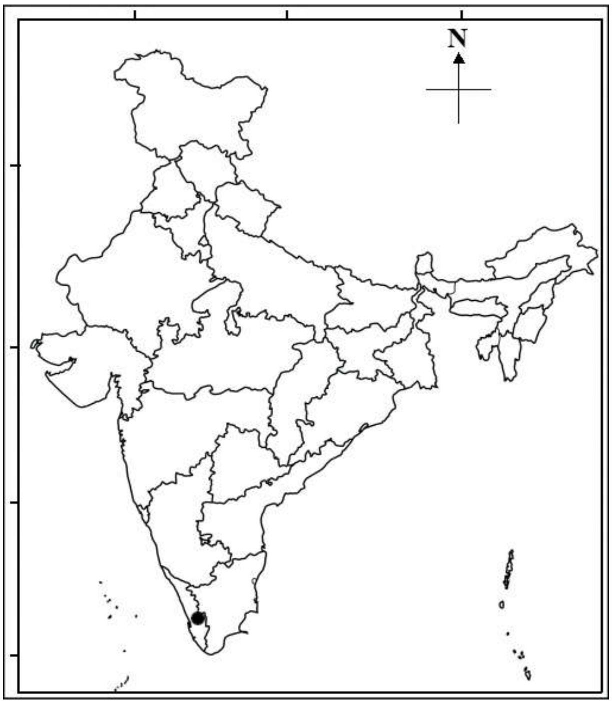
Fig. 3.34. *Plectranthus sahyadricus*. A. Habit; B. Flower; C. Corolla; D. Corolla tube opened; E. Flowering calyx; F. Calyx opened; G. Bract; H. Corolla posterior lip; I. Corolla anterior lip; J. Stamen; K. Ovary; L. Fruiting calyx.

anterior but not united, filament of posterior pair ca. 1.5 mm long, anterior pair ca. 2 mm long, included in anterior lip; anthers bilobed, dorsifixed, ca. 1 mm long, yellowish, dehisces longitudinally. Disc anterior side enlarged, white, ca. 0.5 mm long, smaller than ovary; ovary ca. 1 mm high; style sigmoid, ca. 5 mm long, glabrous; stigma bifid with equal branches.

Phenology:—Flowering and fruiting occurs between September and January.

Etymology:— The species is named after the type locality, Western Ghats which is also known as 'Sahyadri' in regional Malayalam language (It was collected from Lockhart Gap view point of Idukki district).

Habitat and Distribution:— *Plectranthus sahyadricus* is known only from Lokhart gap view pont, Munnar, Idukki district, southern Western Ghats. The plants grow on wet rocky surfaces and sides amidst mosses, at an elevation of ±1600 m.



Additional specimens examined (paratypes):—India. **Kerala**: Idukki district, Munnar, Lokhart Gap view point, elev. 1600 m, 13 August 2017, *Smitha & Sunojkumar 135477* (CALI!)

Conservation status:— *P. sahyadricus* was collected from Lokhart Gap view point, Munnar in Southern Western Ghats. In the present collection, very few mature plants (less than 30) are noticed at a height of 1600 m. near a tourist place. This species was found in a single location and this area is prone to severe grazing and other disruptive people activities like tourism and widening of roads. Thus the habitat is under severe threat. The extent of occurrence for *P. sahyadricus* was less than 100 km^2. Therefore, we suggest that *P. sahyadricus* should be evaluated as critically endangered, CR [B1a, b (ii, iii) + D] according to the IUCN (2012) categories and criteria.

3.6.17. Plectranthus scutellarioides (L.) R.Br., Prodr. 506. 1810; Roxb., Fl. Indica 465. 1832; Keng in Steenis, Fl. Males. 8(3): 389. 1978; Willemse, Blumea 25(2): 509. 1979; B.D.Sharma *et al*., Fl. Karnataka Anal. 224. 1984; A.N.Henry *et al*., Fl. Tamil Nadu 2: 183. 1987. **(Fig. 3.35 & 3.36)**

≡ *Ocimum scutellarioides* L., Sp. Pl. ed. 2 (2): 834.1763, as '*Ocymum*'.

Type:— Majana (alba et rubra) Rumphius, Herb. Amboin. 5: 291, t. 101 (1747), designated by Merrill (Interpr. Rumph. Herb. Amboin.: 460 (1917))

= *Coleus scutellarioides* (L.) Benth. in Wall., Pl. As. Rar. 2: 15. 1830; Benth., Lab.Gen. Sp. 53. 1832; in DC., Prodr. 12: 73. 1848; Hook.f., Fl. Brit. India 4: 626. 1885; Mukerjee., Rec. Bot. Surv. India 14: 54.1940; L.H.Cramer in Dassan. & Fosberg, Rev. Handb. Fl. Ceylon 3: 140. 1981; S.K.Murthi & Panigrahi, Fl. Bilaspur Dist. 2: 493. 1999; N.P.Singh et al., Fl. Bihar Analysis 420. 2001; K.G.Bhat, Fl. Udupi 519. 2003; G.P.Sinha et al., Fl. Mizoram 2: 315. 2012.

Type:— as for *O. scutellarioides.*

= *Majana scutellarioides* (L.) Kuntze, Revis. Gen. Pl. 2: 524. 1891.

Type:— as for *O. scutellarioides.*

= *Solenostemon scutellarioides* (L.) Codd, Bothalia 11: 439. 1975.

Type:—as for *O. scutellarioides.*

= *Polypodium ovatum* Burm.f., Fl. India 233. 1768.

Type:— Java, Unknown collector (Holotype G)

= *Plectranthus nudiflorus* willd., Sp. Pl. ed. 3: 168. 1800; Benth., Lab. Gen. Sp. 46. 1832.

Type:—Amboina, Willdenow Herbarium 11079.1 &11079.2 (Syntypes B-W)

= *Germania nudiflora* (Willd.) Poir. in Lam., Encycl. Suppl. 2: 763. 1812.

Type:—as for *P. nudiflorus*.

= *Plectranthus aromaticus* Roxb., Hort. Beng.: 45. 1814.

Type:—Rumphius Ic. In Herb. Amb. 5: t.101. 1750 (Holotype illustration!)

= *Plectranthus ingratus* Blume, Bijdr. 836. 1826.

Type:—Indonesia, Java, G. Parang, *Blume* 992 (Lectotype L!)

= *Coleus ingratus* (Blume) Benth.,Lab. Gen. Sp.: 53. 1832; in DC., Prod.12: 73. 1848.

Type:— as for *P. ingratus*.

= *Coleus scutellarioides* (L.) Benth. var. *ingratus* (Blume) Miq., Fl. Ind. Bat. 2: 950. 1858.

Type:—as for *P. ingratus*.

= *Plectranthus scutellarioides* Blume [non (L.) R.Br. 1810], Bijdr.: 837. 1826, *nom. illeg.*

= *Plectranthus laciniatus* Blume, Bijdr. 838. 1826.

Type:— Indonesia, Java, *Blume s.n*. (Lectotype L!)

= *Coleus laciniatus* (Blume) Benth., Lab. Gen. Sp.: 56. 1832; in DC., Prodr. 12: 76. 1848; Mukerjee, Rec. Bot. Surv. India 14: 56. 1940.

Type:—as for *P. laciniatus*.

= *Coleus scutellarioides* (L.) Benth. var. *laciniatus* (Blume) Miq., Fl. Ind. Bat. 2: 950. 1858.

Type:— as for *P. laciniatus.*

= *Coleus atropurpureus* Benth. in Wall., Pl. As. Rar. 2: 16. 1830; Benth., Lab. Gen. Sp.: 54. 1832; in DC., Prodr. 12: 74. 1848; Hook.f., Fl. Brit. India 4: 626. 1885.

Type:—Singapore, *Wall. Cat*. 2733A (Lectotype K!)

= *Majana scutellarioides* (L.) Kuntze var. *atropurpureus* (Benth.) Kuntze, Revis. Gen. pl. 2: 524. 1891.

Type:— as for *C. atropurpureus*.

= *Coleus atropurpureus* Benth. var. *ramosus* Benth. in wall., Pl. As. Rar. 2: 16. 1830.

Type:—Malaysia, Penang, *wall. Cat.* 2733B (Lectotype K!, Syntypes G-DC)

= *Coleus acuminatus* Benth., Linneae 6: 81. 1831; Benth., Lab. Gen. Sp. 53. 1832; in DC., Prodr. 12: 73. 1848.

Type:—Philippines, Island of Samar, 1841, *Cuming 1683* [K! (Herbarium Benthamianum), Neotype chosen by Suddee *et al.* 2004; isoneotypes BM!, K! (Herbarium Hookerianum), P!, TCD!].

= *Coleus grandifolius* Benth., Lab. Gen. Sp. 54. 1832; in DC., Prodr. 12: 73. 1848.

Type:—Timor, *Guichenot* s.n. [syntype P!; Isosyntypes K!, L!, G-DC!].

= *Coleus scutellarioides* (L.) Benth. var. *grandifolius* (Benth.) Keng, Gard. Bull. Singapore 24: 58. 1969.

Type:— as for *C.grandifolius* Benth.

= *Coleus atropurpureus* Benth. var.*densiflorus* Benth., Lab. Gen. Sp.: 54. 1832; in DC., Prodr. 12: 74. 1848.

Type:— Philippines, Manila, 1830, *Chamisso* s.n. [syntype K! (Herb. Benthamianum)].

= *Coleus multiflorus* Benth., Lab. Gen. Sp.: 55. 1832.

Type:— Philippines, Manila, *Perrotet* s.n. (holotype P!)

= *Coleus secundiflorus* Benth., Lab. Gen. Sp.: 55. 1832; in DC., Prodr. 12: 75. 1848.

Type:—Timor, *Guichenot* s.n. (holotype P!).

= *Coleus blumei* Benth., Lab. Gen. Sp. 56. 1832; in DC., Prod. 12: 75. 1848; Mukerjee., Rec. Bot. Surv. India, 14: 55. 1940; N.C.Nair, Fl. Punjab Plains 21 (1): 212. 1978

Type:—Indonesia, Java, *Blume* s.n. (L! Lectotype chosen by Suddee *et al.* 2004).

= *Coleus scutellarioides* (L.) Benth. var. *blumei* (Benth.) Miq., Fl. Ind. Bat. 2: 950. 1958.

Type:—as for *C. blumei.*

= *Majana scutellarioides* (L.) Kuntze var. *blumei* (Benth.) Kuntze, Rev. Gen. Pl. 2: 524. 1891.

Type:—as for *C. blumei.*

= *Solenostemon blumei* (Benth.) Maza in Maza & Roig., Fl. Cuba, 127. 1914.

Type:—as for *C.blumei.*

= *Plectranthus blume* (Benth.) Launert, Mitt. Bot. Staatssamml. Munchen 7: 301. 1968.

Type:—as for *C.blumei.*

= *Coleus grandifolius* Blanco (non Benth. 1832), Fl. Filip. 482. 1837, *nom. illeg.*

= *Coleus pumilus* Blanco, Fl. Filip. 482. 1837.

Type:— Philippines, Barrio of Pineda, Pasig, Rizal Province, Luzon, Oct. 1914, *Merill: Species Blancoanae No*. 190 (K! neotype chosen by Suddee *et al*. 2004).

= *Coleus atropurpureus* Benth. var. *javanicus* Benth. in DC., Prod. 12: 74. 1848.

Type:—Indonesia, Java, *Zollinger* 138 [syntypes G-DC (microfiche!), K!

(Herb. Benthamianum), K! (Herb. Benthamianum)].

= *Coleus scutellarioides* (L.) Benth. var. *gracilis* Miq., Fl. Ind. Bat. 2: 950. 1858.

Type:— Indonesia, Ceram, Bangka, *Miquel*?

= *Coleus scutellarioides* (L.) Benth. var. *celebica* Miq., Fl. Ind. Bat. 2: 950. 1858.

Type:—Indonesia, Celebes, *Reinwardt s.n.*

= *Coleus verschaffeltii* Lem., Illustr. Hort. 8: t. 293. 1861.

Type:—based on cultivated plants from Java.

= *Plectranthus monadelphus* Llanos *ex* F.-Vill. & Naves (non Roxb. 1832) in Blanco, Fl. Filip. ed. 3 (4): 105. 1880, *nom illeg.*

= *Coleus igolotorum* Briq., Annuaire Conserv. Jard. Bot. Geneve 2: 236. 1898.

Type:— Philippines, fle de Luzon, dans le pays des Igolotes, *Callery 48* (holotype G-DEL; isotype P!).

= *Coleus gaudichaudii* Briq., Annuaire Conserv. Jard. Bot. Geneve 2: 237. 1898.

Type:—Philippines, fle de Luzon pres de Manille, Dec. 1836, *Gaudichaud s.n.* (holotype G-DEL).

= *Coleus formosanus* Hayata in Matsum. & Hayata, En. Pl. Formos. 320.1906.

Type:—Kotosho, 21 Nov. 1899, *Miyake s.n*. (holotype TI!).

= *Coleus macranthus* Merr. var. *crispipilus* Merr., Philipp. J. Sci. 1: Suppl. 234. 1906.

Type:— Philippines, Suyoc to Panai, Province of Benguet, Luzon, 2200m, Nov. 1905, *Merrill 4780* (holotype PNH; isotypes BM!, K!, NY).

= *Coleus crispipilus* (Merr.) Merr., Philipp. J. Sci. %: Bot. 382. 1910.

Type:—as for *C. macranthus* var. *crispipilus* Merr.

= *Coleus scutellarioides* (L.) Benth. var. *crispipilus* (Merr.) Keng, Gard. Bull. Singapore 24: 56. 1969; Cramer, Kew Bull. 32 (3): 555. 1978; Cramer in Dassan. & Fosberg, Rev. Handb. Fl. Ceylon 3: 141.1981.

Type:—as for *C.macranthus var. crispipilus*.

= *Coleus pubescens* Merr., Philipp. J. Sci. 3: Bot. 432. 1908.

Type:—Philippines, Babuyan Island, 17 June 1907, *Eugenio Zenix, Bureau of Science* 3892 (Holotype PNH; isotype BM!).

= *Coleus zschokkei* Merr., Philipp. J. Sci. 5: Bot. 432. (1910).

Type:—Philippines, Mt. Pulong, Prov. of Bengnet, Luzon, May 1909, *Merril 6529* (Holotype

PNH; isotypes K!, NY, P!).

= *Coleus rehneltianus* A. Berger, Bot. Jahrb. Syst. 54, Beibl. 120: 71. 1915.

Type:—types of Alwin Berger are probably in NY.

= *Coleus integrifolius* Elmer, Leafl. Philipp. Bot. 7: 2696. 1915.

Type:—Philippines, Mindanao, Cabadbaran (Mt. Urdaneta), Prov. of Agusan, Islan of Mindanao, August 1912, *Elmer 13627* (Holotype PNH; isotypes A, BM!, K!, L!, NY, P!).

= *Coleus scutellarioides* (L.) Benth. var. *integrifolius* (Elmer) Keng, Guard. Bull. Singapore 24: 58. 1969.

Typ:—as for C. *integrifolius.*

= *Coleus gibbseae* S.Moore in L.S.Gibbs, Phytogeogr. & Fl. Arfak Mts: 178. 1917.

Type:—Indonesia, New Guinea, Arfak Mts, 2100 m, *Gibbs 5909* (holotype BM!; isotypes K!, L!).

= *Coleus Scutellarioides* (L.) Benth. var. *gibbseae* (S.Moore) Keng, Gard. Bull. Singapore 24: 58. 1969.

Type:—as for *C. gibbseae*.

Erect or ascending annual or perennial herbs, up to 70 cm tall. Stem branched, succulent, round-quandrangular, pubescent with sessile glands. Leaves variegated, ovate, or ovate-lanceolate, 50–100 × 30–60 mm, apex obtuse, acute or acuminate, base cuneate, rounded, truncate or sub cordate, margin crenate-serrate, teeth up to19, pubescent on both sides with sessile glands and prominent veins beneath; petiole 10–40 mm, pubescent, internodal length 20–75 mm. Inflorescence terminal, simple up to 30 cm long axis pubescent, verticils 5–10 mm apart, cymes pedunculate; bracts sessile, caducous, ovate, acute or acuminate, ciliate, pubescent; pedicels 1–2 mm long. Calyx campanulate, 3–5 mm long; posterior lip ovate, acute at apex, margin entire or ciliate, decurrent on tube, glabrous inside, pubescent on outside, nerves prominent on both sides; anterior tip with median teeth united for two-third of their length, teeth acuminate at apex, longer than posterior lip; lateral teeth oblong or obovate, rounded or truncate at apex, tube 10-nerved, pubescent, brown in colour. Corolla bluish, 8–10 mm long; posterior lip with lobes pubescent with sessile glands on back, median lobes rounded at apex, lateral lobes minute, obtuse at apex; anterior lip ovate-oblong, 4–5 mm long, sigmoid below the middle, slightly dilated at base, widely expanded at throat, slightly pubescent with sessile glands outside. Stamens united for half of their length, included in anterior corolla lip. Style bifid with subequal branches exceeding anterior corolla lip. Disc with anterior side obtuse at apex exceeding ovary.

Phenology:—Throughout the year.

Habitat & Distribution:—Cultivated and sometimes naturalized. Distributed in India, Himalaya, Sri Lanka, China, Myanmar, Thailand, Laos, Vietnam, Malaysia, Indonesia, Australia, and widely cultivated in other tropical regions as an ornamental plant.

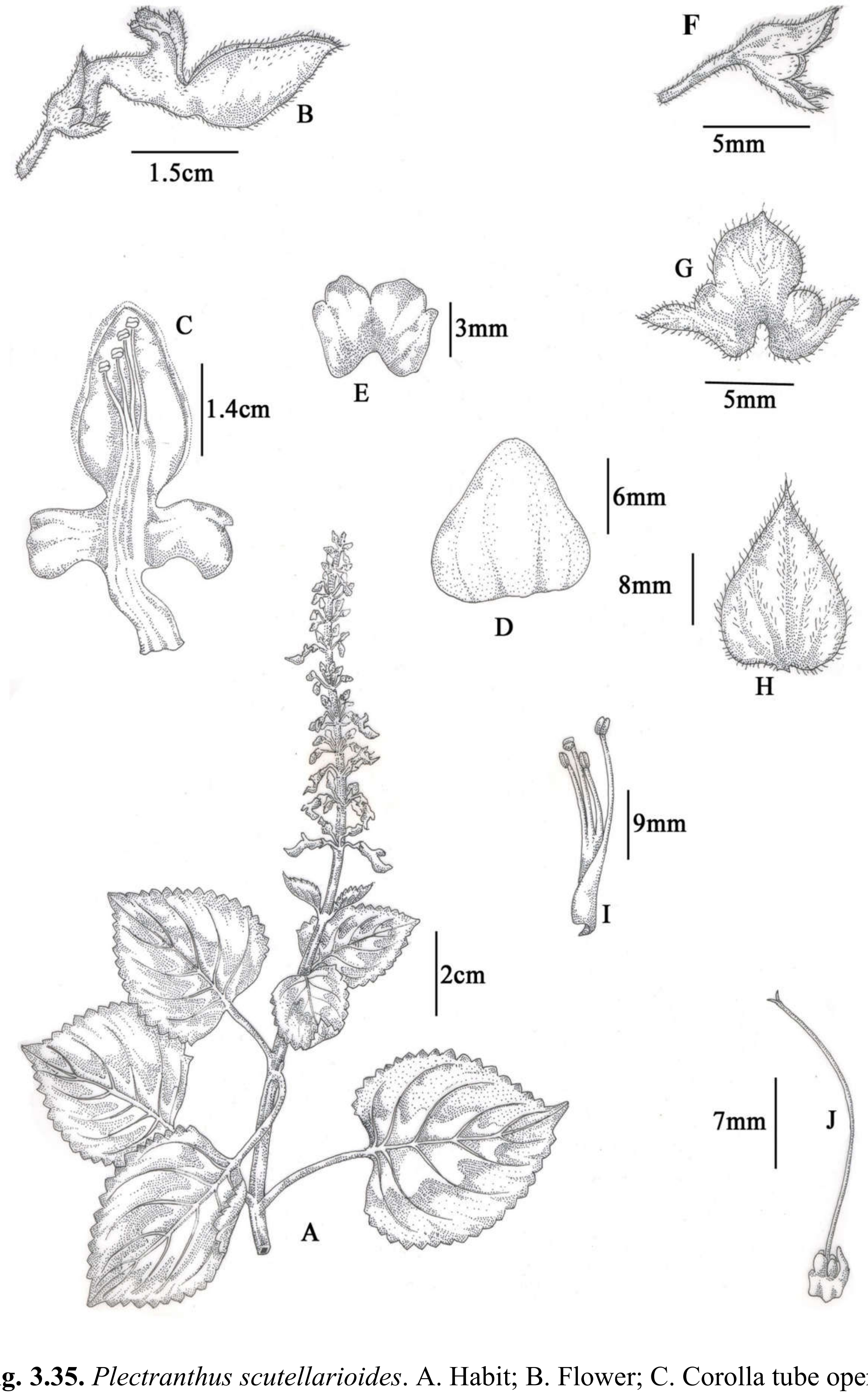


Fig. 3.35. *Plectranthus scutellarioides*. A. Habit; B. Flower; C. Corolla tube opened; D. Corolla anterior lip; E. Corolla posterior lip; F. Flowering calyx; G. Calyx opened; H. Bract; I. Stamen; J. Gynoecium.

Fig. 3.36. Type of *Plectranthus scutellarioides.* (Rumphius, Herb. Amboin. 5: 291, t. 101, 1747)

Notes:— *P. scutellarioides* is an extremely variable species in leaf shape, colour and inflorescence size. There is no clear discontinuity to divide the species in to infraspecific taxa.

Specimens examined:—**India**. **Assam**: Naga hills, May 1895, *G.Watt 11853* (CAL!); **Kerala**: Calicut district, Kuruvattur, 18 March 2010, *Smitha & Sunojkumar 124107* (CALI!); Thrissur district, Kodakara, 20 March 2010, *Smitha & Sunojkumar 124113* (CALI!); **Maharashtra**. Poona, BSI campus, 22 August 1960, *P.J.Cherian 63595* (CAL!); **Meghalaya**. Shillong, Tirap, 02 September 1958, *G.Panigrahi 15093* (CAL!); **West Bengal**. Dickechu, 29 May 1959, *S.K.Mukerjee 5020* (CAL!); Santhinikethan, 22 February 1986, *M.C.Biswas 19517* (CAL!)

3.6.18. Plectranthus subincisus Benth. in Wall. Pl. Asiat. Rar. 2: 16. 1830; Labiat. Gen. Spec.: 36. 1832; in DC., Prodr. 12: 66. 1848; Hook.f., Fl. Brit. India 4: 621. 1885; Trimen, Hanb. Fl. Ceylon 3: 370. 1895; Gamble, Fl. Pres. Madras 2. 1119. 1921; Mukerjee, Rec. Bot. Surv. India 14: 49. 1940; L.H.Cramer in Dassan. & Fosberg, Rev. Handb. Fl. Ceylon 3: 133. 1981

(Fig. 3.37, 3.38 & 3.39)

Type:—India. Tamil Nadu: Courtallum, 1829, *N. Wallich, Cat. No. 2737* (Holotype K-W!)

= *Plectranthus mollis sensu* Sunil & Sivadasan, Fl. Alappuzha Dt. 584. 2009, *non* Spreng. 1825

Erect or ascending annual herbs, up to 80 cm tall. Stems succulent, branched, quadrangular, aromatic, scarcely pubescent with simple hairs, internodes 5–10 cm long. Leaves simple, membranous, smooth, broadly ovate, 7–15 × 7–15 cm, apex acute-acuminate, base cordate, margin mainly crenate or lobed, often double serrated, glabrous on both sides, margin scarcely pubescent, with 6–8 lateral veins from leaf base, venation eucamptodromous; petioles slender, 5–14 cm long, pubescent to pilose. Inflorescence terminal, up to 25 cm long, simple or sometimes branched at inflorescence base, axis slender, pubescent; floral nodes 5–10 mm apart, distant, cymes subsessile, lax, 2–3-flowered, peduncle 2–4 cm long; bracts persistent, rhombic, ca. 3 × 1 mm, apex acute, margin entire, pubescent below; in fruit ovate, ca. 4 × 2 mm; bracteole absent; flower 10–13 mm long, ca. 5 mm in diameter, pale violet; pedicels slender, 3–4 mm long at anthesis, 4–5 mm in fruit, pubescent. Calyx green with brown shaded, campanulate, ca. 3 × 2 mm at anthesis, accrescent, enlarges up to 5–7 × 2–3 mm in fruit, tube 10-nerved, pubescent on nerves; posterior lip broad, rounded, sub decurrent to tube, apex acute-rounded, margin entire, ca. 1 × 1 mm at anthesis, ca. 1 × 3 mm in fruit, pubescent on nerves; anterior lip teeth acuminate, margin ciliate, lateral teeth smaller than median teeth, ca. 0.5 mm long, median teeth 1 mm long, less pubescent. Corolla pale violet, 7–8 mm long, ca. 5 mm in diameter, pubescent; tube ca. 4 mm long, sigmoid below the middle, gradually dilated towards base, widely expanded at throat, glabrous inside; posterior lip 4-lobed, lobes rounded at apex, pubescent, median lobes (ca. 3 × 2 mm) larger than lateral lobes (ca. 2 × 1 mm); anterior lip pale violet colored, ovate, boat shaped, ca. 4 mm long, concave, simple hairs present inside, pubescent with sessile glands outside. Stamens 4, posterior pair attached just below anterior but not united, filament of posterior pair ca. 3 mm long, anterior pair 4 mm long, appendages absent, included in anterior corolla lip; anthers bilobed, dorsifixed, ca. 1 mm long, yellowish, dehisces longitudinally. Disc with anterior side enlarged, white, ca. 0.5 mm long, smaller and not exceeding ovary; ovary ca. 1 mm high, ovules ca. 0.5 mm, hairy at apex; style sigmoid, ca. 7 mm long, glabrous; stigma bifid with equal branches. Mericarps sub orbicular, ca 1 × 1 mm, brownish, ridged on the surface, not producing mucilage when moistened.

Phenology:—Flowering and fruiting occurs between September and January.

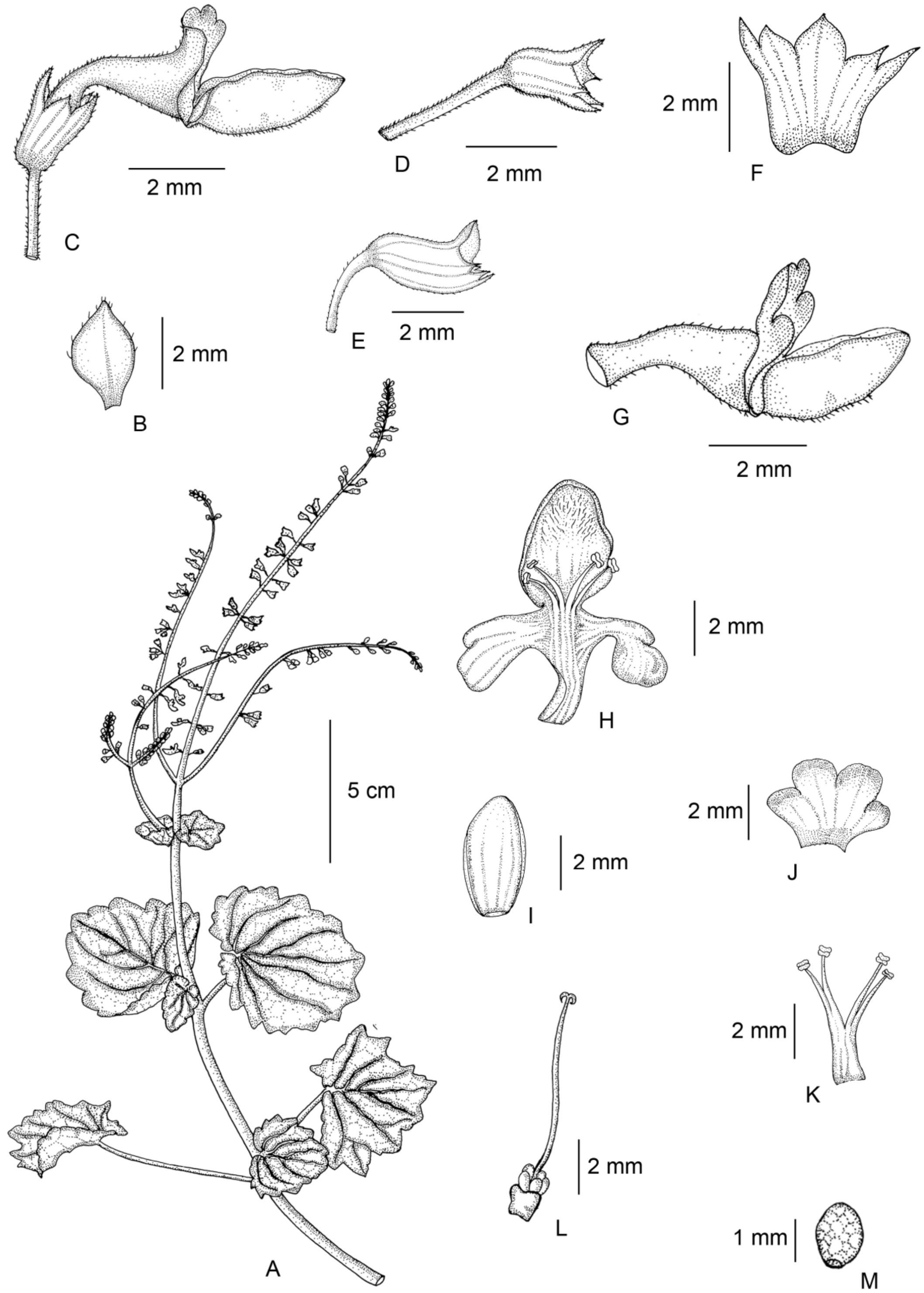


Fig. 3.37. *Plectranthus subincisus.* A. Habit; B. Bract; C. Flower; D. Flowering calyx; E. Fruiting calyx; F. Calyx tube opened; G. Corolla; H. Corolla tube opened; I. Lower lip of corolla; J. Upper lip of corolla; K. Stamen; L. Gynoecium; M. Mericarp. All drawn from *Smitha & Sunojkumar 135430* by K. Smitha.

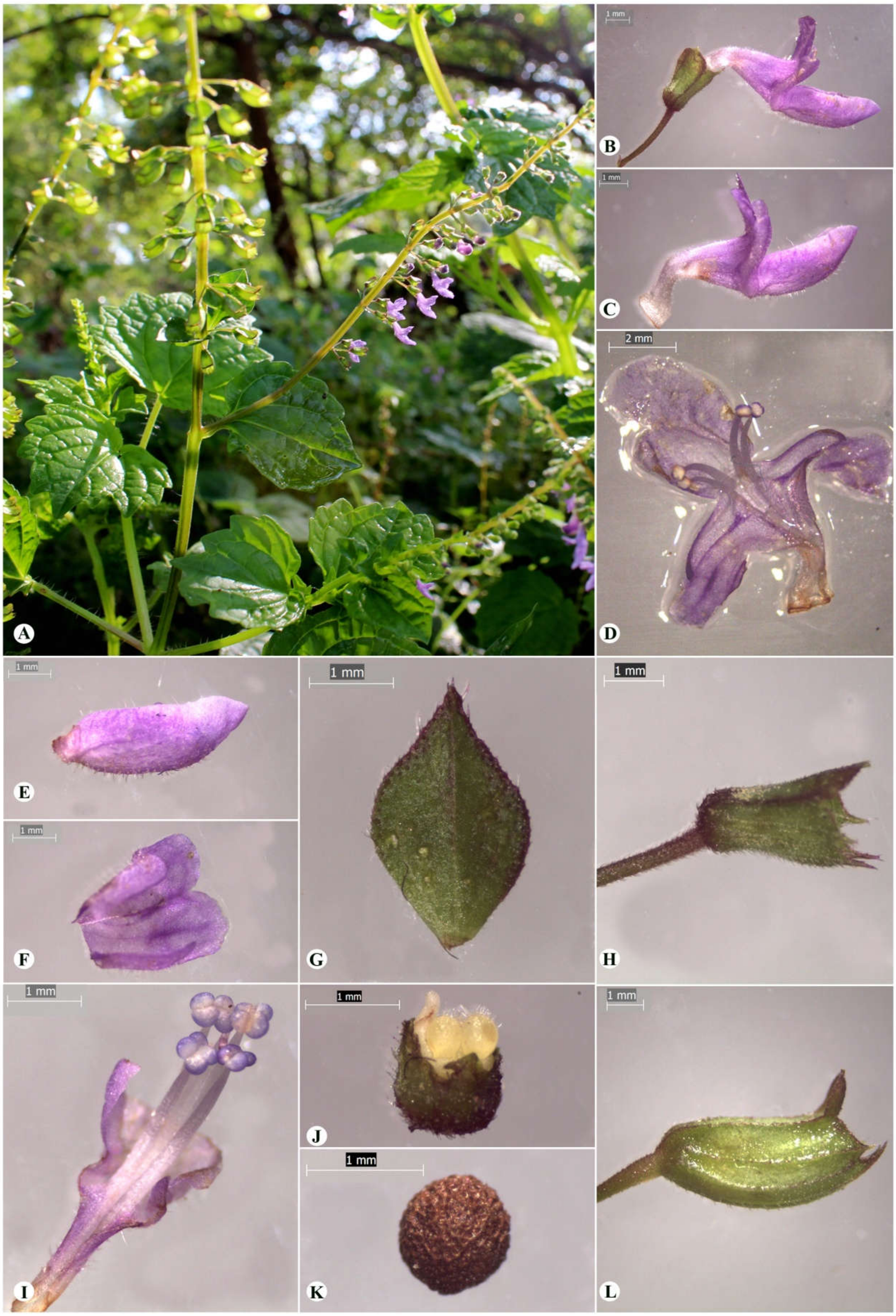
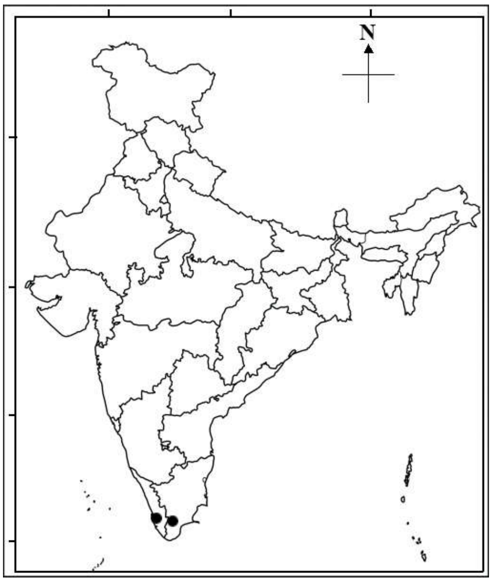


Fig. 3.38. *Plectranthus subincisus.* A. Habit; B. Flower; C. Corolla; D. Corolla tube opened; E. Corolla lower lip; F. Corolla upper lip; G. Bract; H. Flowering calyx; I. Stamen; J. Ovary; K. Mericarp; L. Fruiting calyx.

Fig. 3.39. Holotype of *Plectranthus subincisus*. (K000820179, “Reproduced by permission of Board of trustees of Royal Botanic Gardens, Kew”).

Habitat and Distribution:—*P. subincisus* grows in open wet sandy soils in coastal areas. As per the information available in the literature, *Plectranthus subincisus* is distributed in Southern India (Kerala and Tamil Nadu) and in Sri Lanka (probably extinct).



Notes:—After examining Indian Herbaria (CAL, CALI, KFRI, MH, TBGT) as well as of relevant literature, it is confirmed that there is no recent collection of *Plectranthus subincisus* made in India or in Sri Lanka. Therefore the present collection and those made by Sunil & Sivadasan (2009), forms a recollection of this species from southern India after a time span of 150 years. This species is included under the threatened species list (IUCN 2000) in Sri Lanka. *P. subincisus* is morphologically much similar to *P. mollis* in its leaf shape and size, nature of inflorescence, persisting bracts, swelling of the mature fruiting calyx tube and on the length of the corolla, but differ from each other in the size of fruiting calyx, presence or absence of hairs inside the lower lip of corolla and size and nature of mericarps. The areas where the plants were located face threats due to various anthropogenic factors and hence efforts were made to conserve the plants in Calicut University Botanical Garden.

Specimens examined:—India. Kerala: Alappuzha district, Vandanam, 10 October 2013, *Smitha & Sunojkumar135430* (CALI!); Pallippuram, 1 October 1998, *Sunil 1612* (CALI!).

Conservation status:— *P. subincisus* was collected from Medical college campus,Vandanam, Alappuzha district, Kerala. In the present collection, very few mature plants (less than 40) are noticed and the area face threats due to various anthropogenic activities like construction of buildings. This species was found in two or three locations and these areas are prone to severe grazing and other disruptive people activities like construction of buildings and widening of roads. Thus the habitat is under severe threat. The extent of occurrence for *P. subincisus* was less than 100 km^2. Therefore, we suggest that *P. subincisus* should be evaluated as critically endangered, CR [B1a, b (ii, iii) + D] according to the IUCN (2012) categories and criteria.

3.6.19. Plectranthus verticillatus (L.f.) Druce, Rep. Bot. Soc. Exch. Club Brit. Isles 4: 640. 1917; Sunojk., *et al.* J. Econ. Taxon. Bot. 36: 4. 2012.

(Fig. 3.40)

≡ *Ocimum veticillatum* L.f., Suppl. Pl. 276. 1782.

= *Ocymum racemosum* Thunb. Prodr. Pl. Cap. 96. 1800.

= *Plectranthus thunbergii* Benth., Lab. Gen. Sp. 37. 1832.

= *Plectranthus nummularius* Briq. Bull. Herb. Boissier, ser. 2, 3: 1072. 1903.

Erect or ascending perennial herbs, up to 60 cm tall. Stem slightly woody at base, profusely branched, obtusely quadrangular, pubescent, internodes 4–6 cm long. Leaves simple, membraneous, dark green, rough, ovate, 3.5–8 × 2–3.5 cm, apex acute, base rounded to slightly cuneate, margin deeply serrate with 6–10 toothed, upper side pubescent with dense fine hairs, glandular punctuate, shining, lower side slightly violet with more colour towards mid vein, less pubescent, lateral veins 2–4, prominent; petiole 1.5–4 cm long, laxly pubescent, dark green-violet tinged. Inflorescence terminal, 12–15 cm long, unbranched, stalk deeply violet, pubescent, 4–6 verticils per branch, usually spaced by ±2.5 cm prolonged internodes, 4–6 flowers at each node; bracts sessile, caducous, ovate to lanceolate, 2–4 × 2–2.5 mm towards base, linear with 2–3 × 1–1.5 mm or absent towards apex, pubescent; bracteole

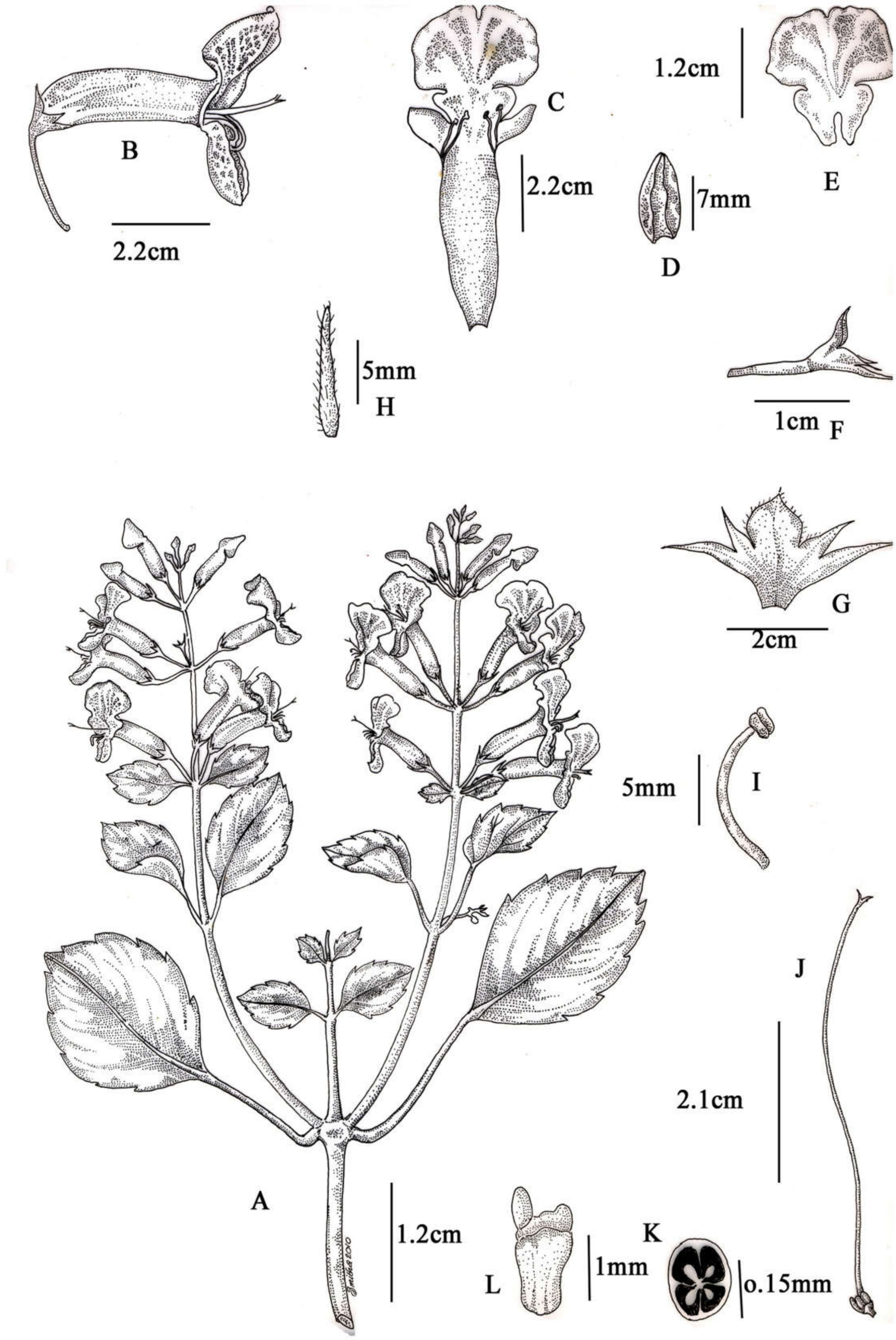


Fig. 3.40. *Plectranthus verticillatus*. A. Habit; B. Flower; C. Corolla tube opened; D. Corolla anterior lip; E. Corolla posterior lip; F. Flowering calyx; G. Calyx opened; H. Bract; I. Stamen; J. Gynoecium; K. Ovary C.S.; L. Disc.

absent; flowers with pedicel 0.5– 7 mm long, pubescent. Calyx campanulate, 1–2 mm long, dark green, hispidulous outside, glabrous inside, minute glands present on both sides; posterior lip broadly ovate with a prominent mid-vein, tip acute, decurrent on tube; anterior lip 4-lobed with acute tips, lateral lobes slightly incurved, linear, margin laxly ciliate, median pair ca. 2 mm long, longer than lateral pair, connate for their greater parts towards base. Corolla 2–2.8 cm long, light violet coloured with deep violet spots on lobes, pubescent with minute sessile glands outside; tube straight, ±1.5 cm long, base slightly bent and dilated, 2-lipped; posterior lip 4-lobed, pubescent; anterior lobe ca. 7 mm long, boat-shaped. Stamens attached to corolla throat; filaments 4–5.5 mm long, united for one third of their length; anthers light violet, theca divaricate, lobes orbicular, ca. 0.75 mm long, dorsifixed, filament attached on the middle of a fleshy connective. Style ±20 mm long, exceeding corolla lips, bifid, lobes equal, ovary ca. 0.5 mm long. Disc fleshy, anterior lobe ca. 0.5 mm long, others smaller.

Phenology:—Throughout the year

Habitat and Distribution:—grow on open places, among herbs. Widely cultivated in Tropical Africa as an ornamental.

Notes:—*P. verticillatus* is an African species commonly called as 'Swedish ivy' and introduced and cultivated as an ornamental in India.

Specimens Examined:—India. **Kerala:** Malappuram district, Calicut University Botanical Garden, 16 February 2010, *Smitha & Sunojkumar 124109* (CALI!).

3.6.20. Plectranthus vettiveroides (Jacob) N.P.Singh & B.D.Sharma, J. Bombay Nat. Hist. Soc. 79: 712. 1983; A.N.Henry et al., Fl Tamil Nadu 2: 181. 1987 **(Fig. 3.41)**

≡ *Coleus vettiveroides* Jacob, J. Bombay Nat. Hist. Soc. 42: 320. 1941; Chandrab. & N.C.Nair, Fl. Coimbatore 242. 1988

Type**:**—INDIA.Thanjavore, Shiyali, 30 April 1939, *85675* (Holotype MH!)

= *Coleus osmirrhizon* Elliot *nomen tantum*

Type**:**—India. Chingleput district, Mahabalipuram, 25 May 1879, *T.Abboy Naidu 40797* (MH)

Erect annual herbs, up to 60 cm tall. Roots copiously fibrous, up to 50 cm long, slender, thin, strawcoloured and slightly fragrant when fresh, but turn dark and are strongly aromatic when dry. Stem branched, quadrangular, succulent, green or brown, minutely pubescent. Leaves subfleshy, opposite, orbicular to ovate, up to 10–12 × 8–10 cm, apex acute, base rounded, margin crenate, 40–44-toothed, minutely pubescent on both sides, venation eucamptodromous; petioles fleshy, 10–12 cm long, slightly purplish, pubescent. Flowers and fruits are so far not been described and flowering has also not been seen by the farmers who traditionally cultivate this species for more than a century.

Phenology:—Flowers and fruits are not seen

Habitat and Distribution:— Endemic to Kerala and Tamil Nadu. It is seems to be extinct in the wild and survive only under cultivation. This species is largely cultivated on the river banks in sandy loams. At the beginning of the 20^{th} century, it was under large-scale in Coimbatore, Madurai, Thanjavur, Tirunelveli and Chengalpet districts of Tamil Nadu and Palakkad district of Kerala. While the field surveys in the known regions of its cultivation reveal that *P. vettiveroides* is currently cultivated in a small pocket of sandy loam soil in Thillaimangalam village near Kollidam in Sirkazhi Taluk, Nagapattinam district and in Sundaraperumal Koil village in Thanjavur district, Tamil Nadu. Apart from these two places, the germplasm is expected to be present in Jawaharlal Nehru Tropical Botanic Garden and Research Institute (JNTBGRI), Thiruvananthapuram and The Institute of Trans-Disciplinary Health Sciences & Technology at FRLHT, Banglore (Murugan et al. 2015).

Notes:— *P. vettiveroides*, known as Hrivera (in Sanskrit), Iribeli (in Malayalam), Kuruver and Vetiver (in Tamil), has long been used in both Ayurveda and Siddha. The species was first described and illustrated as Iribeli by Van Rheede in 1689. It was scientifically described with a valid nomenclature by Jacob (Jacob, 1942) as *Coleus vettiveroides*. Later, the species was transferred to the genus *Plectranthus* (Singh & Sharma, 1983). Further information on this species is lacking in Indian literature and Herbaria and all the above mentioned reports and specimens describe and illustrate *P. vettiveroides* in vegetative condition.

There is confusion on the botanical identity of the name Iribeli and Hrivera. The name Iribeli has been equated with *Plectranthus amboinicus* and *Plectranthus hadiensis*. Rheede has mentioned two types of Iribeli, namely black and white. The white Iribeli or Ramacciam (in Malayalam) refers to the aromatic grass *Vetiveria zizanioides* whereas the clear description and illustration of black Iribeli distinctly refers to *P. vettiveroides*. The root of Rheede's black Iribeli is ash-obscure coloured and strongly aromatic. The roots of *P. vettiveroide*s are straw coloured when fresh and turn black and are strongly aromatic on drying. But the roots of *P. amboinicus* and *P. hadiensis* neither turn black nor are aromatic on drying. Other important distinguishing characters of Iribeli are the length of the leaf petiole and fragrance of the leaf.

Fig. 3.41. Holotype of *Plectranthus vettiveroides*. (MH00002421, "Reproduced by permission of Madras Herbarium, Coimbatore).

Rheede has described and illustrated Iribeli with long petiole and never described that the leaf is aromatic. The leaf of *P. vettiveroides* is not aromatic and the petiole is very long (up to 10 cm long). Where as in *P. amboinicus* and *P. hadiensis*, the leaves are aromatic and the petioles are short (less than 4 cm) (Murugan et al. 2015).

Uses:— The fibrous and strongly aromatic root of *P. vettiveroides* has economical and religious significance. The roots are used in various formulations in Ayurveda and Siddha. The roots and root oil are traditionally used in anti-cachetic, fever, burning of liver, swelling of hands and feet, head-ache, dysentery and eye pain. The roots are also used for the treatment of burning eyes, diarrhoea, intrinsic haemorrhage, strangury, hyperdipsia, leprosy, leucoderma ulcer, vomiting, skin diseases, giddiness and quenching thirst. It is also used to promote hair growth. The extract has anti-bacterial, deodorant and cooling properties, is also used as one of the ingredients in hand sanitizer. In Ayurveda *P. vettiveroides* is traditionally used for vomiting and nausea. The plant is used in some ayurvedic preparations like iruveli kashayam, devashtagandha and snana choornam.

Specimens Examined:—India. Tamil Nadu: Thanjavur, 26 January 1978, *K.Ramamurthy 53589* (CAL!); **Karnataka**. Bangalore district, Yelahanka, FRLHT campus, *Smitha & Sunojkumar 135472* (CALI!).

Conservation status:—Extinct in the wild (EW) (IUCN 2012)

3.6.21. Plectranthus sp.1 (Fig. 3.42)

Erect perennial herbs, up to 90 cm tall. Stem woody, light green with purple spots, branches quadrangular, glabrous, internodes 2–4 cm. Leaves membraneous, cordate, 10–19 × 6–13 cm, apex acute, base deeply cordate, a small leafy appendages at leaf base, margin mainly crenate, sometimes doubly crenate, 19-pairs of tooth, upper and lower surface glabrous, 6–8-nerved,

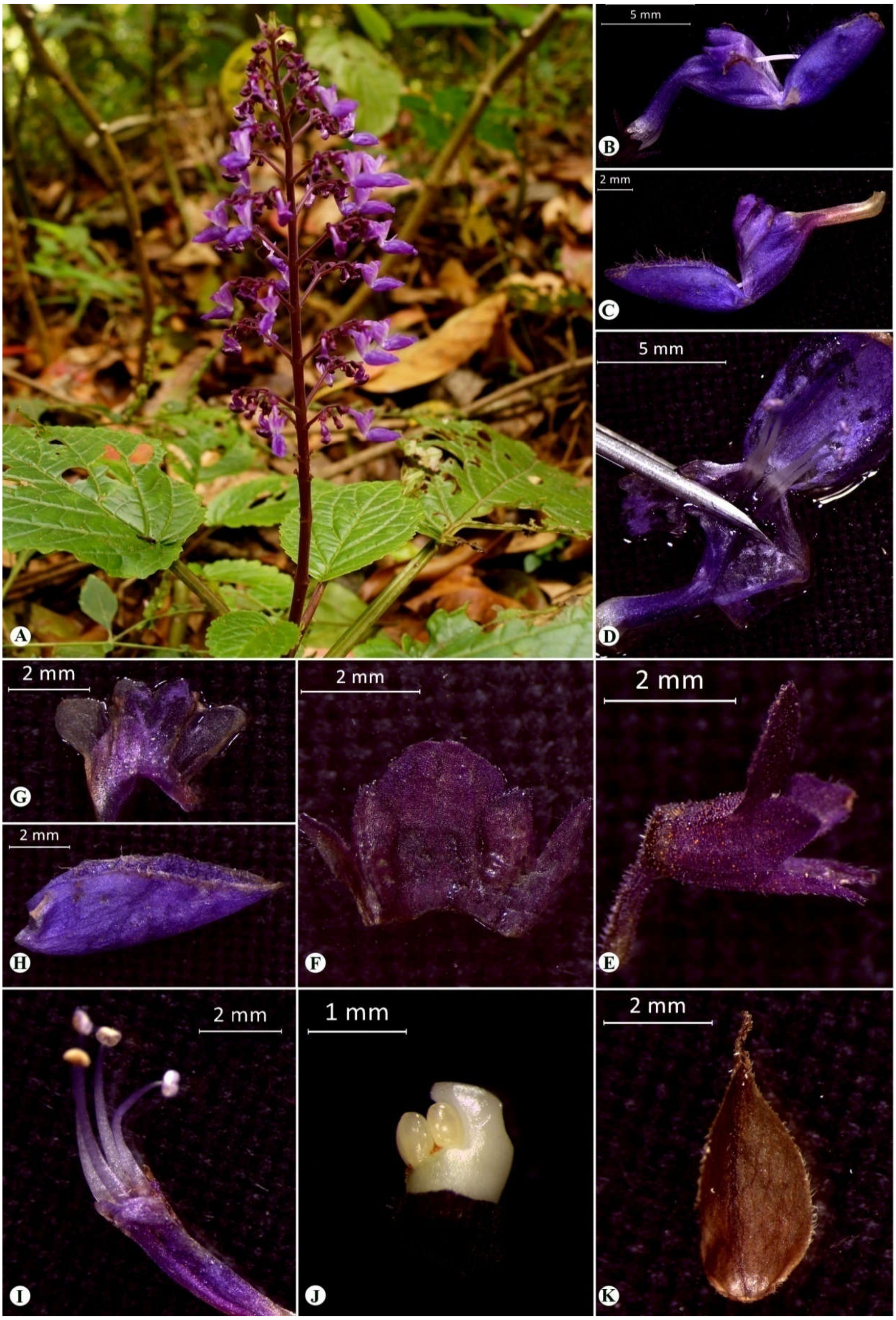


Fig. 3.42. *Plectranthus* sp. 1. A. Habit; B. Flower; C. Corolla; D. Corolla tube opened; E. Flowering calyx; F. Calyx opened; G. Corolla upper lip; H. Corolla lower lip; I. Stamen; J. Ovary; K. Bract.

venation eucamptodromous; petioles fleshy, ridged, 3–9 cm long, green, glabrous. Inflorescence terminal, up to 25 cm long, without basal branches, purple, axis fleshy, pubescent with simple hairs; floral nodes 1–2 cm apart, cymes 3–4 cm long, pedunculate, producing lax lateral cincinnal, 5–12-flowered, peduncle 1–2 cm long; bracts caducous, ovate, ca. 5 × 2.5 mm, apex acuminate, margin ciliate, pubescent along margins; bracteole absent; flower 17–20 mm long, purple; pedicels slender, ca. 3 mm long at anthesis, ca. 4 mm in fruit, pubescent. Calyx purple, campanulate, ca. 4 × 4 mm at anthesis, enlarges up to 5 × 4 mm in fruit, tube 1–2 mm long, 10-nerved, inside glabrous, pubescent with sessile glands outside; posterior lip broad, orbicular, decurrent to tube, apex obtuse, margin ciliate, ca. 2 × 2 mm at anthesis, ca. 3 × 2 mm in fruit, inside glabrous, pubescent with sessile glands outside; teeth of the anterior lip lanceolate, margin ciliate, lateral teeth larger than median teeth, 2 mm long at anthesis, ca. 2.5 mm in fruit, median teeth 1.5 mm long at anthesis, 2 mm in fruit, pubescent with sessile glands outside. Corolla purple, 15–17 mm long, pubescent; tube 5–7 mm long, sigmoid below the middle, gradually dilated towards base, widely expanded at throat, long white hairs inside; posterior lip 4-lobed, lobes rounded at apex, pubescent, median lobes (ca. 1.5 × 2 mm) larger than lateral lobes (ca. 1.5 × 1 mm); anterior lip ovate, boat shaped, ca. 8 × 6 mm, long hairs along inner margin, pubescent with sessile glands outside. Stamens free, anterior pair attached at the mouth of corolla tube, posterior pair attached just below anterior but not united, filament of posterior pair 4 mm long, filament of anterior pair ca. 5 mm long, included in anterior lip; anthers bilobed, dorsifixed, ca. 1 mm long, yellowish, dehisces longitudinally. Disc anterior side enlarged, white, ca. 1 mm long, larger than ovary; ovary ca. 0.5 mm high; style sigmoid, ca. 1.3 mm long, glabrous; stigma bifid with unequal branches.

Phenology:— Flowering and fruiting occurs between February and April.

3.6.22. Plectranthus sp.2 (Fig. 3.43)

Erect perennial herbs, aromatic, up to 50 cm tall. Stem woody, purple, branches quadrangular, villous, internodes 1–2 cm, rootng at nodes. Leaves membraneous, cordate, 3–8 × 2.5–6 cm, apex acute, base truncate, margin mainly crenate, sometimes doubly crenate, 19-pairs of tooth, upper and lower surface glabrous, 6–8-nerved, venation eucamptodromous; petioles fleshy, , 1–3 cm long, purple, villous. Inflorescence terminal, up to 15 cm long, without basal branches, purple, axis fleshy, pubescent with simple hairs; floral nodes ca. 1 cm apart, cymes 2–3 cm long, pedunculate, producing lax lateral cincinnal, 3–6-flowered, peduncle 1–2 cm long; bracts persistant up to fruiting stage, cordate, 5 × 4 mm, apex acute, margin ciliate, pubescent along margins; bracteole absent; flower 22–24 mm long, purple; pedicels slender, ca. 5 mm long at anthesis, ca. 6 mm in fruit, pubescent. Calyx pale green, campanulate, ca. 3.5 × 3 mm at anthesis, enlarges up to ca. 5 × 4 mm in fruit, tube 1–2 mm long, 10-nerved, inside glabrous, pubescent with sessile glands outside; posterior lip broad, orbicular, decurrent to tube, apex obtuse, margin ciliate, ca. 2 × 2.5 mm at anthesis, ca. 3 × 3 mm in fruit, inside glabrous, pubescent with sessile glands outside; teeth of the anterior lip lanceolate, margin ciliate, lateral teeth larger than median teeth, ca. 0.5 mm long at anthesis, ca. 1 mm in fruit, median teeth ca. 0.3 mm long at anthesis, ca. 0.5 mm in fruit, pubescent with sessile glands outside. Corolla purple, 20–22 mm long, pubescent; tube 8–10 mm long, sigmoid below the middle, gradually dilated towards base, widely expanded at throat, long white hairs inside; posterior lip 4-lobed, lobes rounded at apex, pubescent, median lobes (ca. 1.5 × 2 mm) larger than lateral lobes (ca. 1.5 × 1 mm); anterior lip ovate, boat shaped, ca. 10 mm, long hairs along inner margin, pubescent with sessile glands outside. Stamens free, anterior pair attached at the mouth of corolla tube, posterior pair attached just below anterior but not united, filament of posterior pair ca. 6 mm long, filament of anterior pair ca. 8 mm long, included in anterior lip; anthers bilobed, dorsifixed, ca. 1 mm long, yellowish, dehisces longitudinally. Disc anterior side enlarged, white, ca. 1 mm long, larger than

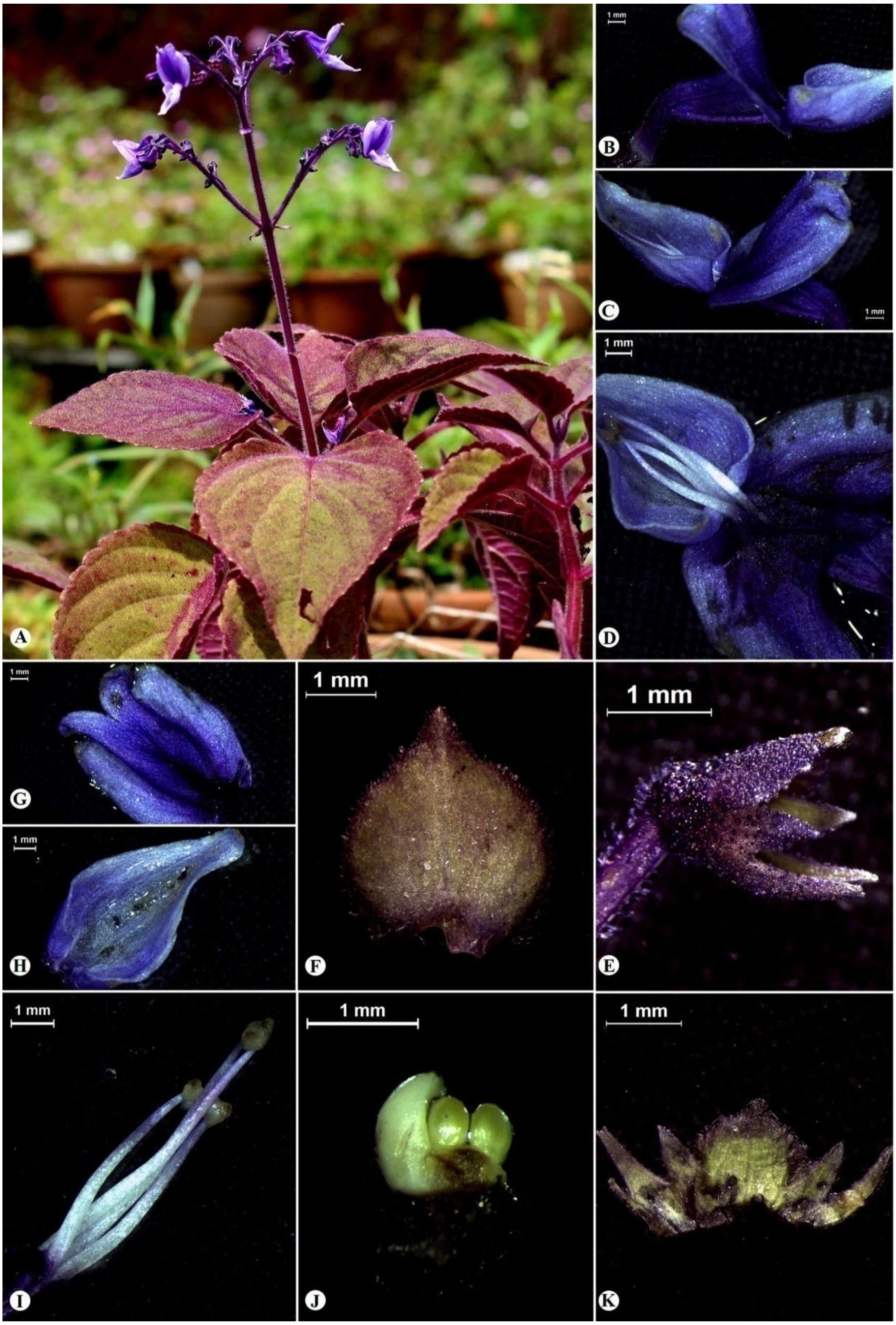


Fig. 3.43. *Plectranthus* sp. 2. A. Habit; B. Flower; C. Corolla; D. Corolla tube opened; E. Flowering calyx; F. Bract; G. Corolla upper lip; H. Corolla lower lip; I. Stamen; J. Ovary; K.. Calyx opened.

ovary; ovary ca. 0.5 mm high; style sigmoid, ca. 1.6 mm long, glabrous; stigma bifid with equal branches. Mericarps ca. 1.42 × 1.10 mm, widely elliptic, surface veruucate, black in color.

Phenology:— Flowering and fruiting occurs between August and November.

3.7. Conclusions

After a critical taxonomic revision of the genus, altogether 22 species are identified from India, with 5 new species. The new species described in this study are *P. anamudianus, P. gamblei, P. sahyadricus*, *Plectranthus* sp.1 and *Plectranthus* sp. 2. The present investigation revealed that eleven species are found endemic to India especially in Sothern Western Ghats. The endemics are: *P. anamudianus, P. beddomei, P. bishopianus, P. bourneae, P. deccanicus, P. gamblei*, *P. subincisus, P. vettiveroides, Plectranthus sahyadricus, Plectranthus* sp.1 & *Plectranthus* sp. 2.

As part of this revision the taxonomic identity of *P. bourneae* was clarified (Smitha & Sunojkumar 2018 in press). Gamble described *P. bourneae* based on two collections. The subsequent critical study of fresh specimens with the aid of SEM analysis of mericarps confirmed that *A. G. Bourne & E. G Bourne*'s collection and Gamble's collection hitherto considered as a single entity belongs to two different species. Gamble's application of the name is restricted to *A. G. Bourne & E. G Bourne*'s specimen and also lectotypified *P. bourneae*. Gamble's collection in 1883 from Coonoor (Gamble 12263) assigned a new name, *P. gamblei*.

Another major finding of this study is the resurrection of *P. bishopianus* from the synonymy of *P. deccanicus* (Smitha & Sunojkumar 2018 in press). The Western Ghat endemic species *Plectranthus bishopianus* was described by Gamble (1924) based on two collections (*A. G. & E. G. Bourne 1329* and *1398*) from Pulney hills. Later, Matthew (1993) synonymized it under *P. deccanicus* based on Bourne's specimens. His interpretation was that Bourne's type collection was from deep shade and was a smaller, thinner and variegated leaved form with a sparse inflorescence, as is to be expected from plants growing in insufficient light. After a critical morphological and micromorphological analysis it is concluded that *P. bishopianus* is not conspecific with *P. deccanicus*. This study showed that both species are distinct in vegetative as well as floral characters. SEM analysis of pollen and mericarp also shed light towards the independent status of these two species.

In this study, *Plectranthus subincisus* a poorly known species is recollected after 150 years from southern India and the taxonomic identity and distribution of this species is also discussed (Smitha & Sunojkumar 2015). The identity of another poorly known species *P. montanus* is discussed as part of this study and a new synonym *Coleus subbaraoi* is also proposed (Smitha & Sunojkumar 2017). Recently described three new species are also synonymized after a critical taxonomic study. *P. petricola* J.Mathew & B.J.Conn is found to be conspecific with *P. anamudianus*.

Plectranthus idukkianus J.Mathew, Yohannan & B.J.Conn and *Plectranthus saxorum* J.Mathew, Yohannan & B.J.Conn are synonymized under *P. malabaricus*. This study showed that *P. malabaricus* is a highly polymorphic species which exhibit a vast range of variation. We could collect more than eight different accessions of this species from different localities of Western Ghats. All these accessions show differences vegetatively but floral characters are same. Apart from morphological study, molecular analysis was also conducted with three choloplast genes (*trnL* intron, *trnL-F* intergene spacer and *rps 16*). In this analysis, all the eight accessions form polytomy and we couldn't came up with any more conclusion than to decide it is a polymorphic form. Thus it is evident that more markers are needed to find out the status of this complex. Of these eight accessions, now, two of them were published (Mathew *et al.* 2017) as new species. All the characters used to delimit these two accessions as species are variable vegetative characters and this lead us to treat these two species as synonyms under *P. malabaricus.*

CHAPTER 4
MICROMORPHOLOGY

CHAPTER 4
MICROMORPHOLOGY

Plectranthus is one of the largest genera of Lamiaceae with confusing taxonomy. The main research problem addressed in this study was to confirm whether the genera *Plectranthus* and *Coleus* are congeneric or not. Hence, a combined approaches of morphology, micromorphology (SEM studies) and molecular approaches was followed in circumscribing the taxon boundary within the complex. Here a systematic study using SEM analysis of pollen and mericarps was employed to resolve the existing problem of generic level circumscription and species taxonomy of the *Plectranthus*-*Coleus* complex in India. This study was conducted to check the utility of micromorphological data and its support with the molecular phylogenetic analysis of the complex. We discussed the obtained results of pollen and mericarp micromorphology on the background of both molecular phylogeny and classical taxonomy of *Plectranthus*.

Among various taxonomic data sources, fruit morphology has proven particularly interesting in the family Lamiaceae and has been used regularly for the past 150 years (Bentham 1832; Gray 1878; Briquet 1897). Subsequently, workers with Old World species have also demonstrated the taxonomic utility of fruit morphology as well as anatomy (Fabre and Nicoli 1965; Wojciechowska 1966, 1972; Wunderlich 1967; Ryding 1992a, b). Morphology, shape, colour and size of the nutlets were used as diagnostic characters in classification (Schermann 1967). Studies of nutlets in the Lamiaceae have progressed over the past two decades from purely light microscopy to scanning electron microscopy. Nutlet characters can be used successfully at many taxonomic levels, depending on the characters chosen and the variation present.

Earlier studies on pollen of Lamiaceae have mainly involved the use of light microscope only. Nabli (1976), who initiated the use of both Scanning Electron microscopy (SEM) and Transmission Electron microscopy (TEM) to investigate the surface structure and exine ultra- structure of pollen of *Teucrium* and various other selected genera of the family. Erdtman (1945) originally proposed a subfamilial level classification of Lamiaceae based only on pollen features. Pollen morphology including aperture number, size, shape and tectum ornamentation were studied in different members of the family Lamiaceae and found these features were helpful in its taxonomy (Abu-Asab and Cantino 1994; Bazarragchaa *et al.* 2012). However, Perveen and Qaiser (2003) and Al-Watban *et al.* (2015) studied pollen morphology of several species in different genera of the family Lamiaceae and suggested that it is useful in grouping and identifying the species. The pollen and mericarp morphologic studies of different species of *Plectranthus* is carried out to check whether the phylogeny of the genus is supported by this study or not.

4.1. Pollen micromorphology

4.1.1. Introduction

Pollen morphology has been proved to be useful in phylogenetic reconstructions (Abu-Asab and Cantino 1992) and systematics of the family Lamiaceae (Abu-Asab and Cantino 1994). However only a few investigations have been conducted on the pollen morphology of tribe Ocimeae (Harley *et al*. 1992; Harley 1992). Harley (1992) studied the pollen morphology of subtribe Ociminae (Nepetoideae). The results showed the potential value of pollen characters both in taxonomic revision and in the understanding of relationships and evolution within the Lamiaceae. During the revionary work of Arabian *Plectranthus*, Abdel Khalik (2016) included pollen morphology as one of the distinguishing character among species. On the other hand, Doaigey *et al*. (2017) investigated the pollen morphology of 16 genera of the Lamiaceae, and this study included only one species of *Plectranthus* (*P. asirensis*).

In the course of a revision for *Plectranthus* in India, which is home to 22 species of the genus, we carried out a detailed study of the pollen morphology of 12 Indian species. Therefore, the main objectives of the present study are 1) to provide a detailed account of the pollen morphology of 12 Indian species of the genus *Plectranthus* using scanning electron microscopy (SEM); 2) to evaluate the systematic significance of the palynological data and to discuss them on the background of both macromorphological and molecular results; 3) To check whether palynological data support any kind of sectional classification of the genus.

4.1.2. Materials and methods

Pollen grains of 18 taxa representing 12 species of the genus *Plectranthus* were analyzed. The mature pollen grains used in this study were collected from field and voucher specimens were deposited at Calicut University Herbarium (CALI). A list of voucher specimens used in the present study including some notes on the location of the plants is given in Table 4.1. For scanning electron microscopy (SEM), pollen samples were directly mounted onto stubs with double-sided tape and then sputter-coated with gold. Micromorphological observations were conducted using a Jeol JSM – 6390LV/ JED – 2300 and Gemini SEM 300 scanning electron microscopes with 15 kV voltage. SEM micrographs were used mainly for studying the overall shape, size, type of sculpturing, and to get more detailed information on the sculpturing (Table 2). We followed the terminologies used by Harley *et al.* (1992) and Punt *et al*. (2007) for pollen grains.

Table 4.1. Taxa, Voucher specimens and herbarium data of species of *Plectranthus* used in the pollen micromorphology

Sl. No.	Taxa	Locality	Collector	Herbarium number & abbreviation
1	*Plectranthus anamudianus* Smitha & Sunojk.	India, Idukki, Rajamala	Smitha & Sunojkumar	135412 (CALI)
2	*Plectranthus barbatus* Andrews	India, Wayanad, Myladi	Smitha & Sunojkumar	135415 (CALI)
3	*Plectranthus beddomei* Raizada	India, Kottayam, Vagamon	Smitha & Sunojkumar	135422 (CALI)
4	*Plectranthus bishopianus* Gamble	India, Wayanad, Aranamala	Smitha & Sunojkumar	135465 (CALI)
5	*Plectranthus bourneae* Gamble	India, Kodaikanal, Poombarai	Smitha & Sunojkumar	135474 (CALI)
6	*Plectranthus caninus* Roth	India, Idukki, Marayur	Smitha & Sunojkumar	135409 (CALI)
7	*Plectranthus deccanicus* Briq.	India, Idukki, Munnar	Smitha & Sunojkumar	135467 (CALI)
8	*Plectranthus glabratus* (Benth.) Alston	India, Tamil Nadu, Coonoor	Smitha & Sunojkumar	135462 (CALI)
9	*Plectranthus malabaricus* (Benth.) R.H.Willemse	India, Karnataka, Kodachadri	Smitha & Sunojkumar	135438 (CALI)
10	*Plectranthus mollis* (Aiton) Spreng.	India, Wayanad, Muthanga	Smitha & Sunojkumar	135414 (CALI)
11	*Plectranthus subincisus* Benth.	India, Alappuzha, Vandanam	Smitha & Sunojkumar	135430 (CALI)
12	*Plectranthus* sp.1	India	Smitha & Sunojkumar	135468 (CALI)

4.1.3. Results

The main pollen characteristics of the studied taxa are summarized in Table 4.2. The SEM micrographs of the pollen grains examined are illustrated in Fig. 4.1. & Fig. 4.2. The pollen features (size, shape, colpi and exine sculpturing) are described below.

Size and shape

The pollen grains are shed as monads. Size of polar axis (P) varies from 16.40 µm, in *P. bishopianus*, to 36.93 µm, in *P. caninus*, while size of equatorial axis (E) varies from 19.55 µm, in *Plectranthus* sp.1, to 33.02 µm, in *P. beddomei* (Table 2). The shape of the pollen grains in equatorial view ranges from oblate, sub-oblate, oblate-spheroidal, prolate, sub-prolate, prolate-spheroidal to spheroidal whereas their shape in polar view is more or less circular (Table 4.2; Fig. 4.1).

Colpi

Pollen grains are radially symmetric and isopolar in all the taxa. They are hexacolpate in all the species and simple colpi are distributed symmetrically. Colpus length varies from 13.2 µm, in *P. bishopianus*, to 26.3 µm, in *P. caninus*. Colpus width ranges from 1.05 µm, in *P. malabaricus*, to 5.3 µm in *P. deccanicus*. Colpus length is strongly correlated with length of polar axis. Colpi are narrow towards the poles and their ends are acute. They have granulate, granulate–scabrate membranes

Exine sculpturing (ornamentation)

Exine sculpturing, examined with SEM, shows three distinct types of surface structures, reticulate (Type I), bireticulate–perforate (Type II, the common type) and bireticulate–finely reticulate (Type III). Based on the detailed configuration of the exine ornamentation bireticulate–perforate patterns can be subdivided into two subtypes. In one subtype the width of the muri of the primary reticulum is > 0.5 µm and in other type width of the muri of the primary reticulum is < 0.5 µm.

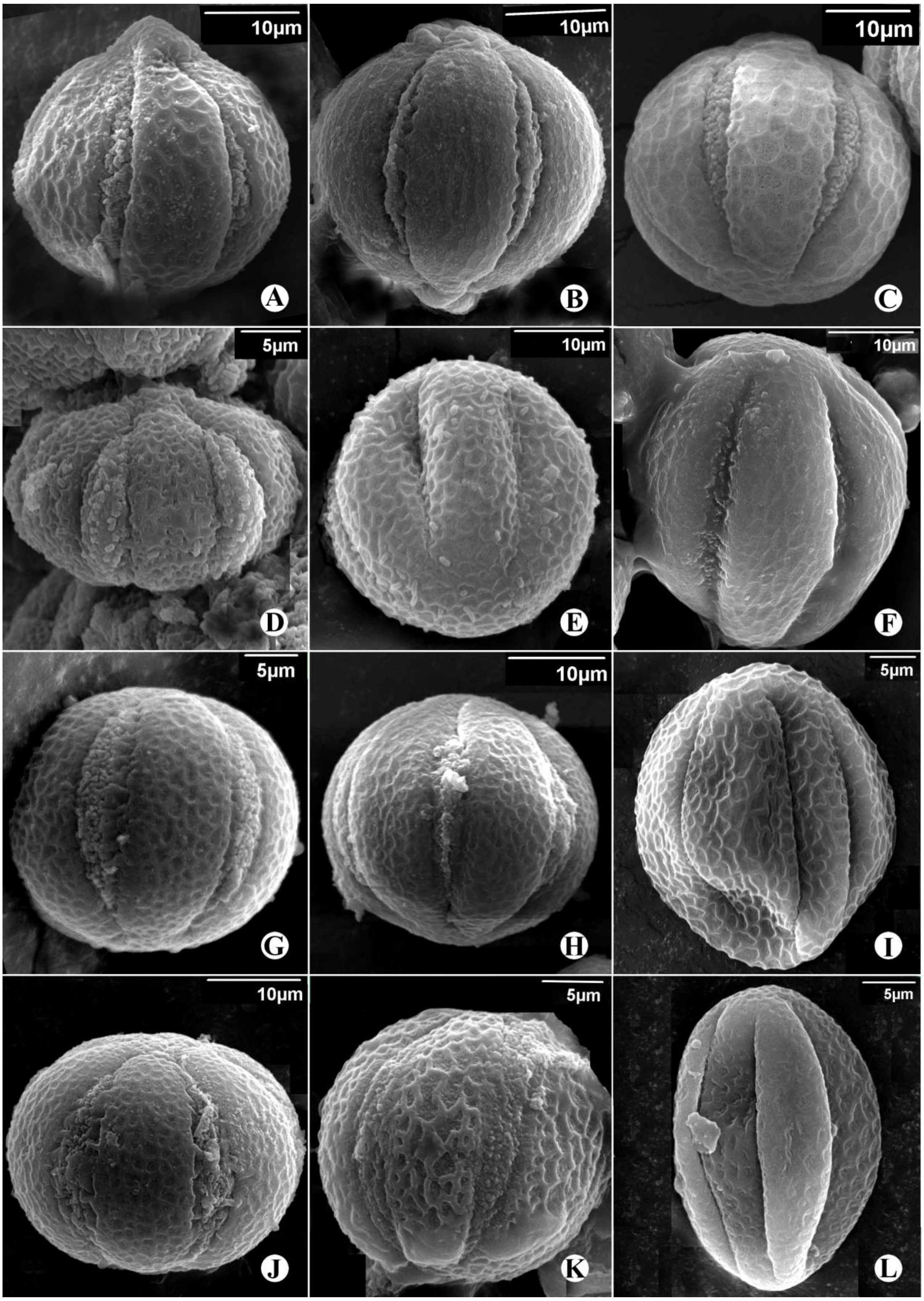


Fig. 4.1. SEM micrographs of pollen grains in *Plectranthus*. A. *P. anamudianus*; B. *P. barbatus*; C. *P. beddomei*; D. *P. bishopianus*; E. *P. bourneae*; F. *P. caninus*; G. *P. deccanicus*; H. *P. glabratus*; I. *P. malabaricus*; J. *P. mollis*; K. *P. subincisus*; L. *Plectranthus* sp.1.

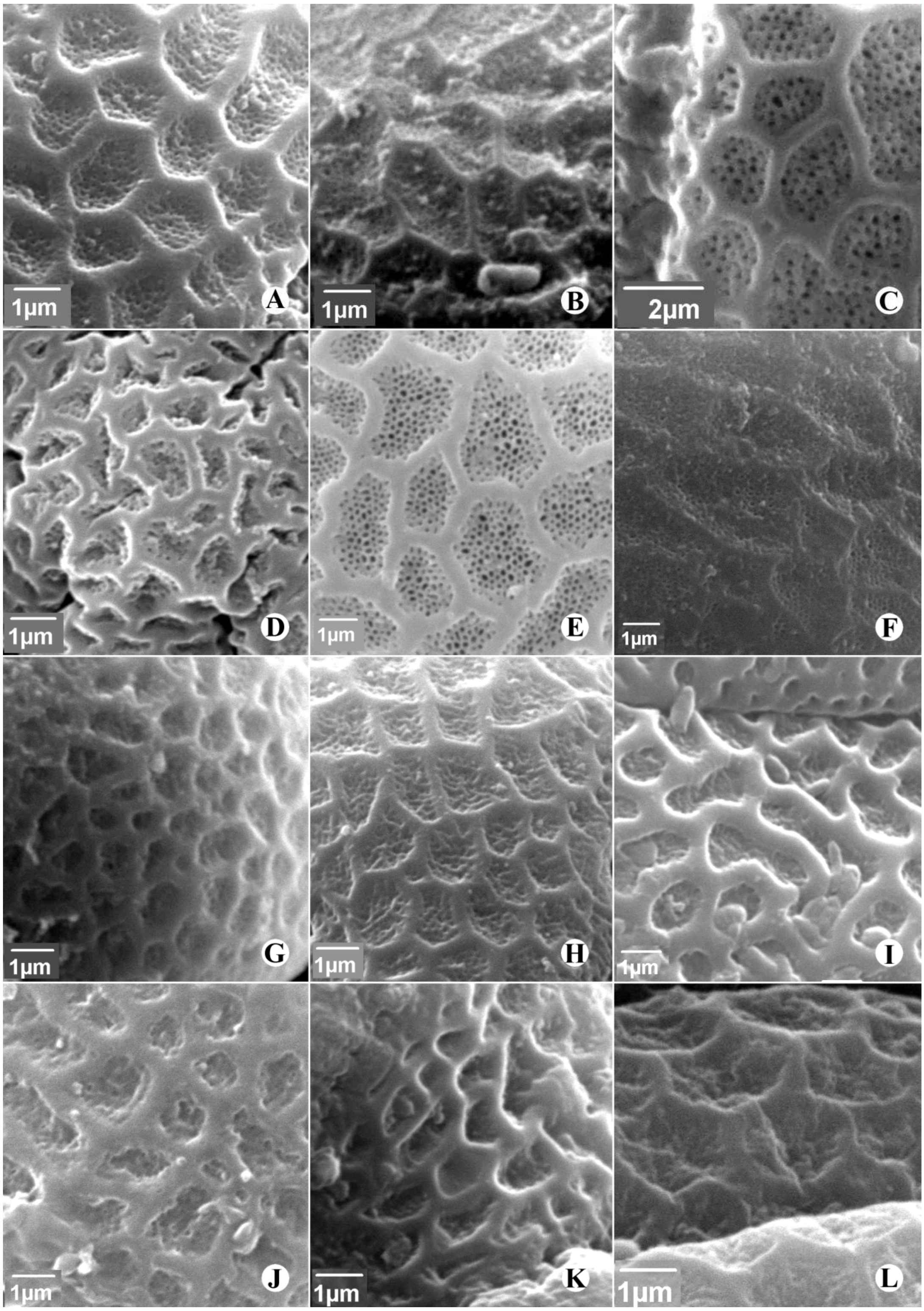


Fig. 4.2. SEM micrographs of surface sculpturing of pollen grains in *Plectranthus*. A. *P. anamudianus*; B. *P. barbatus*; C. *P. beddomei*; D. *P. bishopianus*; E. *P. bourneae*; F. *P. caninus*; G. *P. deccanicus*; H. *P. glabratus*; I. *P. malabaricus*; J. *P. mollis*; K. *P. subincisus*; L. *Plectranthus* sp.1.

Table 4.2. Details of pollen micromorphological characters in different species of *Plectranthus*

Sl.No.	Taxa	Size of pollen (Mean)			Shape	Type	Exine sculpture
		P(µm)	E(µm)	P/E(µm)			
1	*Plectranthus anamudianus* Smitha & Sunojk.	29.85	29.02	1.03	Spheroidal	Hexacolpate	Bireticulate, perforate
2	*Plectranthus barbatus* Andrews	25.72	30.38	0.85	Sub oblate	Hexacolpate	Bireticulate, perforate
3	*Plectranthus beddomei* Raizada	25.28	33.02	0.77	Sub oblate	Hexacolpate	Bireticulate, perforate
4	*Plectranthus bishopianus* Gamble	16.40	23.97	0.68	Oblate	Hexacolpate	Bireticulate, perforate
5	*Plectranthus bourneae* Gamble	31.20	30.20	1.03	Prolate spheroidal	Hexacolpate	Bireticulate, perforate
6	*Plectranthus caninus* Roth	36.93	30.41	1.21	Sub prolate	Hexacolpate	Bireticulate, perforate
7	*Plectranthus deccanicus* Briq.	24.73	26.82	0.92	spheroidal	Hexacolpate	Reticulate
8	*Plectranthus glabratus* (Benth.) Alston	26.20	28.22	0.91	Oblate spheroidal	Hexacolpate	Bireticulate, finely reticulate
9	*Plectranthus malabaricus* (Benth.) R.H.Willemse	36.21	28.24	1.28	Sub prolate	Hexacolpate	Reticulate
10	*Plectranthus mollis* (Aiton) Spreng.	25.97	31.89	0.81	Sub oblate	Hexacolpate	Reticulate
11	*Plectranthus subincisus* Benth.	21.83	22.99	0.95	Oblate spheroidal	Hexacolpate	Reticulate
12	*Plectranthus* sp.1	28.50	19.55	1.46	Prolate	Hexacolpate	Reticulate

Reticulate

In this type a network-like pattern consisting of lumina or other spaces wider than 1µm bordered by elements narrower than the lumina. Species which exhibit this pattern (Type I) are *P. deccanicus*, *P. malabaricus*, *P. mollis*, *P. subincisus* and *Plectranthus* sp.1.

Bireticulate–perforate

In bireticulate–perforate sculpturing pattern, a two-layered reticulum consisting of a primary reticulum supported by a secondary reticulate tectum which is perforate (Type II). It is the most common (6 species) pattern among the species examined and can be divided into two subtypes according to the thickness of the muri of the primary reticulum. The thickness of the muri of the primary reticulum is > 0.5 µm in *P. anamudianus, P. beddomei, P. bishopianus* and *P. bourneae* (Type IIa). The thickness of the muri of the primary reticulum is < 0.5 µm in *P. barbatus* and *P. caninus* (Type IIb).

Bireticulate–finely reticulate

In bireticulate– finely reticulate sculpturing pattern, a two-layered reticulum consisting of a primary reticulum supported by a secondary reticulate tectum which is finely reticulate (Type III). This pattern is found only in *P. glabratus* (Type III). A key to the species is also constructed based pollen micromorphology.

Key to the species of *Plectranthus* in India based on pollen micromorphology

1. Pollen with surface sculpturing reticulate type in which lumina wider than 1 µm……...2

- Pollen with surface sculpturing bireticulate type …………… ……..……6

2 Length of the polar axis always >30 µm …………....… ….. **P. malabaricus**

- Length of the polar axis always <30 µm……………..................... ……....3

3 Pollen with length of the colpus > 25 µm and the width < 1.5 µm … ....**Plectranthus. sp.1**

- Pollen with length of the colpus < 25 µm and the width > 1 µm …… ..….4

4 Pollen oblate spheroidal in shape……….. ……..…5

- Pollen sub oblate in shape …………… .... …**P. mollis**

5 Length of the polar and equatorial axis always >24 µm … …**P. deccanicus**

- Length of the polar and equatorial axis always <24 µm……..**P. subincisus**

6 Bireticulate sculpturing in which secondary reticulate tectum finely reticulate ……… …… ……………….................. ………..….**P. glabratus**

- Bireticulate sculpturing in which secondary reticulate tectum perforate…... 7

7 The thickness of the muri of the primary reticulum always < 0.5 µm ……………..…….. .8

- The thickness of the muri of the primary reticulum always > 0.5 µm ………………….. ..9

8 Pollen sub prolate in shape, length of the polar axis > 30 µm……………… .... …**P. caninus**

- Pollen sub oblate in shape, length of the polar axis < 30 µm……………... …... **P. barbatus**

9 Length of the polar axis always <20 µm………........…….**P. bishopianus**

- Length of the polar axis always >20 µm………………................... ……10

10 Pollen with length of the colpus < 20 µm and the width < 1.5 µm……. ……...**P. bourneae**

- Pollen with length of the colpus > 20 µm and the width >1.5 µm…………… 11

11 Pollen spheroidal in shape……........................... ..………**P. anamudianus**

- Pollen sub oblate in shape……… ....…..……**P. beddomei**

4.1.4. Discussion

Erdtman (1945) carried out a pollen survey of the family Lamiaceae and classified the family into two subfamilies based on number of apertures and nuclei in the mature pollen grains. The subfamily Lamioideae has tricolpate pollen, shed in a two-celled stage, while the subfamily Nepetoideae has hexacolpate (rarely 8–12 colpate) pollen shed in a three-celled stage. Wunderlich's (1967) extensive pollen survey strongly supported Erdtman's groupings. Cantino (1992b) revised the classification of certain genera in the Lamiaceae on the basis of palynological features. The present investigation shows that all the species studied possess hexacolpate pollen grains.

Pollen of *Plectranthus* is small to large (P = 16.40–36.93 μm, E = 19.55–33.02 μm). The smallest pollen grains occur in *P. bishopianus* whereas the largest ones occur in *P. caninus*. The shape of the pollen grain ranges from oblate, sub-oblate, oblate-spheroidal, prolate, sub-prolate, prolate-spheroidal to spheroidal (Table 2). Colpi of the species studied are long and their ends are acute. The longest colpus is found in *P. caninus* and the shortest in *P. bishopianus*. This result supported that the colpus length is strongly correlated with length of polar axis. Colpus membranes are granulate to scabrate.

Three basic types of surface sculpturing found in the studied taxa are reticulate (Type I), bireticulate–perforate (Type II, common type) and bireticulate–finely reticulate (Type III). Based on the detailed configuration of the exine ornamentation bireticulate–perforate patterns can be subdivided into two subtypes. In Type IIa the width of the muri of the primary reticulum > 0.5 μm and in Type IIb the width of the muri of the primary reticulum < 0.5 μm. Type I surface sculpturing is shown by *P. deccanicus*, *P. malabaricus*, *P. mollis*, *P. subincisus* and *Plectranthus* sp.1. In all these species the lumina is always wider than 1 μm. Type II sculpturing is the common type which was found in six species however Type III is found only in *P. glabratus*. This kind of classification of exine surface was also done by Harley *et al.* (1992). He studied the pollen morphology of 20 species from tribe Ocimeae and four pollen types were described, three were subdivided. Keys were also provided to the types and subtypes. Results showed some notable parallels with taxonomic opinion.

Only few works were undertaken which included the pollen analysis of *Plectranthus*. Abdel Khalik (2016) as part of the revionary work of Arabian *Plectranthus*, included pollen morphology as one of the distinguishing character among species and analysed the pollens of seven species of *Plectranthus*. He examined pollen grains of *P. barbatus* and found some differences in their size and in shape. Pollen size (P/E ratio) of *P. barbatus* given there as 1.29 µm and the shape was characterized as subprolate. In *P. barbatus* material we had collected, the pollen size (P/E ratio) was 0.77 µm, and the shape was sub oblate. These minor differences may result from differences in preparation treatments.

Doaigey *et al*. (2017) investigated the pollen morphology of 20 species of Lamiacean members and this study also include one species of *Plectranthus*, *P. asirensis* from Saudi Arabia. They discussed the surface pattern of exine which is similar to the pattern observed in the present analysis: fine reticulate, rough reticulate, mega-reticulate, reticulate-perforate, bireticulate-perforate or granulate, leading to 6 types of pollen grains. These variations revealed by this study imply that pollen morphology may be of significant value in solving problems in the classification of Lamiaceae members. They also provided a key to the species based on the morphological features of pollen grains.

Variation in pollen morphological characters, such as shape, exine sculpturing pattern, thickness of muri, nature of the secondary sculpturing, and characters of colpus are appears to have particular value for phylogenetic structuring. They render information for the delimitation of different species of *Plectranthus*. However, these characters do not correlate with stamen types, even if the character variation appears useful.

4.1.5. Conclusions

In this study on Indian species of *Plectranthus* shows that several pollen morphological characters can be of taxonomic value. Sexine ornamentation in this genus is variable (Types I–III) and could be of systematic significance. The variability of the various parameters analyzed at inter specific level makes it hard to establish taxonomic boundaries and clearly shows the affinity of species as far as pollen morphological characteristics are concerned. Moreover it is also confirmed that due to constancy of pollen characters among different populations of a particular species, the effects of minor differences in ecological conditions on overall morphology of the plants did not influence pollen morphology of that species. In fact, a comprehensive pollen morphological study of *Plectranthus* is still lacking and detailed observation of pollen surfaces of species from different geographical areas could be relèvent since the surface ornamentation of pollen has been used successfully in a range of systematic studies. As with any morphological study, the more complete the data, the more convincing the subsequent analyses regarding phylogeny and relationships (Celenk *et al.* 2008).

4.2. Mericarp micromorphology

4.2.1. Introduction

Mericarp morphology has been used as the most important character complex for a synthetic approach to the systematics of Lamiaceae that considers both phylogenetic and evolutionary aspects. Mericarp characters are potentially useful within the Lamiaceae at sectional, generic or species levels (Ryding 1993, 1994; Marin *et al.* 1994). Surface features of mericarps have been successfully applied not only in a range of systematic studies, but also in taxonomy or species identification and the Scanning Electron Microscopy (SEM) has improved character evaluation studies (Barthlott 1984; Husain *et al*. 1990; Marin *et al.* 1994). Taxonomically useful characters include surface sculpturing, type of exocarp cells, pericarp anatomy, and indumentum (Barthlott 1981, 1984; Stace 1989). Morphology, shape, colour and size of the mericarps were used as diagnostic characters in classification (Schermann 1967). Hence the mericarp morphology in Lamiaceae has proved useful to varying degrees at different levels in the taxonomic hierarchy (Budantsev and Lobova 1997).

Mericarp micromorphology in *Plectranthus* and its allies has not been examined extensively yet. Hence, the present study has been conducted in order to assess the potential utility of mericarp micromorphological characters in better understanding systematic relationships among the members of this genus and related genera and to provide reliable characters that are useful in infrageneric classification.The aims of the present observation on SEM morphology of mericarps of *Plectranthus* are to: (1) to describe the mericarp micromorphology of most species of the genus in India; (2) to evaluate the systematic implications of mericarp micormorphology, with special emphasis on Indian endemics and (3) to provide reliable characters useful in separation of species within *Plectranthus –Coleus* complex.

4.2.2. Materials and Methods

Mericarps of 19 taxa representing 14 species of the genus *Plectranthus* were analyzed. The mature mericarps used in this study were collected from field and voucher specimens were deposited at Calicut University Herbarium (CALI). A list of voucher specimens used in the present study including some notes on the location of the plants is given in Table 4.3. The mericarps were first observed using a light microscope to ensure that they were normal in size and development. For scanning electron microscopy (SEM), mericarp samples were directly mounted onto stubs with double-sided tape and then sputter-coated with gold. Micro-morphological observations were conducted using a Jeol JSM – 6390LV/ JED – 2300 and Gemini SEM 300 scanning electron microscopes with 15 kV voltage. We followed the terminologies used by Budantsev & Lobova (1997) and Moon et al. (2009) for mericarps. For recording the mericarp morphology and size parameters (length and width), at least 10 mericarps of each taxon were measured. Morphological observations and measurements were focused particularly on the general shape, size, color, and surface sculpturing patterns.

Table 4.3. Taxa, Voucher specimens and herbarium data of species of *Plectranthus* used in the mericarp micromorphology

Sl. No.	**Taxa**	**Locality**	**Collector**	**Herbarium number & abbreviation**
1	*Plectranthus anamudianus* Smitha & Sunojk.	India, Idukki, Rajamala	Smitha & Sunojkumar	135412 (CALI)
2	*Plectranthus barbatus* Andrews	India, Wayanad, Myladi	Smitha & Sunojkumar	135415 (CALI)
3	*Plectranthus beddomei* Raizada	India, Kottayam, Vagamon	Smitha & Sunojkumar	135422 (CALI)
4	*Plectranthus bishopianus* Gamble	India, Wayanad, Aranamala	Smitha & Sunojkumar	135465 (CALI)
5	*Plectranthus bourneae* Gamble	India, Kodaikanal, Poombarai	Smitha & Sunojkumar	135474 (CALI)
6	*Plectranthus caninus* Roth	India, Idukki, Marayur	Smitha & Sunojkumar	135409 (CALI)
7	*Plectranthus deccanicus* Briq.	India, Idukki, Munnar	Smitha & Sunojkumar	135467 (CALI)
8	*Plectranthus gamblei* Smitha & Sunojk.	India, Pallakad, Silent Valley	Smitha & Sunojkumar	135434 (CALI)
9	*Plectranthus glabratus* (Benth.) Alston	India, Tamil Nadu, Coonoor	Smitha & Sunojkumar	135462 (CALI)
10	*Plectranthus malabaricus* (Benth.) R.H.Willemse	India, Karnataka, Kodachadri	Smitha & Sunojkumar	135438 (CALI)
11	*Plectranthus mollis* (Aiton) Spreng.	India, Wayanad, Muthanga	Smitha & Sunojkumar	135414 (CALI)
12	*Plectranthus montanus* Benth.	India, Karnataka, Bababudangiri	Smitha & Sunojkumar	135464 (CALI)
13	*Plectranthus subincisus* Benth.	India, Alappuzha, Vandanam	Smitha & Sunojkumar	135430 (CALI)
14	*Plectranthus* sp.2	India	Smitha & Sunojkumar	135454 (CALI)

4.2.3. Results

The results obtained from macro- and micromorphological investigations are described below and illustrated. The main features of the investigated mericarps are summarized in Table 4.4. Selected LM images and SEM micrographs of mericarp studied are presented in (Fig. 4.3, 4.4, 4.5 & 4.6).

Mericarp size, shape and color

The size of the mericarp in *Plectranthus* varies from 0.68–2.39 mm in length. The smallest mericarp can be found in *P. montanus* (0.68 × 0.52 mm on average) where as *P. malabaricus* has the largest mericarps (2.39 × 1.95 mm on average). The shape can be elliptic (*P. anamudianus* and *P. gamblei*), widely elliptic (*P. beddomei, P. bishopianus, P. deccanicus, P. glabratus, P. malabaricus, P. mollis, P. montanus* and *Plectranthus* sp. 2) and orbicular (*P. barbatus, P. bourneae, P. caninus* and *P. subincisus*). The most common shape is widely elliptic. They show low variation in color from brown to shining black. In *P. mollis* and *P. subincisus* show black spots and pitted condition respectively. The pitted nature observed in *Plectranthus* is unique the genus.

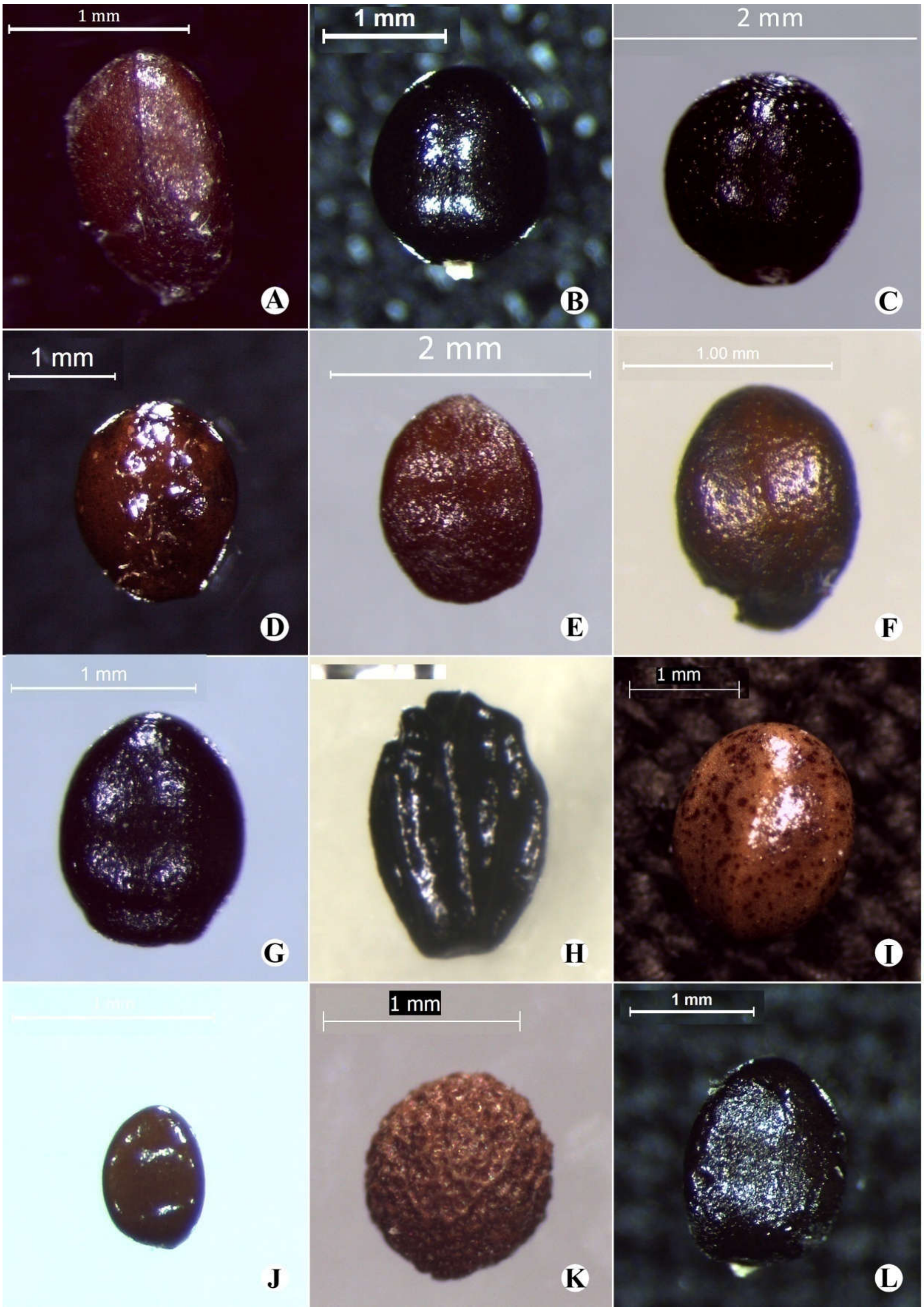


Fig. 4.3. LM micrographs of mericarps in *Plectranthus*. A. *P. anamudianus*; B. *P. barbatus*; C. *P. beddomei*; D. *P. bishopianus*; E. *P. caninus*; F. *P. deccanicus*; G. *P. glabratus*; H. *P. malabaricus*; I. *P. mollis*; J. *P. montanus*; K. *P. subincisus*; L. *Plectranthus* sp.2.

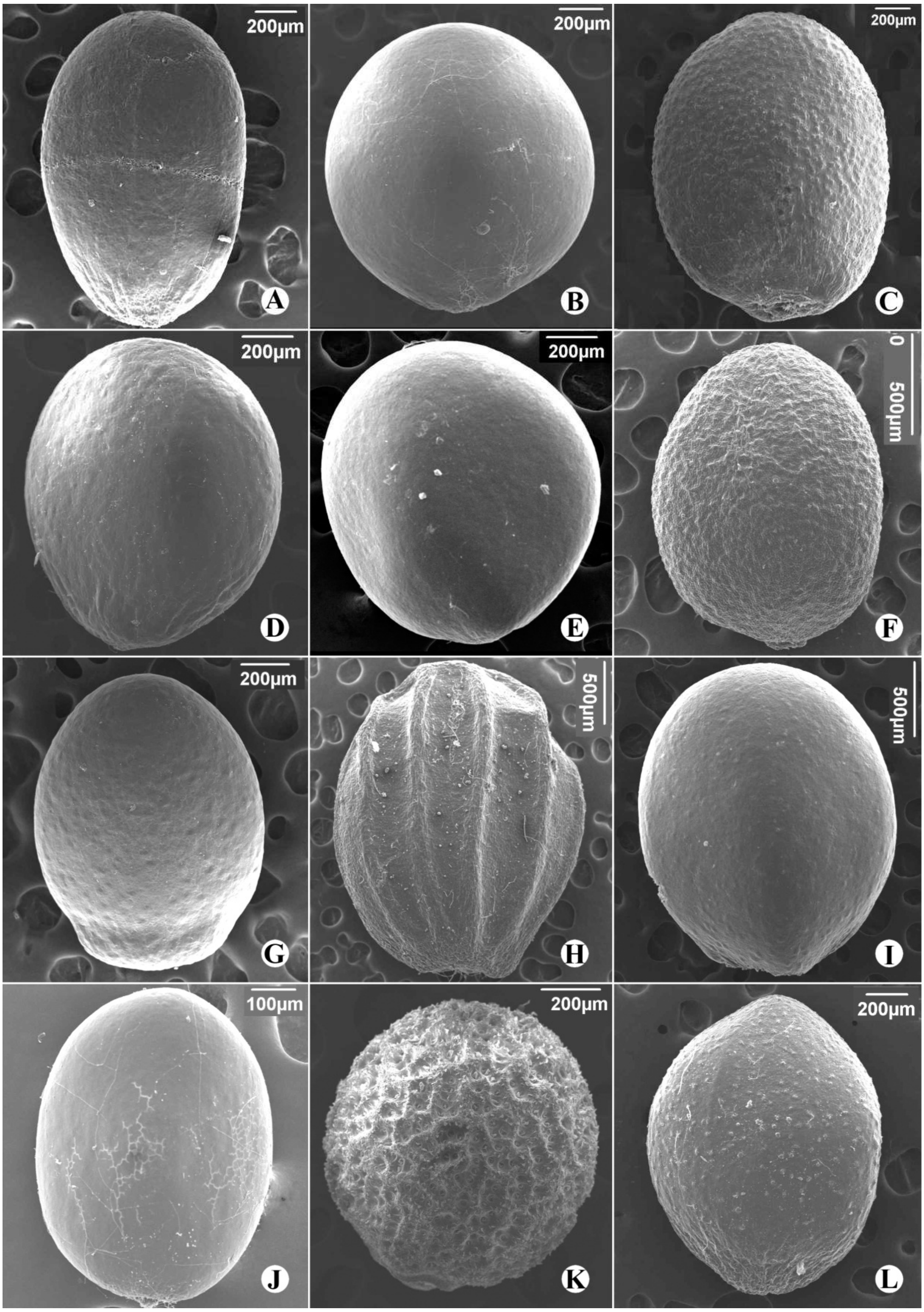


Fig. 4.4. SEM micrographs of mericarps in *Plectranthus.* A. *P. anamudianus*; B. *P. barbatus*; C. *P. beddomei*; D. *P. bishopianus*; E. *P. caninus*; F. *P. deccanicus*; G. *P. glabratus*; H. *P. malabaricus*; I. *P. mollis*; J. *P. montanus*; K. *P. subincisus*; L. *Plectranthus* sp.2.

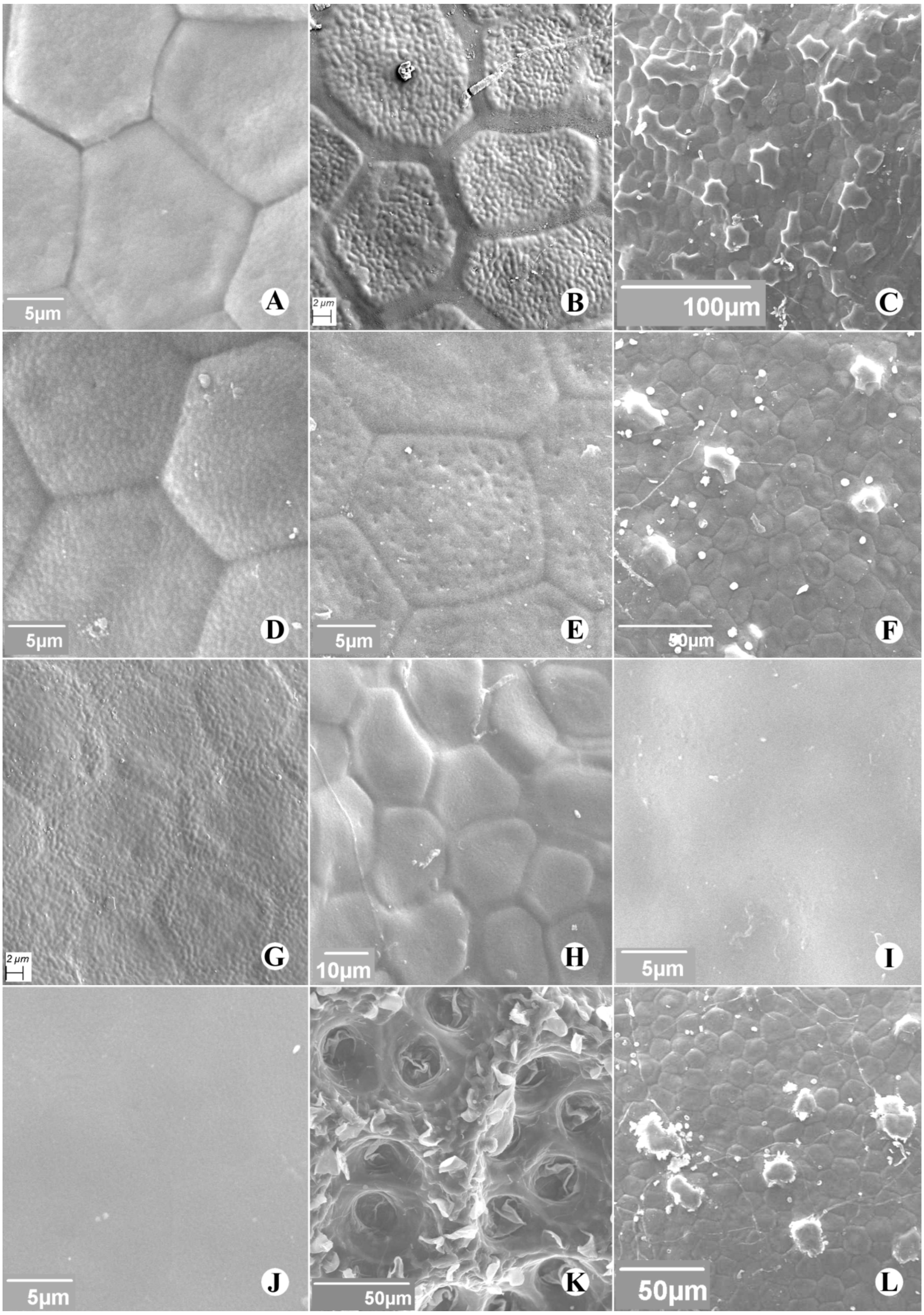


Fig. 4.5. SEM micrographs of surface sculpturing of mericarps in *Plectranthus.* A. *P. anamudianus*; B. *P. barbatus*; C. *P. beddomei*; D. *P. bishopianus*; E. *P. caninus*; F. *P. deccanicus*; G. *P. glabratus*; H. *P. malabaricus*; I. *P. mollis*; J. *P. montanus*; K. *P. subincisus*; L. *Plectranthus* sp.2.

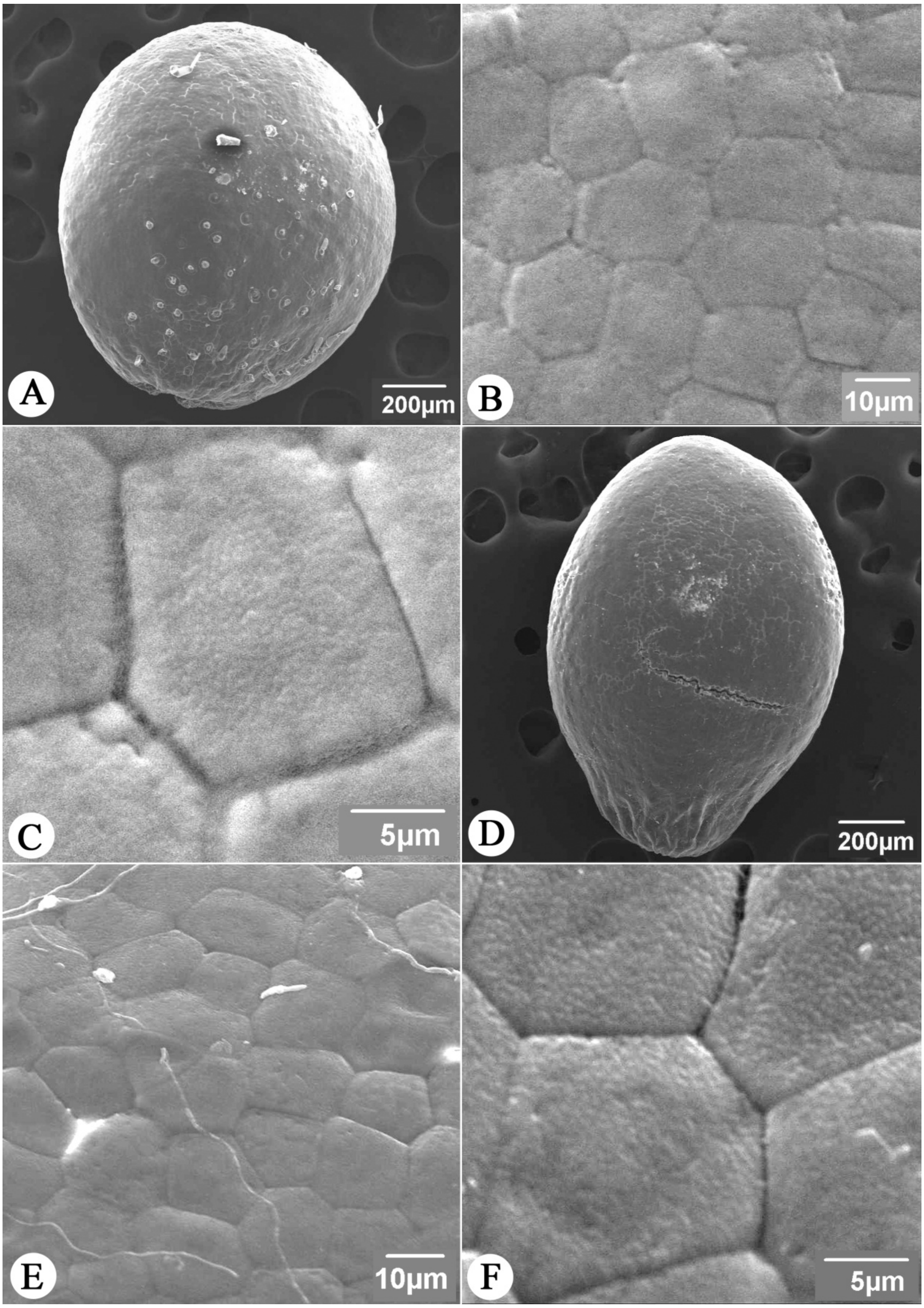


Fig. 4.6. SEM micrographs of mericarps. A, D. mericarps; B, E. Surface close up views at 1000x; C, F. surface close up views at 3000x. A–C. *Plectranthus bourneae,* D–F. *Plectranthus gamblei.*

Table 4.4. Details of mericarp micromorphological characters in different species of *Plectranthus*

Taxa	Mericarp size (mm)	Mericarp shape	color	Surface sculpturing	Epidermal cell shape	Anticlinal boundaries	Periclinal cell wall
Plectranthus anamudianus Smitha & Sunojk.	1.52 × 0.98	Elliptic	Brown	Reticulate	Isodiametric, 5-7 gonals	Chanelled, smooth	Flat to convex, smooth
Plectranthus barbatus Andrews	1.29 × 1.20	Orbicular	Black	Reticulate	Isodiametric, 5-6 gonals	Chanelled, smooth	Flat to Convex, granulate
Plectranthus beddomei Raizada	1.62 × 1.28	Widely elliptic	Black	Verrucate	Isodiametric, 5-6 gonals	Chanelled, smooth	Flat to convex, smooth
Plectranthus bishopianus Gamble	1.22 × 1.01	Widely elliptic	Black	Reticulate	Isodiametric, 5-6 gonals	Chanelled, smooth	Flat to convex, granulate
Plectranthus bourneae Gamble	1.19 × 1.07	Orbicular	Brown	Reticulate	Isodiametric, 5-6 gonals	Chanelled, smooth	Flat to convex, granulate
Plectranthus caninus Roth	1.18 × 1.07	Orbicular	Black	Reticulate	Isodiametric, 5-6 gonals	Chanelled, smooth	Flat, perforated
Plectranthus deccanicus Briq.	1.48 × 1.14	Widely elliptic	Brown	Verrucate	Isodiametric, 5-6 gonals	Chanelled, smooth	Flat to convex, granulate
Plectranthus gamblei Smitha & Sunojk.	1.27 × 0.90	Elliptic	Black	Reticulate	Isodiametric, 5-7 gonals	Chanelled, smooth	Flat to convex, granulate
Plectranthus glabratus (Benth.) Alston	1.29 × 0.94	Widely elliptic	Black	Reticulate	Isodiametric, 5-6 gonals	Straight, smooth	Flat, granulate
Plectranthus malabaricus (Benth.) R.H.Willemse	2.39 × 1.95	Widely elliptic	Black	Reticulate	Isodiametric, 5-6 gonals	Chanelled, smooth	Flat to convex, smooth

Plectranthus mollis (Aiton) Spreng.	2.06 × 1.87	Widely elliptic	Brown with black dots	Smooth	Smooth	Smooth	Smooth
Plectranthus montanus Benth.	0.68 × 0.52	Widely elliptic	Brown	Smooth	Smooth	Smooth	Smooth
Plectranthus subincisus Benth.	0.96 × 0.91	Orbicular	Brown with pitted surface	Foveate	Cells with false partitioning	Raised, folded	concave, perforated
Plectranthus sp.2	1.42 × 1.10	Widely elliptic	Black	Verrucate	Isodiametric, 5-7 gonals	Chanelled, smooth	Flat to convex, granulate

Surface sculpturing pattern

Regarding sculpturing pattern of mericarp surface (column 5 in Table 4.4) four basic types can be distinguished 1) reticulate (Type I, most common); 2) smooth (Type II); 3) foveate (Type III); 4) tuberculate (Type IV). Although a network of raised lines is a common feature of the reticulate type, the species vary in the alignment, shape and size of the polygonal cells and in the architecture of the interspaces enclosed by the raised walls. Based on the appearance of the periclinal surface of polygonal cells of the network, the reticulate type again subdivided in to three subtypes. Type Ia (Reticulate smooth), Type Ib (Reticulate granulate) and Type Ic (Reticulate perforated).

Type I: reticulate

In this type a network-like pattern consists of large rounded-polygonal cells with more prominent walls. Species which exhibit this pattern (Type I) are *P. anamudianus*, *P. barbatus*, *P. bishopianus*, *P. bourneae*, *P. caninus, P. gamblei, P. glabratus* and *P. malabaricus.* It is the most common (8 taxa) pattern among the species examined and can be divided into three subtypes according to the appearance of the periclinal surface of polygonal cells. The periclinal surface of polygonal cell is smooth in *P. anamudianus* and *P. malabaricus* (Type Ia); The surface is granulate in *P. barbatus*, *P. bishopianus*, *P. bourneae*, *P. gamblei* and *P. glabratus* (Type Ib) and the surface is perforated in *P. caninus* (Type Ic)

Type II: Smooth

In this kind of surface sculpturing, the mericarp surface having an even surface, without any irregularities. Species which exhibited this kind of pattern are *P. mollis* and *P. montanus* (Type II)

Type III: Foveate

In Foveate type the surface is pitted or having depressions formed by individual or multiple cells and raised interconnecting ridges which form a false partitions around each cells. This kind of sculpturing is found only in *P. subincisus* (Type III). This is the only species which exhibited such a unique nature of the mericarp.

Type IV: Verrucate

In this pattern, the surface of mericarp formed by polygonal cells with irregular projections or knobs. The species which shows this kind of sculpturing are *P. beddomei, P. deccanicus* and *Plectranthus* sp. 2 (Type IV)

Key to the species of *Plectranthus* in India based on mericarp micromorphology

1. Mericarp with epidermal cells are polygonal in shape………..………2
- Mericarp with epidermal surface smooth or cells form a false partitioning ……..………...12
2 Mericarp having polygonal cells with irregular projections ……......……3
- Mericarp do not have irregular projections on the polygonal cells.......………… ....…....5
3 Mericarp with periclinal cell wall smooth……….......….…**P. beddomei**
- Mericarp with periclinal cell wall granulate………………..……………4
4 mericarp brown in color………………………….........….…**P. deccanicus**
- mericarp shining black in color…………………..........…**Plectranthus sp. 2**
5 The periclinal surface of polygonal cell is perforated………..…**P. caninus**
- The periclinal surface of polygonal cell is not perforated ……………......…6
6 The periclinal surface of polygonal cell is smoth…………………......…**7**
- The periclinal surface of polygonal cell is granulate ……………………8

7 Mericarp elliptic in shape and suface is not ridged under light microscpe………………….......................……………..…**P. anamudianus**

- Mericarp widely elliptic in shape and suface is ridged under light microscpe …………………........……………………….**P. malabaricus**

8 Mericarp orbicular in shape …………………………………….........…9

- Mericarp not orbicular in shape ……………………………........…...…10

9 Mericarp black in color ……………….............………………**P. barbatus**

- Mericap brown in color ……………………….............……**P. bourneae**

10 Anticlinal cell wall boundaries straight…………….........…..**P. glabratus**

- Anticlinal cell wall boundaries channeled ………………….............…11

11 Mericarp elliptic in shape ………………..................………**P. gamblei**

- Mericarp widely elliptic in shape ……………….......…P. **bishopianus**

12 Mericarp with surface sculpturing smooth……….................……….13

- Mericarp with surface sculpturing foveate…….........……..**P. subincisus**

13 Mericarp with length always > 1mm, surface with black spots…………...…..**P. mollis**

- Mericarp with length always < 1mm, surface without black spots……..…...**P. montanus**

4.2.4. Discussion

Variation in mericarp characters appears to have taxonomic value in distinguishing different species of the genus *Plectranthus* in India. From this study it is revealed that the shape, size, surface sculpturing and colour of mericarps have particular value for phylogenetic structuring. They render information for the delimitation of different species of *Plectranthus*. Recent studies on mericarp morphology in Lamiaceae have shown that these characters are potentially of phylogenetic value (Guerin 2005).

Mericarps in *Plectranthus* is small to large (length = 0.68–2.39 mm, breadth = 0.52–1.95 mm). The smallest mericarp is present in *P. montanus* whereas the largest ones occur in *P. malabaricus*. The shape of the mericarps ranges from elliptic, widely elliptic to orbicular (Table 4). The color of the mericarp varies from brown to black, and most of the species have black colored mericarps. *Plectranthus molli*s has black spots on the surface of brown colored mericarps and *P. subincisus* posses pitted mericarps which is a unique character in the genus *Plectranthus*.

The four basic types of surface sculpturing found in the studied taxa are reticulate (Type I), smooth (Type II), foveate (Type III) and tuberculate (Type IV). Based on the appearance of the periclinal surface of polygonal cells of the network, the reticulate type again subdivided in to three subtypes. In Type Ia (Reticulate smooth) the surface is smooth, in Type Ib (Reticulate granulate) the surface is granulate and in Type Ic (Reticulate perforated) small perforations can be found on the periclinal cell surface. The Type I surface sculpturing is shown by *P. anamudianus*, *P. barbatus*, *P. bishopianus*, *P. bourneae*, *P. caninus, P. gamblei, P. glabratus* and *P. malabaricus*. The Type I sculpturing is the most common type which was found in eight species of this genus. Species which exhibited Type II surface pattern are *P. mollis* and *P. montanus.* Whereas *P. subincisus* is the only species which exhibited Type III surface sculpturing pattern and Type IV was shown by *P. beddomei, P. deccanicus* and *Plectranthus* sp. 2. This kind of classification of mericarp surface was also done by Salmaki *et al.* (2008).

Many of the variable mericarp characters particularly that of surface sculpturing, examined here have been shown to be of systematic value in other groups of Lamiaceae (Husain *et al.* 1990; Moon *et al*. 2009). However, Moon *et al.* (2009) found that mericarp morphology in Mentheae (Nepetoideae) has systematic significance and evaluated the existing molecular phylogenies of this group based this character. Although *Plectranthus* is one of the largest genera of Lamiaceae, its mericarp morphology has been poorly reported.

4.2.5. Conclusions

In conclusion it is found that mericarp micromorphology provides valuable data in separating the related species within the genus *Plectranthus*. It seems also that contrary to other genera of Lamiaceae, mericarp characters are of low phylogenetic value in this genus, especially due to high variation even among closely related species. In summary, we observed variation in the external morphology of mericarp characters like shape, size and surface sculpturing were much useful in distinguishing species and a key is also provided based on these characters. Variation in mericarp characters appears to have taxonomic value in distinguishing different species of the genus *Plectranthus* in India. We could clear that a wider sampling of *Plectranthus* species from all over the world would be advantageous and informative. This would provide data towards an understanding of the evolutionary and morphological radiation of the group but also towards building practical identification tools.

CHAPTER 5

MOLECULAR PHYLOGENY

CHAPTER 5
MOLECULAR PHYLOGENY

5.1. Introduction

Plectranthus is well-known for its horticultural and traditional medicinal uses (Lukhoba *et al*. 2006; Rice *et al*. 2011). To date, more than 300 species have been recognized, most of which are restricted to the Old World. The genus is distributed widely in tropical to southern areas of Africa (>200 spp.) and Madagascar (>20 spp.) and also occurs in tropical Asia (>40 spp.) and Australia (>40 spp.) (Harley *et al*. 2004). In tropical Asia, India (22 spp.) has the highest species diversity with regard to this genus (Smitha & Sunojkumar in press). Due to high level of morphological variation, delimitation and infrageneric classifications of the genus have been obscure and controversial. Due to these reasons different species were placed under various generic names (*Coleus* Lour., *Solenostemon* Thonn., *Germanea* Lam. etc) (Lukhoba *et al.* 2006). As a result of morphological studies, all these names have been reduced to synonymy under *Plectranthus* (e.g. Harley *et al.* 2004; Rice *et al.* 2011). Recent study on the molecular phylogeny of the tribe Ocimeae (Paton *et al.* 2004) revealed that the current circumscription of the genus *Plectranthus* is paraphyletic. They recognized two clades: *Coleu*s and *Plectranthus* within subtribe Plectranthinae and opined that previously used morphological characters cannot diagnose clades within the sub-tribe. They emphasised the need of further sampling to support monophyly within the group.

Earlier works on Indian *Plectranthus* treated species distinctly under two generic names *Coleus* and *Plectranthus* and the genus *Isodon* (Schrad. ex Benth.) Spach was also treated congeneric with *Plectranthus* (Bentham 1831, 1832 & 1848; Hooker 1885; Gamble 1921; Mukerjee 1940; Cramer 1978, 1981). The genus *Coleus* was considered as a valid taxa on the basis of nature of the fusion of stamens. However some workers (Brown 1810; Blume 1826; Morton 1962; Launert 1968; Codd 1971) questioned the constancy of the staminal sheath as a safe distinguishing character of *Coleus* and recognized only the genus *Plectranthus*. Recent studies by Harley *et al*. (2004), Rice *et al*. (2011) and Suddee and Paton (2004) treated *Coleus* as congeneric with *Plectranthus*.

Isodon has long been treated as closely related to *Plectranthus* (Bentham 1831, 1832 & 1848; Hooker 1885; Gamble 1921; Mukerjee 1940; Keng 1978; Cramer 1981; Li 1988), but this consideration was changed as new evidence has become available. Wagstaff *et al*. (1995) revealed that *Isodon* is more closely related to *Hyptis.* Later it was found that the genus *Isodon* was allied to three other Asiatic genera *Hanceola*, *Siphocranion,* and *Skapanthus* based on pericarp structure and presence of bracteole in the inflorescence (Ryding 1992a; Paton and Ryding 1998; Harley *et al.* 2003 & 2004; Paton *et al*. 2004). Zhong *et al*. (2010) presented a phylogenetic analysis and revealed that *Isodon* is monophyletic and a new subtribe Isodoninae was proposed within the tribe Ocimeae. Yu *et al*. (2014) also supported monophyly of *Isodon* with two disjunct African species. They pointed out that "there could be native African habitat competitors such as *Plectranthus*, which occupies a similar range of habitats in Africa to *Isodon* in Asia and there are no species of *Plectranthus* in the QTP region where *Isodon* is most diverse, and only two *Isodon* species occur in tropical Africa where there are >180 *Plectranthus* species".

In this account, the generic delimitation of Harley *et al.* (2004) is followed with a broad circumscription of *Plectanthus* which include *Coleus*. This is consistent with recent papers treating Indian species of *Plectranthus* complex (Matthew 1993, Smitha & Sunojkumar 2015, 2016; Mathew *et al*.

2017). Following this circumscription, *Plectranthus* can be recognized from related genera of Lamiaceae in having declinate stamens held in the boat-shaped lower lip of the corolla and these being contiguous or shortly fused at the point of attachment at the base of the lower lip. According to Paton *et al.* (2004), the genus *Plectranthus* is paraphyletic within the subtribe Plectranthinae along with other genera like *Aeollanthus*, *Alvesia*, *Anisochilus*, *Capitanopsis, Dauphinea, Pycnostachys, Tetradenia* and *Thorncroftia*. They realized that these genera nested within two clades and named as *Plectranthus* and *Coleus*. So that there is a question arises after this study on the reappraisal of the name *Coleus*. But it is not easy to separate species from *Plectranthus* to *Coleus* because the clades also included other genera from subtribe Plectranthinae.

This work focus on the systematic problem within *Plectranthus* and the inter generic and inter specific relationship of the genus using molecular approaches with samples from India. The main research problem addressed in this study is to confirm whether the genera *Plectranthus* and *Coleus* are congeneric or not and to check the position of Indian endemics whether it belongs to *Coleus* or *Plectranthus* clade. The main aims of this study are 1) to check the staminal fusion a synapomorphic character separate *Coleus* from *Plectranthus* 2) further confirmation of paraphyly of the genus *Plectranthus* 3) to understand the phylogenetic position of Indian *Plectranthus* with in the subtribe Plectranthinae 4) to recognise monophyletic groups within Plectranthinae 5) finally an attempt to molecular dating of *Plectranthus* based on already reported fossil evidence of Lamiaceae.

5.2. Materials and Methods

5.2.1. Taxon sampling and choice of markers

The ingroup included 143 taxa of which 30 (Table 5.1) (26 species of *Plectranthus* + 4 of *Isodon*) were newly sequenced in this study. Sequences of 21 species of *Plectranthus* were downloaded from Genbank. To evaluate the relationships of *Plectranthus* and its allies, the analysis also included a representative samples of different species from subfamily Nepetoideae (92 species) and these sequences were also downloaded from Genbank (Table 5.2). Outgroups were selected from outside the subfamily Nepetoideae. The sequences of *Gmelina hystrix, Prostanthera nivea, Prostanthera petrophila, Vitex trifolia, Callicarpa giraldii* were downloaded from Genbank as outgroups.

Table 5.1. List of plant samples with voucher information (newly created sequences)

Sl.No	Taxa	*trnL* Genbank Accession	*trnL-F* Genbank Accession	*rps16* Genbank Accession	Voucher
1	*Plectranthus anamudianus* Smitha & Sunojk.	Not submitted	Not submitted	Not submitted	*Smitha & Sunojkumar 135412* (CALI)
2	*Plectranthus barbatus* Andrews (Munnar)	,,	,,	,,	*Smitha & Sunojkumar 135408* (CALI!)
3	*Plectranthus barbatus* Andrews (Kalpetta)	,,	,,	,,	*Smitha & Sunojkumar 135415* (CALI)
4	*Plectranthus beddomei* Raizada	,,	,,	,,	*Smitha & Sunojkumar 135422*
5	*Plectranthus bishopianus* Gamble	,,	,,	,,	*Smitha & Sunojkumar 135465* (CALI!)
6	*Plectranthus bourneae* Gamble	,,	,,	,,	*Smitha & Sunojkumar 135474* (CALI!)
7	*Plectranthus caninus* Roth	,,	,,	,,	*Smitha & Sunojkumar 135409* (CALI!)
8	*Plectranthus deccanicus* Briq.	,,	,,	,,	*Smitha & Sunojkumar 135467* (CALI!)
9	*Plectranthus gamblei* Smitha & Sunojk.	,,	,,	,,	*Smitha & Sunojkumar 135434* (CALI!)
10	*Plectranthus glabratus* (Benth.) Alston (Coonoor)	,,	,,	,,	*Smitha & Sunojkumar 135462* (CALI!)
11	*Plectranthus glabratus* (Benth.) Alston (Silent Valley)	,,	,,	,,	*Smitha & Sunojkumar 135433* (CALI!)
12	*Plectranthus malabaricus*	,,	,,	,,	*Smitha & Sunojkumar 135441*

	(Benth.) R.H.Willemse (Sholayar)				(CALI!)
13	*Plectranthus malabaricus* (Benth.) R.H.Willemse (Tusharagiri)	,,	,,	,,	*Smitha & Sunojkumar 135410* (CALI!)
14	*Plectranthus malabaricus* (Benth.) R.H.Willemse (Kodachadri)	,,	,,	,,	*Smitha & Sunojkumar 135413* (CALI!)
15	*Plectranthus malabaricus* (Benth.) R.H.Willemse (Vagamon 1)	,,	,,	,,	*Smitha & Sunojkumar 135419* (CALI!)
16	*Plectranthus malabaricus* (Benth.) R.H.Willemse (Vagamon 2)	,,	,,	,,	*Smitha & Sunojkumar 135420* (CALI!)
17	*Plectranthus malabaricus* (Benth.) R.H.Willemse (Thollayiram)	,,	,,	,,	*Smitha & Sunojkumar 135402* (CALI!)
18	*Plectranthus malabaricus* (Benth.) R.H.Willemse (Parambiculum)	,,	,,	,,	*Smitha & Sunojkumar 135418* (CALI!)
19	*Plectranthus malabaricus* (Benth.) R.H.Willemse (kurichermala)	,,	,,	,,	*Smitha & Sunojkumar 135403* (CALI!)
20	*Plectranthus mollis* (Aiton) Spreng.	,,	,,	,,	*Smitha & Sunojkumar 135404* (CALI!)
21	*Plectranthus montanus* Benth.	,,	,,	,,	*Smitha & Sunojkumar135464* (CALI!)
22	*Plectranthus subincisus* Benth.	,,	,,	,,	*Smitha & Sunojkumar135430* (CALI)

23	*Plectranthus* sp. 1	,,	,,	,,	*Smitha & Sunojkumar 135468* (CALI!)
24	*Plectranthus sahyadricus*	,,	,,	,,	*Smitha & Sunojkumar135456* (CALI)
25	*Plectranthus* sp. 2	,,	,,	,,	*Smitha & Sunojkumar135454* (CALI)
26	*Plectranthus vettiveroides* (Jacob) N.P.Singh & B.D.Sharma	,,	,,	,,	*Smitha & Sunojkumar 135472* (CALI!)
27	*Isodon walkeri* (Arn) H.Hara (Sholayar)	,,	,,	,,	*Smitha & Sunojkumar 135447* (CALI!)
28	*Isodon nilgherricus* (Benth.) H.Hara (Munnar)	,,	,,	,,	*Smitha & Sunojkumar 135452* (CALI!)
29	*Isodon* sp. (Vagamon)	,,	,,	,,	*Smitha & Sunojkumar 135427* (CALI!)
30	*Isodon nigrescens* (Benth.) H.Hara	,,	,,	,,	*Smitha & Sunojkumar 135424* (CALI!)

Table 5.2. List of species with sequences downloaded from NCBI

Sl. No.	Taxa	trnL-trnF Genbank Accession	rps16 Genbank Accession	Voucher
1	*Plectranthus barbatus* Andr.	AJ505500	AJ505378	Cult., K1982-5914, Thulin 4380 (K)
2	*Plectranthus xanthanthus* (C.Y.Wu & Y.C.Huang) ined..	FJ593411	FJ593291	Zhong, J.S *et al.*
3	*Plectranthus albicalyx* S.Suddee	AJ505498	AJ505376	Suddee *et al.*868 (BKF, K, TCD)
4	*Plectranthus amboinicus* (Lour.) Spreng.	AJ505499	AJ505377	Suddee *et al* 869 (BKF)
5	*Plectranthus buchananii* Bak.	AJ505501	AJ505379	Cult., K-1970-3559, Brummitt 11597 (K)
6	*Plectranthus calycinus* Benth.	AJ505502	AJ505380	Balkwill *et al.*10880 (J, K)
7	*Plectranthus ciliates* E.Mey	AJ505532	AJ505409	Cult., K-1991-6, Chase 13336 (K)
8	*Plectranthus coeruleus* (Gurke) Agnew	AJ505503	AJ505381	Cult., K-1955-42604, Delap s.n. (K)
9	*Plectranthus crassus* N.E.Br.	AJ505504	AJ505382	Cult., K-1970-2059, Brummitt 9700 (K)
10	*Plectranthus cylindraceus* Benth.	AJ505538	AJ505383	Cult., K-1996-1453, Chase 8518 (K)
11	*Plectranthus fredricii* (G.Taylor) A.J.Paton	AJ505505	AJ505384	Cult., K-1999-15, RHS Wisley (K)
12	*Plectranthus fulvescens* (G.Taylor) A.J.Paton	AJ505552	AJ505429	Chase 9768 (K)
13	*Plectranthus glabratus* (Benth.) Alston	AJ505508	AJ505387	Wongprasert, Suddee & Puudjaa s.n (BKF, K, TCD)
14	*Plectranthus helferi* Hook. f.	AJ505509	AJ505388	Suddee & Puudjaa 1098 (BKF, K,

				TCD)
15	*Plectranthus laxiflorus* Benth.	AJ505510	AJ505389	Edwards s.n (K)
16	*Plectranthus parishii* Prain	AJ505511	AJ505390	Suddee 11444 (BKF, K, TCD)
17	*Plectranthus petiolaris* Benth.	AJ505512	AJ505391	Cult., K-1996-2729, U of Natal (K)
18	*Plectranthus sanguineus* Britten	AJ505513	AJ505392	Cult., K-1970-2072, Brummitt s.n (K)
19	*Plectranthus scutellarioides* (L.) R.Br.	AJ505514	AJ505393	Cult., Suddee *et al.*1094 (BKF, K, TCD)
20	*Plectranthus thyrsoideus* (Bak.) B.Matthew	AJ505533	AJ505405	Cult., K-5638704012, Chase 13332 (K)
21	*Plectranthus xerophilus* Codd	AJ505515	AJ505394	Cult., k-1989-1322, Hardy 6735 (K)
22	*Pycnostachys reticulate* (E.Mey.) Benth.	AJ505516	AJ505395	Cult., K-1999-2425, Nat Bot. Gar. S. Africa (K)
23	*Pycnostachys umbrosa* (Vatke) Perkin	AJ505517	AJ505396	Cult., k-1970-3755, Mathew 6067 (K)
24	*Pycnostachys urticifolia* Hook.	AJ505518	AJ505397	Cult., K-1999-2426, Nat. bot. gar. s.Africa (K)
25	*Tetradenia fruticosa* Benth.	AJ505519	AJ505398	Cult., K-1989-1324, Hardy 2910A (K)
26	*Tetradenia nervosa* Codd	AJ505520	AJ505399	Cult., K-1993-3116, Hardy 2910B (K)
27	*Thorncroftia longiflora* N.E.Br.	AJ505521	AJ505401	McDade LM 1281 (J)
28	*Thorncroftia media* Codd	AJ505522	AJ505400	Cult., K-1993-3115, Hardy 3966 (K)
29	*Aeollanthus buchnerianus* Briq.	AJ505434	AJ505327	Cult., K-1970-2734, Brummitt 10401, (K)
30	*Aeollanthus densiflorus* Ryding	AJ505435	AJ505328	Cult., K-1970-3760, Mathew 6137 (K)
31	*Alvesia rosmarinifolia* Welw.	AJ505436	AJ505329	Harder, Luwilka & Zimba 3634 (K)
32	*Anisochilus harmandii* Doan	AJ505437	AJ505330	Suddee 775 (BKF, K, TCD)
33	*Anisochilus pallidus* Benth.	AJ505438	AJ505331	Suddee *et al.*1080 (BKF, K, TCD)
34	*Capitanopsis angustifolia* (Moldenke)	AJ505440	AJ505333	Clement, Phillipson & Mantanantsoa

	Capuron			2117 (K)
35	*Dauphinea brevilabra* Hedge	AJ505441	AJ505334	Cult., K-1998-2417, Hardy & Rauh 2876 (K)
36	*Isodon adenanthus* (Diels) Kudo	FJ593417	FJ593297	Zhong & Li 0039 (HITBC)
37	*Isodon amethystoides* (Benth.) H. Hara	FJ593418	FJ593298	Zhong & Li 2007023 (HITBC)
38	*Isodon bulleyanus* (Diels) Kudo	FJ593419	FJ593299	Zhong & Li 0035 (HITBC)
39	*Isodon calcicola* (Hand.-Mazz.) H. Hara	FJ593420	FJ593300	Zhong & Li 0164 (HITBC)
40	*Isodon coetsa* (Buch.-Ham. ex D. Don) Kudo	FJ593421	FJ593301	Lin s. n. (KUN)
41	*Isodon eriocalyx* (Dunn) Kudo	FJ593422	FJ593302	Zhong ZJS 03 (HITBC)
42	*Isodon flabelliformis* (C. Y. Wu) H. Hara	FJ593423	FJ593303	Zhong & Li 0016 (HITBC)
43	*Isodon flavidus* (Hand.-Mazz.) H. Hara	FJ593424	FJ593304	Lin 081 (KUN)
44	*Isodon flexicaulis* (C. Y. Wu & H. W. Li) H. Hara	FJ593425	FJ593305	Lin 032 (KUN)
45	*Isodon forrestii* (Diels) Kudo	FJ593426	FJ593306	Zhong & Li 0114 (HITBC)
46	*Isodon gesneroides* (J. Sinclair) H. Hara	FJ593427	FJ593307	Lin 035 (KUN)
47	*Isodon glutinosus* (C. Y. Wu & H. W. Li) H. Hara	FJ593428	FJ593308	Zhong & Li 0178 (HITBC)
48	Isodon grandifolius (Hand.-Maz.) H. Hara var. *atuntzeensis* (C. Y. Wu) H. W. Li	FJ593429	FJ593309	Zhong & Li 0194 (HITBC)
49	*Isodon hispidus* (Benth.) Murata	FJ593430	FJ593310	Zhong & Li 0057 (HITBC)
50	*Isodon japonicas* (Burm. f.) H. Hara	FJ593432	FJ593312	Zhang 103 (KUN)
51	*Isodon leucophyllus* (Dunn) Kudo	FJ593434	FJ593314	Zhong & Li 0183 (HITBC)
52	*Isodon lophanthoides* (Buch.-Ham. ex D. Don) H. Hara	FJ593435	FJ593315	Zhong & Li 0061 (HITBC)
53	*Isodon loxothyrsus* (Hand.-Mazz.) H.	FJ593438	FJ593318	Zhong & Li 0186 (HITBC)

	Hara			
54	*Isodon megathyrsus* (Diels) H. W. Li	FJ593439	FJ593319	Lin-Fugong 2 (KUN)
55	*Isodon melissoides* (Benth.) H. Hara	FJ593441	FJ593321	Lin 083 (KUN)
56	*Isodon nervosus* (Hemsl.) Kudo	FJ593442	FJ593322	Zhong 2007065 (HITBC)
57	*Isodon phyllopodus* (Diels) Kudo	FJ593443	FJ593323	Lin 054 (KUN)
58	*Isodon phyllostachys* (Diels) Kudo	FJ593444	FJ593324	Zhong & Li 0133 (HITBC)
59	*Isodon pleiophyllus* (Diels) Kudo	FJ593445	FJ593325	Lin-Lushui 3 (KUN)
60	*Isodon rosthornii* (Diels) Kudo	FJ593446	FJ593326	Zhong 2007051 (HITBC)
61	*Isodon rugosiformis* (Hand.-Mazz.) H. Hara	FJ593447	FJ593327	Zhong 2006008 (HITBC)
62	*Isodon scoparius* (C. Y. Wu & H. W. Li) H. Hara	FJ593448	FJ593328	Lin 050 (KUN)
63	*Isodon sculponeatus* (Vaniot) Kudo	FJ593449	FJ593329	Zhong-West Hill 001 (HITBC)
64	*Isodon taliensis* (C. Y. Wu) Hara	FJ593450	FJ593330	Zhong & Li 0078 (HITBC)
65	*Isodon ternifolius* (D. Don) Kudo	FJ593451	FJ593331	Zhong 0009 (HITBC)
66	*Isodon wikstroemioides* (Hand.-Mazz.) H. Hara	FJ593452	FJ593332	Zhong & Li 0201 (HITBC)
67	*Isodon xerophilus* (C. Y. Wu & H. W. Li) H. Hara	FJ593453	FJ593333	Lin 015 (KUN)
68	*Isodon yuennanensis* (Hand.-Mazz.) H. Hara	FJ593454	FJ593334	Zhong & Li 0172 (HITBC)
69	*Skapanthus oreophilus* (Diels) C. Y. Wu	FJ593466	FJ593346	Zhong & Li 0107 (KUN)

	& H. W. Li			
70	*Hanceola exserta* Y. Z. Sun	FJ593413	FJ593293	Zhong & Li 2007022 (HITBC)
71	*Hanceola sinensis* (Hemsl.) Kudo	FJ593415	FJ593295	Zhong 2007054 (HITBC)
72	*Hyptis capitata* Jacq.	AJ505449	AJ505337	Wongprasert et al. (BKF, K)
73	*Hyptis eriocephala* Benth.	AJ505450	AJ505338	Cult. & Hart 1713 (K)
74	*Hyptis floribunda* Briq.	AJ505451	AJ505339	Cult. & Pedersen s.n. (K)
75	*Hyptis leptostachys* Epling.	AJ505452	AJ505340	Cult. & Harley 19957 (K)
76	*Hyptis suaveolens* (L.) Poit.	AJ505453	AJ505341	Suddee et al. 922 (BKF, K, TCD)
77	*Lavandula buchii* Webb & Berthel.	AJ505460	AJ505346	Upson 299 (RNG)
78	*Lavandula maroccana* Murb.	AJ505461	AJ505347	Upson, s.n. (RNG)
79	*Lavandula minutolii* C. Bolle	AJ505462	AJ505348	Upson s.n (RNG)
80	*Lavandula rotundifolia* Benth.	AJ505463	AJ505349	Upson s.n (RNG)
81	*Siphocranion macranthum* (Hook. f.) C. Y. Wu	FJ593464	FJ593344	Zhong 2007061 (HITBC)
82	*Siphocranion nudipes* (Hemsl.) Kudo	FJ593465	FJ593345	KUN 0821428 (KUN)
83	*Basilicum polystachyon* (L.) Moench	AJ505439	AJ505332	Greenway & Kanuri 14501 (K)
84	*Ocimum americanum* L. var. *pilosum* (Willd.) A.J.Paton	AJ505464	AJ505350	Cult., Suddee 1145 (K)
85	*Ocimum basilicum* L.	AJ505465	AJ505351	Cult., Suddee *et al.* 894 (BKF,K)
86	*Ocimum filamentosum* Forssk.	AJ505466	AJ505352	Brummitt 18993 (K)
87	*Ocimum gratissimum* L. var. *gratissimum*	AJ505467	AJ505353	Cult., Suddee & Meade 1139 (BKF)
88	*Ocimum tenuiflorum* L.	AJ505473	AJ505358	Cult., Suddee et al.893 (BKF, K, TCD)
89	*Orthosiphon parishii* Prain	AJ505475	AJ505359	Suddee & Puudjaa 1118 (BKF, K, TCD)

90	*Orthosiphon rubicundus* (D.Don) Benth	AJ505477	AJ505360	Suddee 809 (BKF, TCD)
91	*Orthosiphon aristatus* (Blume) Miq.	FJ593460	FJ593340	Zhong 0008 (HITBC)
92	*Orthosiphon wulfenioides* (Diels) Hand.-Mazz.	FJ593461	FJ593341	Zhong 2006009 (HITBC)
93	*Platostoma annamense* (G.Tayl.)A.J.Paton	AJ505479	AJ505361	Suddee et al.1028 (BKF)
94	*Platostoma cochinchinense* (Lour.) A.J.Paton	AJ505483	AJ505364	Wongprasert, Suddee & Puudjaa s.n (BKF, K, TCD)
95	*Platostoma coloratum* (D.Don) A.J.Paton var. *minutum* S.Suddee	AJ505486	AJ505367	Suddee *et al*.915 (BKF, K, TCD
96	*Platostoma fimbriatum* A.J.Paton	AJ505487	AJ505368	Suddee 823 (BKF, K, TCD)
97	*Platostoma intermedium* A.J.Paton	AJ505490	AJ505369	Suddee *et al*.947 (BKF, K, TCD)
98	*Platostoma rubrum* (Doan) A.J.Paton	AJ505495	AJ505373	Suddee *et al*.998 (BKF, K, TCD)
99	*Puntia stenocaulis* Hedge	AJ505545	AJ505424	M T Thulin 10506 (UPS)
100	*Syncolostemon rotundifolius* Benth.	AJ505523	AJ505402	Balkwill & Manning 414 (K)
101	*Elsholtzia stauntonii* Benth.	AJ505526	AJ505406	Wagstaff 356, (BHO) (Wagstaff et al. 1995)
102	*Elsholtzia ciliate* (Thunb.) Hyland	FJ593412	FJ593292	Zhong 0010 (HITBC)
103	*Nepeta fissa* C.A.Mey.	AJ505430	AJ505323	Jamzad & Nikchehreh 80486 (TARI)
104	*Nepeta menthoides* Boiss. & Buhse	AJ505431	AJ505324	Jamzad s.n. (K)
105	*Nepeta racemosa* Lam.	AJ505432	AJ505325	Jamzad s.n. (TARI)
106	*Nepeta straussii* Hausskn. & Bornm.	AJ505433	AJ505326	Jamzad *et al.* 76846 (TARI)
107	*Mentha suaveolens* Ledeb.	AJ505541	AJ505418	Cult., K-1970-3169 (K)
108	*Origanum vulgare* L.	AJ505543	AJ505422	Cult., K-000-69-19317, Chase 13334 (K)
109	*Clinopodium vulgare* L. subsp.	AJ505547	AJ505426	Cult., K-453-79-04649 (K)

	Arundanum (Boiss.)			
110	*Salvia guaranitica* Benth.	AJ505549	AJ505421	Cult., K-1973-14217 (K)
111	Salvia evansiana Hand.-Mazz.			
112	*Rosmarinus officinalis* L.	AJ505546	AJ505425	Cult., K-1975-1177, Chase 13331 (K)
113	*Melissa officinalis* L.	AJ505529	AJ505410	Wagstaff 88-09 (BHO) (Wagstaff et al., 1995)
114	*Gmelina hystrix* Kurz	AJ505527	AJ505407	Cult., K-381-74-02999 (K)
115	*Prostanthera nivea* Benth.	AJ505524	AJ505403	M.W. Chase 6980 (K)
116	*Prostanthera petrophila* B.J.Conn	AJ505525	AJ505404	M.W.Chase 6975 (K)
117	*Vitex trifolia* L.	AJ505539	AJ505416	TCMK 15, Chase 8757 (K)
118	*Callicarpa giraldii* Hesse ex Rehder	FJ593410	FJ593290	Zhong 0012 (HITBC)

Chloroplast DNA markers—The *trnL–trnF* region (*trnL* intron and *trnL–trnF* intergene spacer) and *rps16* intron—were used in this study as: (1) they have been used widely in phylogenetic reconstructions of Lamiaceae at generic, tribal or subfamilial level (Wagstaff *et al.* 1998; Paton *et al*. 2004; Li *et al*. 2017) and (2) many species of Lamiaceae have already been sequenced for these markers in previous molecular studies. We sequenced three regions *trnL* intron, *trnL–trnF* intergene spacer and *rps16* intron separately. For phylogenetic analysis *trnL* intron and *trnL–trnF* intergene spacer combined together and called as *trnL–trnF* region because in Genbank these two regions are deposited as combined *trnL–trnF* region.

5.2.2. DNA extraction, amplification, and sequencing

Total DNA was extracted from fresh or silica-dried leaves using 2× CTAB method of Doyle & Doyle (1987) and also by using DNA extraction kit (DNeasy Plant Mini Kit, QIAGEN). Purity of DNA was confirmed by repeated agarose gel electrophoresis. The *trnL* intron was amplified with primers c (CGAAATCGGTAGACGCTACG) and d (GGGGATAGAGGGACTT GAAC); *trnL–trnF* intergene was amplified with primers e (GGTTCAAGTCCCTCTATCCC) and f (ATTTGAACTGGTGACACGAG) f (TTTGAACTGGTGACACGAG) from Taberlet *et al.* (1991); and *rps16* intron was amplified using primers *rpsF* (GTGGTAGAAAGCAACGTGC GACTT) and *rps2R* (TCGGGATCGAACATCAATTGCAAG; Oxelman et al., 1997) (Table 5.3) using the following PCR program: initial denature step of 4 min at 94°C followed by 30 cycles, 30 s denaturation at 94°C, 30 s annealing at 60°C, 1 min extension at 72°C, ending with 4 min final extension (72 °C). The gels were visualized in a UV transilluminator (Genei) and the image was captured under UV light using Gel documentation system (Bio-Rad). Sequencing reaction was done in a PCR thermal cycler (GeneAmp PCR System 9700, Applied Biosystems) using the Big Dye Terminator v3.1 Cycle sequencing Kit (Applied Biosystems , USA). The cleaned up air dried product was sequenced in ABI 3500 DNA Analyzer (Applied Biosystems). The sequence quality was checked using Sequence Scanner Software v1 (Applied Biosystems).

Table 5.3. Primers for amplification of cpDNA regions

	Region	Primers used	Reference
1	trnL introns	Forward c (CGAAATCGGTAGACGCTACG)	Taberlet *et al.* 1991
		Reverse d (GGGGATAGAGGGACTTGAAC)	
2	trnL-trnF intergene spacers	Forward e (GGTTCAAGTCCCTCTATCCC)	
		Reverse f (ATTTGAACTGGTGACACGAG)	
3	Rps16 intron	Forward rpsF (GTGGTAGAAAGCAACGTGCGACTT)	Oxelman *et al.* 1997
		Reverse Rps2R (TCGGGATCGAACATCAATTGCAAG)	

5.2.3. Sequence alignment and phylogenetic analyses

Sequences were edited in BioEdit and aligned using Clustal W in MEGA 5.2. Alignment gaps were treated as missing data. We used PartitionFinder v1.1.0 (Lanfear *et al.* 2012) to select the best-fitting nucleotide substitution models for analyses of Bayesian inference (BI) and BEAST according to the Bayesian information criterion (BIC). The model GTR + G was chosen for combined cpDNA. The partition homogeneity test (ILD; Farris et al. 1994) was calculated to determine the incongruence between the datasets as implemented in PAUP* version 4.0 beta 10 (Swofford 2003).

BI analyses were performed using the program MrBayes 3.2 (Ronquist *et al.,* 2003). Two runs were conducted in parallel with four Markov Chain Monte Carlo (MCMC) chains, with each running for 1,000,000 generations and sampled every 100th generation. Examination of the loglikelihood values suggested that stationarity was reached in about 25,000 generations. Thus, the first 100,000 generations (10%) were discarded to make sure the burn-in period was sufficiently long. A majority rule consensus tree was produced, showing nodes with posterior probability of 50% or more. For purposes of results and discussion, clades with posterior probability values of 0.50−0.79 were considered weakly supported, 0.80−0.94 moderately supported, and 0.95−1.00 strongly (well-) supported.

Maximum likelihood phylogenetic analyses were implemented with raxmlGUI 1.3 (Silvestro and Michalak 2012), a graphical front-end for RAxML (Stamatakis 2006). A partitioned model was selected, and the robustness of the internal branches of the ML tree was evaluated by calculating 1000 thorough Bootstrap replications with other parameters using the default settings.

5.2.4. Molecular dating of *Plectranthus*

There is no known fossil evidence for *Plectranthus*. Molecular dating attempted in this work was based on fossils from related clades in Lamiaceae, such as the early Eocene fossil hexacolpate putative pollen of *Ocimum* L. identified by Kar (1996). This fossil has also been employed in recent phylogenetic studies of Lamiaceae (Drew and Sytsma 2012, 2013). As hexacolpate and three-nucleate pollen was considered to be a synapomorphy for subfamily Nepetoideae (Harley *et al.* 2004), the fossil was suggested to place at the crown of Nepetoideae (as opposed to the crown of Ociminae). In this study we also agreed with this conservative placement.

Divergence times were estimated using a Bayesian method implemented in the program BEAST v1.72 (Drummond *et al.* 2006; Drummond and Rambaut 2007). For all BEAST analyses, we implemented a Yule process speciation prior and both the uncorrelated exponential (UCED) and lognormal (UCLN) relaxed clock model of rate change were conducted. Bayes factors calculated with Tracer v1.5 (Rambaut and Drummond 2007) were used to compare the results of UCED and UCLN. Two separate runs were conducted, each with 10,000,000 generations sampled every 1000 generations. Tree Annotator v1.72 was used to summarize the set of post burn-in (10%) trees and their parameters. The combined log file was checked using Tracer v1.5 to ensure that the effective sample sizes (ESS) were all above 200. Finally, the maximum clade credibility (MCC) chronogram was visualized using the program FigTree v1.3.1 (Rambaut and Drummond 2010).

Estimation of *Plectranthus* divergence times was done using a combined cpDNA data sets. Through adjusting the value of mean and standard deviation, the 95% highest posterior density (HPD) of main nodes yielded from the detailed analyses was also checked.

5.3. Results

5.3.1. Base pair length in newly created sequence

Total length of the base pairs of each newly created sequence of three chloroplast genes are shown in Table 5.4. The maximum base pair length in *trnL-F* region is 1204, in *rps16* is 1903. The maximum base pair length for the concatenated sequence is 2304.

Table 5.4. Length of the base pairs in newly sequenced regions

Sl. No	Taxa	*trnL-F*	*rps16*	*trnL-F* + *rps16*
1	*Plectranthus anamudianus* Smitha & Sunojk.	1191	1090	2301
2	*Plectranthus barbatus* Andrews (Munnar)	1191	1090	2301
3	*Plectranthus barbatus* Andrews (Kalpetta)	1191	1090	2301
4	*Plectranthus beddomei* Raizada	1191	1090	2301

5	*Plectranthus bishopianus* Gamble	1173	1089	2300
6	*Plectranthus bourneae* Gamble	1173	1089	2300
7	*Plectranthus caninus* Roth	1173		2300
8	*Plectranthus deccanicus* Briq.	1173	1089	2300
9	*Plectranthus gamblei* Smitha & Sunojk.	1191	1089	2300
10	*Plectranthus glabratus* (Benth.) Alston (Coonoor)	1173	1089	2300
11	*Plectranthus glabratus* (Benth.) Alston (Silent Valley)	1191	1054	2265
12	*Plectranthus malabaricus* (Benth.) R.H.Willemse (Sholayar)	1191	1090	2301
13	*Plectranthus malabaricus* (Benth.) R.H.Willemse (Tusharagiri)	1191	1090	2301
14	*Plectranthus malabaricus* (Benth.) R.H.Willemse (Kodachadri)	1191	1090	2301
15	*Plectranthus malabaricus* (Benth.) R.H.Willemse (Vagamon 1)	1191	1090	2301
16	*Plectranthus malabaricus* (Benth.) R.H.Willemse (Vagamon 2)	1191	1090	2301
17	*Plectranthus malabaricus* (Benth.) R.H.Willemse (Thollayiram)	1191	1084	2295
18	*Plectranthus malabaricus* (Benth.) R.H.Willemse (Parambiculum)	1191	1090	2301
19	*Plectranthus malabaricus* (Benth.) R.H.Willemse (kurichermala)	1191	1056	2267
20	*Plectranthus mollis* (Aiton) Spreng.	1191	1089	2300
21	*Plectranthus montanus* Benth.	1173	1089	2300
22	*Plectranthus subincisus* Benth.	1191	1089	2300
23	*Plectranthus* sp. 1	1173	1089	2300
24	*Plectranthus sahyadricus*	1173	1089	2300
25	*Plectranthus* sp. 2	1173	1089	2300
26	*Plectranthus vettiveroides* (Jacob) N.P.Singh & B.D.Sharma	1173	1089	2300

27	*Isodon walkeri* (Arn) H.Hara (Sholayar)	1211	470	1681
28	*Isodon nilgherricus* (Benth.) H.Hara (Munnar)	1200	1093	2304
29	*Isodon* new (Vagamon)	1200	1093	2304
30	*Isodon nigrescens* (Benth.) H.Hara	1204	1093	2304

5.3.2. Phylogenetic analysis

5.3.2.1. Bayesian Phylogeny reconstruction

The incongruency was not observed for the combined cpDNA datasets during partitions ($p>0.01$). The Bayesian phylogeny reconstruction of the three combined cpDNA is shown in Fig. 5.1. Monophyly of the Ocimeae clade (posterior probability pp 1) is well supported. Menthae (pp 1) and Elsholtziae (pp 1) are supported as the sister groups to the tribe Ocimeae. *Siphocranion* and *Lavandula* are sister to the remainder of the Ocimeae clade with all clades well supported (*Siphocranion* pp 1, *Lavandula* pp 0.8 and remainder of Ocimeae pp 1). Isodoninae (Zhong *et al.* 2010) (pp 1), Hyptidinae (pp 1), Ociminae (pp 0.92) and Plectranthinae (pp 1) are supported as monophyletic groups within Ocimeae. Within Ociminae *Basilicum* (pp 1), *Platostoma* (pp 1), *Ocimum* (pp 1) and *Orthosiphon* (pp 0.98) minus *Orthosiphon parishi* are well supported as monophyletic groups. Due to poor representation, *Puntia* and *Syncolostemon* are unresolved. In Bayesian Phylogeny some clades are fragmented, ie, *Orthosiphon* clade is fragmented in to two parts.

Within Plectranthinae (Fig. 5.2), *Plectranthus* (pp 0.97) and *Coleus* (pp 1) form two well supported sister clades. In *Plectranthus* clade *Tetradenia* (pp 1), *Thorncroftia* (pp 1) and *Aeollanthus* (pp 1) are well supported. Another monophyletic group within *Plectranthus* clade comprising species of

Plectranthus (Subclade A) plus *Capitanopsis* is well supported (pp 0.9). Most of the Indian *Plectranthus* species are nested within the *Coleus* clade. Within *Coleus* clade, two well supported monophyletic groups in which first group (pp 0.54) comprising *Pycnostachys*, *Anisochilus*, and species of *Plectranthus* and the other group (pp 0.95) consists of *Plectranthus* species only. *Pycnostachys* forms a well supported monophyletic group within this *Coleus* clade (pp 1). *P. beddomei*, *Plectranthus* sp.3, *P. gamblei*, and *P. anamudianus* form a well supported monophyletic group (Subclade B, pp 1). All the accessions of *P. malabaricus* form a complex with a good support value (Subclade C, pp 1) within *Coleus* clade. Different accessions of *P. barbatus* form a separate lineage (Subclade D). Similarly *P. montanus*, *P. caninus, P. bishopianus, P. glabratus* (Coonoor), *Plectranthus* sp.1*, P. vettiveroides, P. bourneae, P. deccanicus, P. sahyadricus,* and *Plectranthus* sp.2 form another cluster with good support (Subclade E, pp 1) within *Coleus* clade.

5.3.2.2. Maximum likelihood based phylogenetic analysis

The maximum likelihood based phylogenetic reconstruction of the three combined cpDNA datasets was shown in Fig. 5.3. Again the monophyly of tribe Ocimeae is supported (BS 100 %). Menthae (BS 100%) and Elsholtziae (BS100%) are also well supported as sister groups to clade Ocimeae. *Siphocranion* (100%) and *Lavandula* (100%) are again supported as the sister groups to the rest of the Ocimeae. Within the remainder of the Ocimeae, Hyptidinae (82%), Isodoninae (99%), Ocimineae (41%) and Plectranthinae (53%) are well supported as clades. At lower levels of Ocimineae some well supported groupings are also noticed. *Orthosiphon* (45%), *Syncolostemon+Ocimum* (20.3%), *Basilicum* (99%), *Platostoma* (42%), *Puntia* (41%), and *Plectranthinae* (53%) are well supported monophyletic groups within Ocimineae.

Within Plectranthinae (Fig. 5.4), a clade comprising most of the species of *Plectranthus* in India, *Anisochilus*, and *Pycnostachys* is supported (BS 90%). This is *Coleus* clade. Another clade which contains rest of the *Plectranthus* species plus *Capitanopsis*, *Thorncroftia*, *Tetradenia*, and *Aeollanthus* is sister to the *Coleus* clade (BS 53%). At lower levels in *Plectranthus* clade, subgroups like *Aeollanthus* (100%), *Tetradenia* (100%), *Thorncroftia* (97%), *Capitanopsis*+*Plectranthus* (40%) appear to be well supported. Within *Coleus* clade Subclade B, Subclade C and Subclade E are supported as sisters (BS 48%).

The main areas of incongruence between the Bayesian and Maximum likelihood based reconstructions are caused by the fragmentation of some clades in the Bayesian phylogeny inference. For example *Orthosiphon* clade, which is a monophyletic group in maximum likelihood analysis and fragmented in to two parts in Bayesian phylogeny inference. In Bayesian phylogeny *Ocimum* supported as monophyletic group while in maximum likelihood based phylogeny *Ocimum* plus *Syncolostemon* formed a clade. In maximum likelihood analysis Subclade B, Subclade C and Subclade E are supported as sisters within *Coleus* clade while in Bayesian analysis they are not supported as sisters.

5.3.3. Molecular dating

The result of the combined cpDNA BEAST analysis is shown in Fig. 5.5. The result of BEAST analysis suggested that Plectranthinae originated ca. 110 million years ago (Ma) in the Cretaceous. *Coleus* and *Plectranthus* clades diversified ca. 88 Ma and ca.73 Ma respectively in the late Cretaceous. The result also suggested that the *Ocimum* crown node was found to have originated 63 Ma and diversified around 57 Ma at the Paleocene-Eocene border. Molecular dating also reveals that subtribe Plectranthinae consists of two groups which split from a common ancestor and diversified differently in different times. Majority of Indian *Plectranthus* comes under the *Coleus* clade and the Western Ghat endemics shows very recent radiation.

5.4. Discussion

There is no well-supported incongruence between the Bayesian and Maximum likelihood based phylogeny reconstruction. In Bayesian reconstruction some clades are fragmented in to two parts however Maximum likelihood gave support. Tribe Ocimeae is a well supported clade with a morphological synapomorphy of dorsifixed synthecous anthers. Tribe Menthae and tribe Elsholtzieae is sister to tribe Ocimeae. In plastid DNA restriction site studies of Wagstaff *et al*. (1998) and cpDNA phylogenetic studies by Paton *et al.* (2004), tribe Ocimeae is sister to the tribe Elsholtzieae. But in the *rbcL* study of Kaufmann and Wink (1994) where *Ocimum* is embedded within the tribe Mentheae, and is sister to *Melissa* and *Origanum* [*Majorana*]. *Siphocranion* is monophyletic and is sister to *Lavandula*. This is an agreement with the phylogenetic studies by Zhong *et al*. (2010).

In this study Isodoninae, Hyptidinae, Plectranthinae, and Ociminae are supported as well resolved monphyletic groups. However the relationships among these four subtribes were found unresolved in molecular phylogenetic studies of tribe Ocimeae by Paton *et al.* (2004). The status of *Hanceola* is unresolved in this study due to under-representation of this genus. The monophyly of *Isodon* is also confirmed in this study and supported the studies by Zhong *et al*. (2010) and Yu *et al.* (2014). New subtribe Isodoninae proposed by Zhong *et al.* (2010) to accommodate all the species of *Isodon* is well supported with clear morphological synapomorphies. This result again proved that the genus *Isodon* is not allied to *Plectranthus*.

The study also confirmed parphyly of the genus *Plectranthus* along with other genera of subtribe Plectanthinae. This result is an agreement with cpDNA phylogenetic analysis of Paton *et al.* (2004). Within Plectranthinae, there are two well supported monophyletic groups: *Coleus* and *Plectranthus* which is also congruent with the result of Paton *et al.* (2004). In Bayesian phylogenetic analysis, *Plectranthus* clade consists of several monophyletic groups ie., *Tetradenia*, *Thorncroftia, Aeollanthus* and species of *Plectranthus* (Subclade A) plus *Capitanopsis*. Subclade A includes *P. mollis* and *P. subincisus* which form sister groups to other African species.

All the other Indian *Plectranthus* were nested within the *Coleus* clade. This clade shows a paraphyletic nature consists of two well supported monophyletic groups in which first group comprising *Pycnostachys, Anisochilus*, and species of *Plectranthus* and the other group consists of *Plectranthus* species only. *Pycnostachys* forms a well supported monophyletic group within this *Coleus* clade. Similarly *P. beddomei*, *Plectranthus* sp.3, *P. gamblei*, and *P. anamudianus* form another well supported monophyletic group (Subclade B). All accessions of *P. malabaricus* clustered together and form a group (Subclade C) within *Coleus* clade. Different accessions of *P. barbatus* form a separate lineage (Subclade D). *P. montanus, P. caninus, P. bishopianus*, *P. glabratus* (Coonoor), *Plectranthus* sp.1, *P. vettiveroides, P. bourneae, P. deccanicus*, *P. sahyadricus*, and *Plectranthus* sp.2 form another well supported monophyletic group (Subclade E) within *Coleus* clade.

5.5. Conclusions

As general conclusions, this study used cpDNA sequences to investigate the phylogeny of *Plectranthus-Coleus* complex and related genera. The study well supported monophyly of tribe Ocimeae with a morphological synapomorphy of dorsifixed synthecous anthers. New subtribe Isodoninae (Zhong *et al,* 2010) was well supported with clear morphological synapomorphies such as the basal insertion of stamens in the corolla tube and the absence of enlarged, finger-like abaxial disc lobes. Within Plectranthinae, two well supported clades *Coleus* and *Plectranthus* were identified. This analysis also suggested that these two clades *Plectranthus* and *Coleus* were not diagnosed by any non-molecular synapomorphies. This result was highly congruent with the study by Paton *et al.* (2004). Here the paraphyly of genus *Plectranthus* was again confirmed. With regard to the Indian *Plectranthus* two species were nested within the *Plectranthus* clade. Among the two species, *P. mollis* is found widely in India, Nepal and Burma. The Western Ghat endemic *P. subincisus* appears closely related to *P. mollis* and this species is reported from few localities in Kerala. These two species are remotely related to other species as all other species falls in *Coleus* clade. All other species were formed four strongly supported subclades with in the *Coleus* clade. These five subclades were not easily diagnosable with morphological synapomorphies. It is concluded that increased sampling of species from all over the world is required to solve the *Plectranthus-Coleus* complex and also to recognize monophyletic groups within Plectranthinae.

Molecular dating attempted shows two large clades in Plectranthinae (*Coleus* and *Plectranthus*) and both are paraphyletic. Both these groups split from a common ancestor and diversified independently. All these point out need for further studies by including taxa from other region to circumscribe generic boundaries within Plectranthinae. Similarly, the generic boundaries within the genus *Plectranthus* (*Coleus-Plectranthus* complex) could not be assessed in the present study.

CHAPTER 6
SUMMARY AND CONCLUSION

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As presently circumscribed (Harley *et al*. 2004), Lamiaceae are the largest family-level clade within Lamiales (APG 2016). They are cosmopolitan in distribution with high economic potentialities. Indian region exhibit very high diversity of Lamiacean plants with many endemics having overlapping morphologic characters. *Plectranthus* L'Hér. also known as 'spurflowers', is one of the largest genera of family Lamiaceae, subfamily Nepetoideae, tribe Ocimeae, and subtribe Plectranthinae. Recent study on the molecular phylogeny of the tribe Ocimeae (Paton *et al*. 2004) revealed that the current circumscription of the genus *Plectranthus* is paraphyletic. This research work was conducted to generate an account of the genus *Plectranthus* L'Hér. in India by incorporating morphological, micromorphological and molecular data. The proposed study focus on the systematic problem within the genus *Plectranthus* and the intra specific and inter generic relationship of the complex, using morphological, micromorphological and molecular approaches and to check the paraphyly of the genus.

The genus consists of herbaceous medicinal plants used widely in modern and indigenous medicinal practices. *P. ambonicus, P. barbatus, P. hadiensis* and *P. vettiveroides* are important medicinal plants. Moreover, various species are used as horticultural herbs due to its ornamental importance. *Plectranthus* is a horticulturally important genus of predominantly herbaceous plants that is becoming increasingly popular in indigenous landscaping in South Africa (Rice *et al*. 2011). *P. scutellarioides* is a horticultural herb grown in home gardens due to its highly variegated leaves and *P. rotundifolius* producing edible tubers. The pharmacological activities of certain unique compounds reported from *Plectranthus* make this an important genus to search for drug development (Gaspar-Marques et al., 2006). Lukhoba *et al.* (2006) reviewed the genus *Plectranthus* and its ethnobotanical uses extensively, providing a comprehensive understanding of the global ethnobotany of *Plectranthus*. Van Jaarsveld (2006) provides a comprehensive horticultural review of South African species providing valuable information on cultivation.

6.1. Taxonomy

The study was carried out in India which consists of ten biogeographical zones. Extensive field trips were conducted throughout India for specimen collection. Collected specimens were immediately processed for making herbarium and parts were preserved for laboratory studies. Young leaves were stored in silica for molecular studies and mature mericarps and pollen grains were also preserved for micromorphological observations. The details of collections such as locality, altitude, habitat and ecology, phenology, etc., were recorded in the field book. Live specimens were brought into Calicut University Botanical Garden for further studies. All the specimens were worked out from the laboratory and the habitat information were recorded from the field itself. Identifications were done using relevant literatures, protologues and type materials. Apart from field collection, specimens deposited in various herbaria within India and abroad were also studied. The following herbaria were consulted: BM, CAL, CALI, FRC, FRLH, G, JCB, K, KFRI, L, MH, P, PDA, RHT, TBGT and UPS. The present work reports 22 species of *Plectranthus* from India. The important conclusions of taxonomic study of the genus *Plectranthus* are given below:

6.1.1. New taxa discovered

The present study identified five new species; they are *P. anamudianus, P. gamblei, P. sahyadricus*, *Plectranthus* sp.1 and *Plectranthus* sp. 2. *P. anamudianus* is described from slope of the Anamudi Peak of western Ghats and it is allied to *P. glabratus*. *P. gamblei* is described based on Gamble's collection from Coonoor. And *P. sahyadricus* is collected from Munnar area and close to *P. beddomei*. Another two species of *Plectranthus* has been collected from India and are yet to be published.

6.1.2. Nomenclatural problems resolved and recollection

Several nomenclatural problems were identified in the genus *Plectranthus* and clarified by analyzing the available literature and type specimens. Following are some of the important findings related to nomenclature:

i) The identity of *P. bourneae* was clarified and lectotypified. (Smitha & Sunojkumar 2018 in press).

ii) Reinstated *P. bishopianus* from the synonym of *P. deccanicus* (Smitha & Sunojkumar 2018 in press).

iii) The identity of another poorly known species *P. montanus* is discussed and a new synonym *Coleus subbaraoi* is proposed (Smitha & Sunojkumar 2017).

iv) *P. petricola* J.Mathew & B.J.Conn is found to be conspecific with *P. anamudianus*. As a result of thorough analysis of both species enabled us to treat *P. petricola* under *P. anamudianus.*

v) *Plectranthus idukkianus* J.Mathew, Yohannan & B.J.Conn and *Plectranthus saxorum* J.Mathew, Yohannan & B.J.Conn are synonymized under *P. malabaricus*.

vi) *Plectranthus subincisus,* a poorly known species is recollected after 150 years from southern India and the taxonomic identity and distribution of this species is also discussed (Smitha & Sunojkumar 2015).

6.1.3. Endemism

The present investigation revealed that eleven species are found endemic to India especially in Sothern Western Ghats. The endemics are: *P. anamudianus, P. beddomei, P. bishopianus, P. bourneae, P. deccanicus, P. gamblei*, *P. subincisus, P. vettiveroides, Plectranthus sahyadricus, Plectranthus* sp.1 & *Plectranthus* sp. 2

6.1.4. Conservation status

Conservation status is proposed for each species based on IUCN (2012) guidelines. *P. vettiveroides* is extinct in the wild (EW); *P. anamudianus*, *P. bishopianus*, *P. gamblei*, *P. sahyadricus*, *P. subincisus* are critically endangered (CR); *P. bourneae* belongs to Endangered (EN) category and *P. beddomei* is near threatened (NT).

In this treatment we did not attempt any sectional classification of the genus *Plectranthus* in India. In the course of this study, we failed to locate any morphological synapomorphies for a particular species. Due to high level of morphological variation and overlapping characters, we could clear that sectional treatment is a difficult task considering only the Indian species. So that a worldwide sampling is very essential for the better understanding of the interspecific relationships in *Plectranthus-Coleus* complex.

6.2. Micromorphology

6.2.1. Pollen micromorphology

This study on Indian species of *Plectranthus* shows that several pollen morphological characters can be of taxonomical value. Sexine ornamentation in this genus is variable (Types I–III) and could be of systematic significance. The variability of various parameters analyzed at inter specific level makes it hard to establish taxonomical boundaries and clearly shows the affinity of species as far as pollen morphological characteristics are concerned. Moreover it is also confirmed that due to constancy of pollen characters among different populations of a particular species, the effects of minor differences in ecological conditions on overall morphology of the plants did not influence pollen morphology of that species. In fact, a comprehensive pollen morphological study of *Plectranthus* is still lacking and detailed observation of pollen surfaces of species from different geographical areas could be relèvent since the surface ornamentation of pollen has been used successfully in a range of systematic studies. As with any morphological study, the more complete the data, the more convincing the subsequent analyses regarding phylogeny and relationships.

6.2.2. Mericarp micromorphology

In conclusion it is found that mericarp micromorphology provides valuable data in separating the related species within the genus *Plectranthus*. It seems also that contrary to other genera of Lamiaceae mericarp characters are of low phylogenetic value in this genus, especially due to high variation even among closely related species. In summary, we observed variation in the external morphology of mericarp characters like shape, size and surface sculpturing were much useful in distinguishing species. A key is also provided based on these characters. Variation in mericarp characters appears to have taxonomic value in distinguishing different species of the genus *Plectranthus* in India. We could clear that a wider sampling of *Plectranthus* species from all over the world would be advantageous and informative. This would provide data towards an understanding of the evolutionary and morphological radiation of the group but also towards building practical identification tools.

6.3. Molecular phylogeny

This study used cpDNA sequences to investigate phylogeny of *Plectranthus-Coleus* complex and related genera. The study well supported monophyly of tribe Ocimeae with a morphological synapomorphy of dorsifixed synthecous anthers. New subtribe Isodoninae (Zhong *et al*. 2010) was supported with clear morphological synapomorphies. Within Plectranthinae, two well supported clades *Coleus* and *Plectranthus* were identified. This analysis also suggested that these two clades *Plectranthus* and *Coleus* were not diagnosed by any non-molecular synapomorphies. This result was highly congruent with the study by Paton *et al.* (2004). Here the paraphyly of genus *Plectranthus* was again confirmed. With regard to the Indian *Plectranthus* two species were nested within the *Plectranthus* clade. All other species formed four strongly supported subclades with in the *Coleus* clade. These five subclades were not easily diagnosable with morphological synapomorphies.

Phylogenetic analysis reveals that all species except *P. mollis* and *P. subincisus*, are in *Coleus* clade. Majority of the Indian *Plectranthus* are endemic to Southern Western Ghats and this shows that *Plectranthus* evolution is going on in Western Ghats. Moreover recent radiations of morpho-forms are found in species like *P. malabaricus* which is difficult to circumscribe using morphological or molecular studies as attempted here. All these point to the fact that a comprehensive study is required in this genus while circumscribing new taxa. This is the reason why the new taxa recognized by Mathew *et al.* (2017) were sunk in to synonymy.

Western Ghats endemics like *P. bourneae*, *P. deccanicus*, *P. bishopianus*, *Plectranthus* sp.1, *Plectranthus* sp.2 etc. are very recent radiation as sisters to a common stock consisting of *P. beddomei*, *P. anamudianus* and *P. gamblei* (Fig. 5.4). All these species are confined to high altitude areas and prefers shady habitats. This also point out the relevance of Southern Western Ghats in the evolution of this genus. It is concluded that increased sampling of species from all over the world is required to solve the *Plectranthus-Coleus* complex and also to recognize monophyletic groups within Plectranthinae.

The result of BEAST analysis suggested that the subtribe Plectranthinae originated ca. 110 million years ago (Ma) in the Cretaceous. The paraphyletic *Coleus* clade diversified ca. 88 Ma and *Plectranthus* clade diversified ca.73 Ma in the late Cretaceous. The result also suggested that the *Ocimum* crown node was originated 63 Ma and diversified around 57 Ma at the Paleocene-Eocene border.

Molecular dating attempted shows that *Coleus* and *Plecranthus* clades split from a common ancestor and diversified independently. These facts point out need for further studies by including more taxa from the subtribe Plectranthinae from other region to trace monophyly within it. The genus *Plectranthus* as considered today is paraphyletic and the present study is not sufficient to fix generic boundaries within this genus (called as *Plectranthus-Coleus* complex). Wider sampling from all the genera currently considered under the subtribe is required to circumscribe generic boundaries within the subtribe.

Recently, Downes and Darbyshire (2017), two *Coleus* species are newly established to the flora of Mozambique and Zimbabwe. According to them the diagnostic characters of *Coleus* are the "posterior corolla lobe shorter than the anterior, and usually markedly so with the anterior lobe often large and navicular; the calyx usually asymmetric at the base with the pedicel attached behind the posterior lip; and the stamens free or fused". The '*Plectranthus*', on the other hand, is characterized by having ± equal corolla lobes, a symmetrical calyx base with the pedicel attaching at the mid-line, and free stamens. But these characters are overlapping in Asian taxa. Hence the concept of Downes and Darbyshire (2017) is ruled out here and propose that more studies are needed to circumscribe generic boundaries within the complex.

6.4. Directions of future work

- Morphological variability study in *P. malabaricus* complex by incorporating data from other areas like anatomy, micromorphology, and molecular analysis including nuclear and other cpDNA sequences.
- Molecular phylogeney of *Plectranthus*-*Coleus* complex in Asia including more species from outside India and by using more markers.
- Divergence time estimation of the genus *Plectranthus* including more fossils from Lamiaceae.
- Biogeography of the genus *Plectranthus.*

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APPENDIX 1

HERBARIUM ACRONYMS USED

BM	:	The Natural History Museum, London, England, UK
CAL	:	Central National Herbarium, Botanical Survey of India, Howrah, West Bengal, India
CALI	:	University of Calicut, Kerala, India
FRC	:	Herbarium of Institute of Forest Genetics and Tree Breeding, Coimbatore, Tamil Nadu, India
FRLH	:	Foundation for Revitalisation of Local Health Traditions, Bangalore, Karnataka, India
G	:	Conservatoire et Jardin botaniques de la Ville de Genève, Genève, Switzerland.
JCB	:	Indian Institute of Science (IISc), Bangalore, Karnataka, India
K	:	Royal Botanic Gardens, Kew, England, UK
KFRI	:	Kerala Forest Research Institute, Trichur, Kerala, India
L	:	Naturalis, Leiden, Netherlands
MH	:	Madras Herbarium, Coimbatore, Tamil Nadu, India
P	:	Museum of National d'Historie naturelle, Paris, France
PDA	:	National Herbarium, Royal Botanic Gardens, Peradeniya, Sri Lanka
RHT	:	Rapinat Herbarium, St. Joseph's College, Tiruchirapalli, Tamil Nadu, India
TBGT	:	Tropical Botanic Garden and Research Institute, Trivandrum, Kerala, India
UPS	:	Museum of Evolution Herbarium, Uppsala University, Sweden.

APPENDIX 2

LIST OF PUBLICATIONS

1. **Smitha, K**., Paton, A.J. & Sunojkumar, P. (2018) Re-establishment of *Plectranthus bishopianus* based on morphological and micro-morphological data. **Plant Systematics and Evolution** 304 (7): 807–816; Impact factor: **1.452**

2. **Smitha, K**. & Sunojkumar, P. (2018) *Plectranthus gamblei* (Lamiaceae): a new endemic species from India and notes on the identity and lectotypification of *Plectranthus bourneae*. **Nordic Journal of Botany** 36 (8) doi: 10.1111/njb.01639; Impact factor: **0.9**

3. **Smitha, K.** & Sunojkumar, P. (2018) *Plectranthus sahyadricus* (Lamiaceae): a new species from Western Ghats, India. **Phytotaxa** 345 (2): 165–169; Impact factor: **1.24**

4. **Smitha, K.** & Sunojkumar, P. (2017) Notes on *Plectranthus montanus* (Lamiaceae)—a poorly known species in India and reduction of *Coleus subbaraoi* as one of its synonyms. **Phytotaxa** 302 (3): 290–293; Impact factor: **1.24**

5. **Smitha, K**. & Sunojkumar, P. (2016) *Plectranthus anamudianus* (Lamiaceae): a new species from Western Ghats, India. **Phytotaxa** 284 (1): 51–60; Impact factor: **1.24**

6. **Smitha, K.** & Sunojkumar, P. (2015) Notes on the Identity and distribution of *Plectranthus subincisus* (Lamiaceae)—a poorly known species recollected after 150 years in southern India. **Phytotaxa** 192 (2): 105–111; Impact factor: **1.24**

7. Sunojkumar, P., **Smitha, K**., Jayesh, P Joseph (2012) *Plectranthus verticillatus* (L.F.) Druce (Lamiaceae): a new distributional record for India. **Journal of Economic and Taxonomic Botany** 36 (4): 823–825

Papers/ Posters presented in International and National Seminars/ Symposia:

1) Smitha, K. & Sunojkumar, P. 2017. Molecular phylogeny of *Plectranthus* L'Hér. (Lamiaceae) in India using chloroplast DNA sequences. International Symposium on Plant Systematics, University of Delhi, November 10-12, 2017. (Received Fr. Antony Mukkath – Prof. K.S. Manilal award for best oral presentation in modern trends in Plant Taxonomy)

2) Smitha, K. & Sunojkumar, P. 2016. The genus *Plectranthus* L'Hér. (Lamiaceae) in India – A Taxonomic Approach. International seminar on Conservatiosn and Sustainable Utilization of Biodiversity, Shivaji University November 07-09, 2016.

3) Smitha, K. & Sunojkumar, P. 2016. Inflorescence morphology and its implications in Taxonomy of *Plectranthus* L'Hér (Lamiaceae) in Southern Western Ghats. 28th Kerala Science Congress, Calicut University January 28-30, 2016.

4) Smitha, K., & Sunojkumar, P. 2015. Taxonomic identity of *Plectranthus* – *Isodon* complex (Lamiaceae) in Western ghats. National Seminar on Advancement of Biosystematics on Biodiversity Conservation, S. N. College, Sivagiri October 8-9, 2015.

5) Smitha, K., Vimal, K. P. & Sunojkumar, P. 2015. Study of infrageneric variations within *Plectranthus* L'Hér (Lamiaceae) in Western Ghats – Morphology vs Molecular. International seminar on Advancements in Angiosperm Systematics and Conservation, University of Calicut November 19-21, 2015.

Achievements/Awards

- Received IAPT (International Association for Plant Taxonomy) Research Grants 2018 in Plant Systematics (IAPT Research Grant in the amount of 2000 US $ and a free IAPT membership for 2018 with on-line access to journal Taxon).
- Received Fr. Antony Mukkath – Prof. K.S. Manilal award for best oral presentation in modern trends in Plant Taxonomy at IAAT 2017 Conference.