

1. INTRODUCTION

1.1 General Introduction

The genus *Ophiorrhiza* L. belongs to the tribe Ophiorrhizeae of the family Rubiaceae. *Ophiorrhiza* was first described by Linnaeus in Flora of Zeylanica (Linnaeus 1747) and also included in his other books, Materia Medica (1749), Species Plantarum (1753) and Genera Plantarum (1754). The name *Ophiorrhiza* is derived from the Greek terms ‘Ophis’ meaning a snake and ‘rhiza’, meaning a root that has a healing property in snake bites in the Indian subcontinent (Don 1834).

The members of *Ophiorrhiza* vary in habit from herbs to small shrubs upto 4 m high, growing in humid regions, mostly in evergreen, deciduous forests at varying altitudes. The plants have an erect stem, creeping root, mostly 10–50 cm, herbaceous, sometimes woody. Leaves are simple, sometimes broadly oblong, elliptic, petiolate, stipules deciduous, or persistent. Flower are terminal and sometimes axillary, bracts and bracteoles present or absent. Calyx small with a suborbicular tube, 5, persistent teeth. Corolla tubular, white or sometimes whitish pink in colour, often dimorphic because of heterostyly, 5 lobed. Stamens 5, subsessile, anther linear. Ovary 2 celled, ovules many, style filiform, long or short with stigmas. Fruit compressed capsule, seed many, small and angled.

The candidates of the genus are noteworthy for their medicinal and economic significance, particularly due to the presence of the anticancer compound Camptothecin, which is utilised in cancer treatment. *Ophiorrhiza mungos* is used as medicine and also as a dye. The roots of *O. japonica* and *O. mungos* have healing properties in snakebite (Don 1834, Drury 1864, Baillon 1881). The decoction of roots, leaves and bark is utilised for the treatment of stomach pain. The leaves are used for dressing ulcers. The flowers of some of the members are utilized as a stimulant and cardiac tonic in treating rheumatism and heart diseases (Watt 1891). The roots are used as a red dye for wool and also for hair (Watt 1891). The fruits of *O. fasciculata* are edible among the people of Koppu to Geling in the Siang district of Arunachal Pradesh (Deb & Mandal 1997). The leaves of *O. rugosa* var. *prostrata* are used for preparing juice and tea for the treatment of diarrhoea and body aches by the Mama tribe of Bangladesh (Adnan *et al.* 2019).

Vivipary, a phenomenon where seed germinates within the fruits are also reported in some species (Tan & Rao 1981, Dintu *et al.* 2015, Bhuyan & Baruah 2021).

1.2 Taxonomy of the genus

In Flora of Zeylanica (1747), Linnaeus described the genus *Ophiorrhiza* as '*Ophiorrhiza*' with one species, *O. mungos* based on the collection of P. Hermann from Sri Lanka. Linnaeus (1753) in his well-known book Species Plantarum included two species of the genus *O. mitreola* based on Houston's genus *Mitra* (*Mitreola* described in Hortus Cliffortianus 1737) is now recognized as a member of the different genus *Mitreola* L. ex Schaeffer, under the family Spigeliaceae (Airy-Shaw 1973). Linnaeus reduced *Mitreola* to a synonym of *Ophiorrhiza* in his book Species Plantarum (1753). Linnaeus (1754), in his book Genera Plantarum described *Ophiorrhiza* as a different spelling of '*Ophiorrhiza*' and various authors have also accepted the orthographic variant. However subsequently, the spelling has been corrected to '*Ophiorrhiza*'.

In ancient times, many workers placed the genus under different families based on their morphological variations, it is characterized by 5-fid calyx, infundibuliform corolla with 5 lobes, 5 stamens, single style, bilocular ovary, 2 stigmas, 2-loculed capsule, herbaceous habit, opposite leaves and dichotomous cymose inflorescence. Jussieu (1789) placed *Ophiorrhiza* under the family Gentinaceae. Brown (1810) also placed the genus under Gentinaceae, showing the allied characters of *O. mungos* with the family Gentinaceae. Don (1825) followed by Blume (1826), Candolle (1830), Wight & Arnott (1834), Don (1834) classified the genus within the family Rubiaceae.

Bremekamp (1934 & 1952) initially divided the family into 4 subfamilies, namely Guettardoideae, Ixoroideae, Cinchonoideae and Rubioideae then into 6 subfamilies by adding 2 more subfamilies, namely Urophyllloideae and Ophiorrhizoldeae. Subsequently, in the year 1957 he added the seventh subfamily Gleasonioideae and in the year 1966 added the 8th subfamily Hillioideae. He treated *Ophiorrhiza* L., *Spiradiclis* Bl. and *Virectaria* Brem. into a new tribe named Ophiorrhizeae from the earlier tribe Hedyotideae. Later in 1954, he treated *Ophiorrhiza* as the type genus of the subfamily Ophiorrhizoldeae, although the name itself was not validly published. Verdcourt (1958) came across the occurrence of raphide crystals in the genera *Ophiorrhiza* and *Spiradiclis* and included both genera in the subfamily Ophiorrhizeae under Rubioideae, but excluded *Virectaria* from the subfamily due to the absence of

raphide crystals. Schumann (1891) suggested the presence of well-developed heterostyly in *Ophiorrhiza*, but Verdcourt (1958), Vuilleumier (1967) & Darwin (1976) do not agree with the presence of true heterostyly. Anderson (1973) regarded heterostyly in the Rubiaceae family as a balanced polymorphism, where certain plants produce flowers with receptive stigmas positioned above the anthers, while others produce flowers with receptive stigmas located below the anthers. This distinction corresponds with differences in corolla tube length and filament length. Anderson (1973) proposed an alternative view, suggesting that heterostyly represents a form of protandry, wherein pollen matures early and is shed either at or shortly after anthesis. Elongation of the style may be inhibited either before or after anthesis. Immature stigmas are temporarily enclosed within the corolla tube, positioned below the level of the anthers. Subsequently, the style elongates during or after pollen release, eventually exceeding the maturity of both the anthers and the stigmas. Based on the revision of the Pacific species of the genus *Ophiorrhiza* by Darwin in 1976, he suggested the incorporation of the genus into the tribe Hedyotidae, which has been supported by different authors.

1.3 Distribution of genus *Ophiorrhiza*

Genus *Ophiorrhiza* comprises about 382 species worldwide. According to Chen & Taylor (2011) the genus comprises about 200–300 species in tropical and subtropical Asia, Australia, New Guinea, the Pacific islands and 70 species have been reported from China, of which 49 are endemic to the region. About 21 species were recorded from Peninsular Malaysia (Hamjah 1994). The genus comprises about 30–35 species in the shady and moist-wet areas in Thailand's lowland areas and mountain forests (Phoowiang *et al.* 2009). *Ophiorrhiza* (Rubiaceae) is represented by about 150 species, distributed mainly in the Indo-Malay region (Airy-Shaw 1973, Mabberley 2008) which extends from Sri Lanka, eastern India and north-eastwards to China, Taiwan, Japan, and south-eastwards through Myanmar, Thailand, Malay, Java, Sumatra, Borneo and Fiji to the Society Islands (Deb & Mandal 1997). According to Balgooy (1971), the diversity of the genus *Ophiorrhiza* attained its greatest extent in New Guinea and south-eastern Asia and New Guinea is regarded as the centre of origin of the genus (Darwin 1976).

The genus is found in peninsular India, predominately in the Anamalai hills, Nilgiri hills, Palni hills, Tirunelveli hills, north-eastern Himalaya from Nepal, Bhutan to Arunachal Pradesh, Assam, Meghalaya, Sikkim and all other eastern states. Mainly the

genus is distributed in the Western Ghats, the North Eastern Himalaya and the Eastern states of India, but rarely distributed in the western states of India. Most of the species of South East Asia have close affinities with the species of North East India and Peninsular Indian species have lesser affinity with the species of South East Asia, but are closely related to themselves (Deb & Mondal 1997). *Ophiorrhiza*, a genus in the family Rubiaceae, comprises 52 species in India, predominantly found in the Western Ghats and northeastern states. (Akhilesh *et al.* 2021). Nayar *et al.* (2014) reported that a total of 21 species and 7 varieties have been reported from the Western Ghats, of which 17 species and 2 varieties are endemic to the region. Kanjilal *et al.* (1939) recorded with 15 species of *Ophiorrhiza* from undivided Assam.

1.4 Significance of the present study

Historically, plant taxonomy has primarily relied on the comparison of external morphological characteristics (Hicky & Wolfe 1975, Bell & Bryan 2008, Viscosi & Cardini 2011). However, in recent times, characteristics of organisms drawn from various disciplines have been increasingly utilized as a synthetic approach to taxonomy. Many researchers have emphasized the importance and significance of morphological and anatomical characters in taxonomy (Stace 1965, Dilcher 1974, Fischer & French 1978, Paliwal & Anand 1978). From the survey of the literature, it has been observed that much taxonomic work has not been done on the genus except for a few in certain species. It is possible that all types of flowers would not be present in the same area or at the same period, which would makes taxonomic identification of the species difficult, so features such as leaf epidermal characters, stomatal characters, leaf architecture and anatomy of certain parts of the plant have been considered reliable in plant systematic (Wilkinson 1979, Deng *et al.* 2013). In this study, the inclusion of morphology and microscopic features such as foliar and stem anatomical characters has been incorporated for comparative analysis among various species of the genus to ensure accurate taxonomic assessment. The primary objective of this study is to elucidate the taxonomical status of the genus, species distributions and diagnostic characters. Numerous *Ophiorrhiza* species fall within the categories of rare, endangered, not evaluated, or even extinct category (Barbhuiya *et al.* 2014), so effective conservation measures should be employed using different modelling approach, which will help in

improving conservation status of the species with introducing potential areas and habitat for reintroduction.

1.1 Aim and Objectives

The present study is aimed to prepare a comprehensive taxonomic account of the genus *Ophiorrhiza* L. occurring in Assam. The objectives include:

1. To prepare a detailed taxonomic description based on the critical examination of the fresh collections, type material, herbarium specimens, protologues, and literatures.
2. To work out the taxonomic attributes of the taxa through morpho-anatomical, foliar epidermis, and leaf architecture studies.
3. To study the distribution of taxa in Assam and to prepare a distributional map for the taxa under the genus.
4. To categorize the threatened status of the flora and to propose effective conservation measures by using Environmental Niche Modelling (ENM).