CHAPTER 2

2. REVIEW OF LITERATURE

2.1 Taxonomic Studies

Linnaeus first published the genus *Ophiorrhiza* (as *Ophiorhiza*) in his publication Flora Zeylanica (Linnaeus 1747), primarily based on *Ophiorrhiza mungos* collected by P. Hermann from Sri Lanka, and included in Materia Medica (Linnaeus 1749). Subsequently, the genus was included in his books Species Plantarum (Linnaeus 1753) and Genera Plantarum (Linnaeus 1754). Linnaeus published *Ophiorrhiza* with different spellings, *Ophiorhiza* and various authors have considered the name an orthographic variant. Afterwards, the spelling has been uniformly corrected to *Ophiorrhiza*.

The genus was documented in Systema Nature (Linnaeus 1759), Philosophia Botanica (Linnaeus 1770 & 1783), Systema Vegetabilium (Linnaeus 1774) and also incorporated by Murray (1774 & 1784), Turton (1802), Sprengel (1824, 1825 & 1830), Chumann (1891). At the time of the establishment of the genus only two species namely *O. mungos* and *O. mitreola* were recognized and included in Systema Nature (Linnaeus 1759). Only a few species were recognised in the early 19th century. Murray included two species in Systema Vegetabilium (1774 & 1784). Gaertner (1788) included only *O. mungos* in his "De Fructibus et Seminibus Plantarum". Willdenow (1798), Turton (1802), Roemer & Schultes (1819) and Sprengel (1825) included three species of *Ophiorrhiza* namely *O. mungos*, *O.mitreola* and *O. subumbellata* in their respective books.

From the beginning of the 19th century, several workers described and gave a general account of one or more species from India and nearby countries. Roxburgh (1824 & 1832) described *O. villosa*, Wallich (1824) and Jack (1824) collectively in Roxburgh's Flora Indica reported and described two species viz. *O. rugosa* and *O. tomentosa*. Don (1825) included two species namely *O. prostrata* and *O. fasciculata*. Candolle (1830) and Don (1834) provide general account of several species. Wight & Arnott (1834) included *O. brunonis*. Arnott (1836) described one species namely *O. pectinata*. Wight (1848) reported three species from Peninsular India viz. *O. grandiflora*, *O. roxburghiana* and *O. eriantha*. Thwaites (1864) described 4 species

from Sri Lanka in his book "Enumeration Plantarum Zeylanicae: An enumeration of Ceylon plants". Kurz (1872) gave an account of *O. gracilis* from Burma. Hooker (1882) described several species and varieties and provided a general account of his own species as well as the species already described by other workers. He described 31 species from several places in India. After Hooker's work, various authors reported several Indian species with their occurrence, distribution and morphology. Sharma *et al*. (1984) described six species of the genus in Flora of Karnataka Analysis. Clarke (1887) reported the occurrence of some species in Nagaland and Manipur. The occurrence of a few species and a variety in Kachin Hills and Burma was noted by Pottinger & Prain (1898). About 30 species have been recorded from Thailand and adjacent areas of Peninsular Malaysia (King & Gamble 1903, Ridley 1923 & Craib 1932). Prain (1903) reported the occurrence of three species namely *O. harrisiana* var. *argentea*, *O. trichocarpa* and *O. villosa* from Darjeeling district. Craib (1911) reported one species namely *O. lacei* from Burma. Fyson (1915) recorded only one species namely *O. brunonis* from Nilgiri hills. Gamble (1919) noted the occurrence of three species from Peninsular India. *O. heterostyla* was described from Eastern India by Dunn (1920). Gamble (1921) gave an account of the morphology of some species with their distribution in the Peninsular India. Haines (1922) reported the occurrence of one species in the Baruni hill forest. Fischer (1938, 1939 & 1940) gave a general description of few species from Peninsular India and Eastern India.

Burkill (1924) reported occurrence of some species from Abor hills and also their distribution in his book "The Botany of the Abor Expeditions". Kanjilal *et al.* (1939) reported 15 species occurring in Assam and Khasi hills with short morphological description of some of them and few specimens are referred to Hooker's Flora of British India Vol III (1882) for morphological description and distribution. Starchey (1960) reported the occurrence of *O. fasciculata* in Kumaon in Uttarakhand. Biswas (1966) noted the occurrence of some species in Darjeeling and Sikkim. Hara (1966 & 1971) gave some important information on the distribution of some species from Darjeeling, Sikkim, Bhutan, Nepal and Khasi hills. Henry and Subramanyan (1970) reported the occurrence and described one species namely *O. tirunelvelica* from South India. Gandhi (1976) reported the occurrence of *O. hirsutula* from Karnataka. Babu (1977) in his "Herbaceous Flora of Dehradun noted the occurrence of *O. fasciculata* from the region.

Balakrishnan (1980) described one species from Nicobar Island and named the species as *O. nicobarica*. Balakrishnan (1981) recorded some species of the genus from Khasi and Jantia Hills in his book Flora of Jowai Vol I. Manilal & Sivarajan (1982) recorded species of *Ophiorrhiza* in their book Flora of Calicut. Deb (1983) in Flora of Tripura enumerated six species from the genus. In 1988 Manilal included six species of *Ophiorrhiza* in his book Flora of Silent Valley. Subramanian (1995) gave a general account on four taxa of the genus in his book Flora of Thenmala and its Environment. Sasidharan & Sivarajan (1996) reported two species of *Ophiorrhiza* in Flora of Thrissur Forest. Sivarajan & Mathew (1997) enumerated a few species of *Ophiorrhiza* from Nilambur. Singh *et al.* (2002) in Flora of Mizoram vol I recorded nine species of *Ophiorrhiza* from the region. Mohanan & Sivadasan (2002) recorded seven species of the genus from the place Agasthyamala. Nayar *et al.* (2006) documented the presence of 13 species from the genus in the state of Kerala. Nayar *et al*. (2014) reported the occurrence of 23 species from Western Ghats and their distribution. They also gave an important account on endemic species of India. Barooah & Ahmed (2014) mentioned eight species in Assam.

2.2Review of the medicinal importance

The species under the genus contain camptothecin an anticancer compound, alkaloid used to make therapeutic agent. Camptothecin is used as a drug in the treatment of colon, head, breast and bladder cancer (Hsiang *et al.* 1985). Some species of genus is reported to have medicinal properties both in traditional and modern use. Some species of genus is used for the treatment of ovarian, colon cancer and also AIDS. In India only one species is introduced in the gardens of India for its ornamental value (Deb & Mondal 1997). Regarding camptothecin content, nearly six species of *Ophiorrhiza* have been tested for their glycoalkaloid content. Vineesh *et al.* (2007) reported tissue culture studies conducted on *O. prostata*, *O. pumila*, and *O. rugosa* aimed at enhancing the production of camptothecin. Pharmacognostic investigations including macro-micromorphological studies and phytochemical studies including the HPTLC profile of leaf *O. mungos* help in the identification of the leaf drug and confirm camptothecin contents in alcohol and aqueous extracts, which are useful anticancer agents (Madhavan *et al*. 2013). The quantification of campothecin based on HPTLC in species of *Ophiorrhiza*, viz. *O. hirsutula, O. barnesii, O. incarnata, O. radicans* and *O. villosa* has

been reported by Rajan *et al*. (2016). Vivipary, the physiological process reported in *O. mungos* reported by Dintu *et al*. (2014).

According to the study, some members of the genus are rare, endangered and endemic to specific regions of the country. New records of species from the genus have been reported from various regions of the country in recent years. Joseph *et al*. (2013) rediscovered *Ophiorrhiza radicans* from Shenduruney Wild Life Sanctuary of Kerela after a gap of 120 years. Sibi *et al.* (2012) documented a novel discovery on distribution of *Ophiorrhiza trichocarpon* in the Western Ghats of India. Haresh *et al.* (2015) reported *Ophiorrhiza sahyadriensis* a new species from southern Western Ghats, Kerala, India. Hareesh *et al.* (2017) reported *O. meghalayensis* and *O. debiana* a new species from northeast India. No further work on leaf architecture and foliar epidermal studies on the taxa have been reported to date from the study area. Morphological characters in combination with the microscopic characters of leaves and other micro-morphological characters of leaves along with phylogenetic features greatly enhanced the taxonomic judgement of angiosperm systematics (Baruah *et al.* 2012).

2.3Morphology

The morphological characters of the plant have always provided the base and framework for the taxonomy (Baruah *et al*. 2012). The morphological characters have been widely used in the preparation of classification systems and preparation of taxonomic keys. The morphological characters are pioneers in taxonomical studies and are still essential to systematic.

Ogura (1964) and Holttum (1968) explained the role of morphological characters in the classification system. Morphology contributes significantly to the characters utilized in constructing classification systems in taxonomy. Morphological traits are readily observable and accessible, offering a solid foundation for characterizing taxonomic groups, facilitating identification, and elucidating their relationships (Radford, 1986).

There is a growing demand for utilizing information to deduce taxonomic and phylogenetic relationships. It is utmost necessary to collect intensive and extensive taxonomic evidences other than morphological characters to provide proper taxonomic judgement and also to resolve taxonomic problems. In recent times in determining relationship between different taxonomic groups or categories, foliar epidermal characters like stomata, trichomes, nature of epidermal cells are playing a vital role.

Some epidermal characters like stomata, its morphology and ontogeny, number and arrangement of subsidiary cells, nature of trichomes and the relationship with other epidermal cells are expected to provide ideas to various evolutionary trends among taxonomic families and may also help in assigning taxa of unresolved affinities to its proper positions (Paliwal & Anand 1978).

2.4 Foliar epidermis

Different stomatal patterns and subsidiary cells have been reported in various plant species in the field of taxonomy by many workers (Pant 1965, Van Cotthem 1970). The value of various leaf epidermal characters is highlighted by different workers (Palmer & Garbath-Jones 1986, Jayeola *et al*. 2001, Adedeji 2004). The stomatal pattern appears to be the most important and valuable characteristic at higher taxonomic levels (Jones & Luchsinger 1987). Importance of stomata has been confirmed in the taxonomy of different angiospermic families including Combretaceae (Stace 1965b), Rubiaceae (Pant & Mehra 1965), Acanthaceae (Paliwal 1966), Mrytaceae (Van Wyk *et al.* 1982), Cyperaceae (Sharma & Shiam 1984) and several other families.

In the last few years several workers (Stebbins & Khush 1961, Varghese 1969, Sehgal & Paliwal 1974, Hardin 1979, Rejdali 1991, Fang & Fan 1993, Adedeji 2004, Adedeji *et al*. 2007, Adedeji & Jewoola 2008, Song *et al.* 2020, Paul & Chowdhury 2021) have highlighted the use of foliar micromorphological features in solving taxonomic problems at species level under many genera.

Foliar epidermal study is one of the significant characters in the taxonomic point of view among many genera and families. Nature of epidermal cells is also a good taxonomic characteristic for the identification (Sonibare *et al.* 2005) as for example the differentiation between Aethae and Alcea within the Malvaceae family was based on the size of epidermal cells as highlighted by Shaheen *et al.* (2010). Foster (1949) perceived that the mode of evolution of stomata, their relation to the epidermal cells and absence and presence of subsidiary cells are the diagnostic features that can be employed in the classification and phylogeny.

Epidermal hairs and trichomes are also having taxonomic significance because they exhibit great diversity of form, size, structure and functions. Nature of trichomes and their distribution are used as important taxonomic characters in solving taxonomic problems among the genera. Position of the genus Nycanthus in the family Oleaceae has

been confirmed on the basis of structure and ontology of trichomes (Inamdar 1968). The affinities between the family Typhaceae and Sparganiaceae is confirm on the basis of sessile glandular hairs (Solerender & Meyer 1933). Trichome characters have been played a main role in formation of generic key for the Indian members of Asteraceae (Ramayya 1969). Segreagation of African Leucas from Asian Leucas is based on the presence of different types of trichomes was reported by Sajna & Kumar (2018).

In the family Rubiaceae, foliar micromorphological studies assembled by many different features which was reported by Solereder (1908) and Metcalfe & Chalk (1950) which used as taxonomic attributes for delimination and identification of species. Many authors have studied distinguished foliar epidermal features in family Rubiaceae (Pant & Mehra 1965, Bahadur & Rajagopal 1970, Goursat & Guignard 1975, Patel & Zaveri 1975, Singh *et al*. 1975, Bhatt & Inamdar 1977, Vales 1984, Bhatt 1985, Mathew & Sivarajan 1987, Darok *et al*. 2000, Vieira *et al*. 2001, Tarsila *et al*. 2009, Patil & Patil 2009, Patil & Patil 2011, Mussury *et al.* 2012, Fayose & Freke 2016, Balinado & Cardenas 2019). Many members of family Rubiaceae shows uniform stomata but the other epidermal features as distribution of stomata, stomatal index and frequency, types and distributions of subsidiary cells, presences of crystals etc shows great taxonomic significance as they varied among the different species (Patil & Patil 2011). They recognised that although the members of the family rubiaceae shows uniform stomata but other epidermal characters such as stomatal index and frequency, types of subsidiary cells and its distribution, presence of raphide and crystals are also appear to have taxonomic significance and can be helpful to distinguished taxa of rubiaceae.

Leaf epidermal characters for four taxa of *Mussaenda* were studied by Nwafor *et al.* (2019) for easy identification. Tahseen & Nasrullah (2020) studied the anatomy of surface of leaf epidermis and indumentums of six taxa of family Rubiaceae and point out the similarities and dissimilarities among the taxa on the basis of epidermal features.

2.5 Leaf architecture

Leaf architecture study has recognised as another taxonomic attritubes to resolve taxonomic problems. The primary difference between monocot and dicot is only based on the leaf venation. Hicky (1973) studied leaf architecture of dicotyledon and provide with several terminology for the features of leaves. Melvill 1976 recorded different classes of major venation pattern based on the comparative leaf architecture study of

dicotyledons and monocotyledons. Details characteristic of leaf venation pattern is considered as valuable taxonomic clue for identification of different taxa by different workers (Datta & Saha 1968, Chandra *et al.* 1972, Dilcher 1974, Hicky & Wolfe 1975, Rury & Dickson 1977, Mohan & Inamdar 1984, Seetharam & Kotresha 1998). Comparative study of leaf architecture and leaf venation had been carried out among different families of dicotyledons by different authors such as Scrophulariaceae (Varghese 1969), Euphorbiaceae (Sehgal & Paliwal 1975), Berbidaceae (Singh *et al.* 1978), Bignoniaceae (Jain 1978), Lamiaceae (Tyagi & Kumar 1978), Betulaceae (Frank 1979), Rosaceae (Merriell 1978), Solanaceae (Inamdar & Shenoy 1981), Apocynaceae (Mohan & Inamdar 1982), Oleaceae (Mohan & Inamdar 1983), Acanthaceae (Chaudhuri & Inamdar 1984), Brassicaceae (Rao & Inamdar 2006). Size and shape of aeroles, nature of aeroles and free vein endings and along with other anatomical characters greatly strengthened the taxonomic opinion for solving taxonomic problems in angiosperm systematic (Hall & Melville 1954, Dickson *et al.* 1987). According to Levin 1929, vein islets number and its nature are considered to be the valuable character used in distinguishing different species of a genus. Foliar vascular pattern was studied for the Indian members of family Rubiaceae by Saha *et al*. (2014). According to the study the minor venation parttern and free vein ending considered to helpful in the identification of taxa. Leaf venation characters were also studied in the genus Didymaea under the family Rubiaceae by Trejo *et al*. (2009).

2.6 Anatomy

The study of vegetative anatomy plays a crucial role in distinguishing between higher plant groups, such as gymnosperms from angiosperms, and monocots from dicots. In the two volume Book of Metcalf & Chalk (1950) describe in details of stem anatomy and discuss in details about the stem anatomy characters how they can be used in classification system in taxonomy at various levels from separation of dicot from monocot and distinction of various taxa of the genus. Bailey (1951), Metcalfe (1954 & 1961) and Dickinson (1975) have considered that there was possible use of anatomical evidences in the study of phylogeny classification and identification of the plants. Paliwal & Anand (1978) departed the role of anatomical studies in the classification of flowering plants in details. The anatomical characters can be considered as taxonomic tools to distinguish two different species in a genus. Ayensu (1970), considered

characteristics of stem anatomy as identification for the separate species *Dioscorea rotunda* and *Dioscorea cayenesis*, that are very close to each and which are difficult to identify morphologically. He also describes about the genus of the family Dioscoreaceaeon the basis of anatomical features and gives a new insight in the field of taxonomy. Tilney *et al.* 1988 reported the taxonomic significance of anatomical characters of stem in the genus *Canthium.* For the easy identification of *Calamus* species of South India, Bhat *et al.* 1993 carried out an anatomical study on the species. Mathew & Bhat (1997) carried out stem anatomical study of 4 genera of Arecaceae for the easy identification ofthe species among the genera. Costea & Darleen 2001, carried out study on stem anatomy in the genus *Amaranthus*, and characters results in establishment of new infrageneric classification and sepaeration within the complex cultivated Amaranthus and presumed wild ancestors. Makbul *et al*. 2011 gives a note on the stem anatomy of18 species of Scorzonera (Asteraceae) from North East Turkey. Several anatomical characters like structure of hairs thickness of the cuticle, the shape of the epidermal cell, initation of periderm, structure of phellem, the presence of subepidermal collenchyma, the shape of vascular cyclinder and pith are useful in distinguishing among the taxa. On the basis of stem anatomical features three distinct groups were recognised separately viz *Canthium*, *Pysdrax, Keetia*. Nodal anatomy in 20 species belonging to 11 genera of family rubiaceae was studied by Patil & Patil 2012.

2.7 Environmental Niche Modelling

Rapid change in climate, human interference, habitat fragmentation, over- exploitation, invasion of pathogens are most known factors responsible for ecosystem degradation and biodiversity loss (Barnasky *et al*. 2011, Adhikari *et al.* 2012). Due to these factors plants species are at a risk of extinction in near future. Species reintroduction is one of the emerging and successful ecological technique for restoration of biodiversity loss and helps reducing the degradation of habitat loss (Brummitt & Bachman 2010). Habitat distribution modelling or environmental niche modelling (ENM) using MaXent is an Environmental modelling which helps to identify the areas effective for species reintroduction and provide proper conservation measures to the plants species. This model has been successfully used in reinstating habitat and also prediction the impact of environmental and climatic changes on plant species and their ecosystem (Brooks *et al*. 2004, Samways 2005, Giriraj *et al.* 2008, Franklin 2009, Adhikari *et al*. 2012).

Many species are at a brink of extinction due to various environmental and anthropogenic factors, it is utmost necessary for the conservation of species factors, these tool helps to model potential habitat distribution in its native range. To conserve the RET plants worldwide, many authors carried out the study on this model, such as *Agalia bourdillonii* (Irfan 2006), *Rhododendron arboreum* (Giriraj *et al*. 2008), *Canacomyrica monticola* (Kumar & Stohlgren 2009), *Berberis aristata* (Ray *et al*. 2011), *Chromolaena odorata* (Barik & Adhikari 2011), *Illex khasiana* (Adhikari *et al*. 2012), *Mesua assamica* (Baruah *et al*. 2016), *Heterosmilax japonica* (Baruah 2016), *Vanilla borneensis* (Deka *et al*. 2017), *Calamus nambariensis* (Deka *et al*. 2018), *Aristolochia indica* (Sharma *et al*. 2018), *Elaeocarpus serratus* (Baruah *et al*. 2019), *Selaginella adunca* (Srivastava 2020), *Calamus floribundus* (Mehmud *et al*. 2021), *Aristolochia cathcartii* (Sharma & Tanti 2022).