CHAPTER 5

5. DISCUSSION

5.1 Taxonomy of the genus *Ophiorrhiza* L. in Assam

5.1.1 New findings and critical notes

Ophiorrhiza is a large genus of flowering plants belonging to the fourth largest family of Rubiaceae. The taxa under the genus are widely distributed in tropical and subtropical regions of the world. In this study, it was noted that the taxa belonging to the genus *Ophiorrhiza* are shade and moist loving members significantly found in tropical wet evergreen, moist deciduous mixed, and subtropical broadleaf hills forests of Assam.

After consultation of the literature and herbarium specimens followed by field surveys in various parts of Assam, critical findings relevant to the new distribution were inferred for the *Ophiorrhiza* species of Assam. The findings has been enumerated below:

In Flora of Assam, Kanjilal *et al.* (1939) worked on the genus *Ophiorrhiza* and reported 15 species with a description of 3 species from erstwhile Assam (which includes present day Meghalaya, Mizoram, Nagaland, N.E.F.A and Sylhet district of Bangladesh).

During the current investigation, it was noted that several species reported by Kanjilal *et al.* (1939) have not been found to have a range within the current jurisdiction of Assam. The following is a list of such species, together with critical notes on their present status and distribution:

1. *Ophiorrhiza pauciflora* Hook.f. has been found to have distribution in Meghalaya and Arunachal Pradesh. The species has no distribution record from Assam so far. The herbarium present at CAL and ASSAM shows the species collected from Meghalaya and Arunachal Pradesh.

2. *Ophiorrhiza subcapitata* Wall. ex Hook.f. has been found to be endemic to Meghalaya.

3. *Ophiorrhiza wallichii* Hook.f. has been found to have distributed in Meghalaya, Arunachal Pradesh, Nagaland, Myanmar.

4. *Ophiorrhiza griffithi* Hook.f. has been found to be distributed in Nagaland and Myanmar only.

5. *Ophiorrhiza rosea* Hook.f. mainly distributed in Nagaland, Sikkim and Darjeeling.

6. *Ophiorrhiza treutleri* Hook.f. has been found to be distributed in Sikkim, Meghalaya and West Bengal. On critical examination of herbarium sheets of ASSAM and CAL belonging to *Ophiorrhiza tingens*, it was found that there were no herbarium collections of the species from the present political boundary of Assam.

However, as stated by Fischer (1940) the species was collected by Simons from Nowgong (now Nogaon) without a collection number or year of collection. In the present study, no relevant herbarium pertaining to Simon's collection have been traced out. Since 1940, the species has not been collected from anywhere within the present political boundary of the state. So, based on a study on its occurrence and herbarium specimens, the species collected from the present study area would be a new distribution record for Assam.

Apart from these, all the other species mentioned in the literature had valid distribution reports within the present boundary of Assam. The two species, *O. calcarata* and *O. harrisiana* mentioned in the literature are presently treated as synonyms under the accepted names. *O. calcarata* is presently placed as a synonym under *Ophiorrhiza repens* and *O. harrisiana* placed as a synonym under the accepted name *Ophiorrhiza rugosa* var. *prostata*.

Barooah & Ahmed (2014) mentioned the occurrence of 8 species of *Ophiorrhiza* from Assam. Out of them, the valid occurrence and distributional reports of *O. nutans* are untraceable from the present study. The present research work results in the documentation of 10 taxa from the study area, viz., *O. mungos, O. hispida, O. ochroleuca, O. oppositiflora, O. succirubra, O. rugosa* var. *prostata, O. rugosa, O. rugosa* var. *argentea, O. fasciculata, and O. tingens.* In the present study on the genus *Ophiorrhiza,* it was observed that the species were mostly found in the moist and shady areas of the forest, mostly in the evergreen forest areas of North Lakhimpur, the moist semi-evergreen forest of Karbi Anglong and Dima Hasao, Cachar, and some parts of Kamrup (M) districts, which recorded the highest numbers of species (Table 5.1).

The distribution pattern of genus *Ophiorrhiza* shows a range along the altitudinal gradient. In the course of this study, it was noted that species within the genus are shade loving, predominantly found in damp areas near mountainous terrain and hilly slopes. Maximum number of species occurring in altitude ranges of 100–300 m and 400–600 m and 1 species occurring in between 600–800 m and 700–1000 respectively. (Table 5.1 & Fig 7)

Table 5.1 Distribution pattern of the investigated taxa

Name of taxa	Altitude	Distribution in Assam	Distribution in other states	Distribution outside India
O.mungos	400–600 m	Kamrup (M), Morigaon, Jorhat, Cachar, Karbi Anglong, Golaghat	Sikkim, Meghalaya, Nagaland, Manipur, Mizoram, Tamil Nadu,Kerela, Nicober Island	Bangladesh, Nepal, Jawa, Malaya, Myanmar, Sri lanka, Sumatera, Thailand, Vietnam
O. ochroleuca	700–1000 m	Dima Hasao, Kamrup (R), Cachar	Arunchal Pradesh, Mizoram	China, Myanmar, Vietnam
O.succirubra	100–200 m	Lakhimpur, Cachar, Kamrup, Morigaon	Sikkim, Meghalaya, West Bengal	Myanmar, China, Nepal, Tibet
O. fasciculata	600–800 m	Dima Hasao	Western Himalaya, Sikkim, West Bengal, Orissa, Khasi Hills andMizo hill	Myanmar, Nepal, Bhutan
O.oppositiflora	100–200 m	Kamrup (M)	Meghalaya, ArunachalPradesh, Nagaland, Tripura	Myanmar, Nepal, Bhutan
O. rugosa	200–500 m	Lakhimpur, West Karbi Anglong	Sikkim, West Bengal, Bihar, Orissa, Maharastra, Goa	Myanmar, Nepal, Sri Lanka, Thailand, Tibet, Vietnam, Bangladesh, Cambodia, China, Malaya

O. rugosa var. *argentea*	200–400 m	Lakhimpur, Morigaon, Karbi Anglong, Kokrajhar	Sikkim, Meghalaya, Andaman & Nicobar Islands, Karnataka	Nepal, Myanmar, Thailand, Bangladesh, Sri Lanka
O. rugosa var. *prostata*	100–300 m	Lakhimpur, WestKarbi Anglong	Bihar, Orissa, Maharashtra, Goa, Tamil Nadu, Kerala	Nepal, Bhutan, Sri Lanka, Malay, Myanmar
O. tingens	400–600 m	West Karbi Anglong, Golaghat	Meghalaya, Nagaland	Bangladesh, Myanmar
O. hispida	400–600m	Lakhimpur	Arunachal Pradesh	Bangladesh

Out of the 10 taxa of *Ophiorrhiza*, 3 species were found to have significant distributional notes in Assam as well in north-east India. Upon the scrutiny of relevant literatures and herbarium it was found that *O. tingens* and *O. hispida* both endemic to northeast India. Through literature survey, it was found that *O. fasciculata* is only known from Nepal, Bhutan, Uttar Pradesh, Orissa, Uttarkhand, West Bengal, Sikkim, Darjeeling, Arunachal Pradesh, and Mizoram. In the present study, the species was recorded from Jatinga area of Dima Hasao district of Assam. Kanjilal *et al.* (1939) recorded the distribution of the species in undivided Assam (from NEFA). No existing literature (Hooker 1882, Kanjilal *et al*. 1939, Barooah & Ahmed 2014, Barbhuiya 2014) and herbarium collections from the study area can be traced which can refer to the occurrence of the species from the political boundary of Assam. Therefore, it is a new distributional record of the species for the state of Assam and was established in the present study (Bhuyan & Baruah 2022).

The month-wise response of both flowering and fruiting of the taxa shows the spring season and monsoon season as the most favourable seasons. The maximum number of species mostly flowers in the months of April to June. There were the fewest species which flowers in the months of March and December (Table 5.2 & Fig 8).

Table 5.2 Month-wise record of flowering and fruiting in different species of *Ophiorrhiza*

Name of the taxa	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**
O. mungos				+	+	+	+	+	+	+		
O. ochroleuca										+	+	+
O.succirubra			+	+	+	+	+					
O. fasciculata										+	+	
O.oppositiflora			+	+	+	+	+	+	+			
O. rugosa				+	+	+	+	+	+	+	+	
O. rugosa var. *argentea*				+	+	+	+	+	+	+	+	
O. rugosa var. *prostata*				+	+	+	+	+	+	+	+	+
O. tingens			+	+	+	+	+	+				
O. hispida								+	+	+	+	+

5.2 Morphological peculiarities

Peculiar features were recorded in some investigated taxa from the study area. These are presented below.

5.2.1 Report of the occurrence of Vivipary

This study marks the initial observation of vivipary (precocious germination) in *O. rugosa* and was established by Bhuyan and Baruah in 2021. Such feature has not been observed in the other investigated taxa. Dintu *et al.* (2014) and Wu *et al.* (2018) also reported this phenomenon in *Ophiorrhiza mungos* and *Ophiorrhiza macrocarpa* respectively.

5.2.2 Morphological variation

In the present study, a new species, *O. recurvipetala*, has been reported from the Dima Hasao district, Assam. The species epithet was based on the nature of corolla. When *O. recurvipetala* was described, the species was found close to *O. ochroleuca*, but differed in many vegetative and reproductive characteristics (Bhuyan *et al.* 2021).

Hareesh *et al.* (2022) merged *O. recurvipetala* under *O. ochroleuca*. According to the present study, *O. recurvipetala* is an intermediate state of *O. ochroleuca*, and the species has many morphological forms and variations in leaf shape, and colour of flower. In the genus *Ophiorrhiza*, some characteristics like leaf shape, inflorescence size, hair pattern in the corolla tube, length of style, and stamen were used in distinguishing the species. The presence of a prominent yellowish ring in the corolla throat and heterostyly in *O. ochroleuca* was reported by Hareesh 2022, collected from Arunachal Pradesh, but it was not observed when *O. recurvipetala* was described. So based on the earlier study on *O. ochroleuca* (Deb & Mandal 1997), *O. recurvipetala* has variations in some morphological characters.

Interestingly, it was noted that there are some species viz, *Calamus javensis* and *Calamus innermis* (Handerson 2020), were considered as to be 'Ochlospecies' (different morphological forms or variations in different environment). Hareesh & Sabu (2022) observed numerous morphological variations and forms within *O. ochroleuca* in north-east India. This raises the question of whether *O. ochroleuca* can be classified as an Ochlospecies. It can be summarized that more intensive study is required to know the morphological variation in the species.

5.2.3 Heterostyly

Fischer (1940) initially reported the occurrence of heterostyly, with two style types within the same plant in *O. tingens*, advocating for additional research to substantiate this finding. Later,

Deb & Mandal (1997) confirmed this phenomenon, noting long style flowers with small filaments and short style flowers with long filaments in the same plant. In the current study, a similar condition was observed, but in a peculiar way. In this study it was observed that two different kinds of style presence in *O. tingens*. The plant with ovate leaves was found to have a long style with short a filament flower and plant with elliptic leaves found to have a short style with a long filament.

5.3 Macro and micromorphological significance

5.3.1 Macromorphological findings

The habit of *O. mungos, O. succirubra, O. oppositiflora, O. fasciculata, O. ochroleuca* are herb in nature while prostate herb habit seen in *O. rugosa, O. rugosa* var. *prostata, O.hispida* and *O. rugosa* var. *argentea*.

The laminar shape shows variations among the studied species in Assam. Laminar shape is ovate to lanceolate in *O. fasciculata* and *O. rugosa;* broadly ovate to lanceolate in *O tingens;* elliptic to lanceolate in *O. succirubra*, *O. mungos* and *O. ochroleuca*; Ovate in *O rugosa* var. *prostata* and *O hispida;* lanceolate in *O. oppositiflora* and narrowly lanceolate in *O. rugosa* var. *argentea.*

Leaf apex is widely acute to acuminate, caudate in *O. tingens*; acuminate apex in *O. succirubra, O. ochroleuca, O. rugosa* var. *argentea, O. mungos, O. oppositiflora;* acute apex occurs in *O. fasciculata and O. hispida*; obtuse-acute apex in *O. rugosa*, subacute apex in *O. rugosa* var. *prostata*.

Leaf base is tapering in *O. rugosa*, *O. tingens* and *O. fasciculata*; acute in *O. succirubra, O. rugosa* var. *argentea*, *O. oppositiflora*; attenuate in *O. ochroleuca*; subcordate in *O. rugosa* var. *prostate*; obtuse in *O. hispida* and narrowed in *O. mungos.*

Stipules are interpetiolar, found to be caducous to persistent in the studied species. Persistent in *O. rugosa, O. tingens, O. fasciculata, O. succirubra, O. rugosa* var. *argentea, O. oppositiflora, O. rugosa* var. *prostata* and *O. hispida* where as caducous in *O. mungos* and *O. ochroleuca.* Stipule shows variation in the shapes among the studied species. Stipule is filiform to bifid in *O. rugosa, O. tingens*; subulate in *O. oppositiflora, O. rugosa* var. *argentea*; lanceolate in *O.succirubra, O. fasciculata*; Oblate-lanceolate in *O. hispida*; triangular in *O.mungos*; triangular at base in *O. ochroleuca* and *O. rugosa* var. *argentea*.

Inflorescence is usually terminal in all the species but it is both terminal and axiallary in *O. oppositiflora.* Helicoid cyme type of inflorescence was observed in *O. rugosa, O. rugosa* var. *argentea, O. rugosa* var. *prostata*; Corymbose cyme was observed in *O.*

succirubra, *O.mungos*, *O. oppositiflora*; fascicled inflorescence was observed in *O. fasciculata*; trichotomous helicoid cyme was observed in *O.ochroleuca*; Capitate cyme was observed in *O. hispida*.

The presence of villous ring in corolla tube is an important character in the species of the genus. The villous ring within the corolla tube was observed in *O. hispida, O. mungos, O. tingens, O. rugosa* var. *prostata, O. rugosa, O. rugosa* var. *argentea, O. oppositiflora* and *O. ochroleuca.* It is not observed in *O. fasciculata* and *O. succirubra*. Both long and short styles were observed in the studied species of *Ophiorrhiza* in Assam.

Capsule is ovate-oblong in *O. rugosa* var. *prostata, O. rugosa, O. mungos, O. oppositiflora, O. hispida*; obovoid in *O. ochroleuca*; ovate in *O. rugosa* var *argentea, O. succirubra* and *O. fasciculata*.

5.3.2 Micromorphological significance on foliar epidermal studies of the investigated taxa

5.3.2.1 Qualitative of foliar epidermal study

The polygonal and irregular epidermal cell shape was the dominant type found on both the adaxial and abaxial sides of most of the *Ophiorrhiza* species in Assam, followed by the wavy nature of the epidermal cell. Polygonal type of epidermal cell shape was found on both adaxial and abaxial sides of *O. tingens, O. succirubra, O. rugosa* var. *prostata* respectively. An irregular type of epidermal cell shape was found on the adaxial and abaxial surfaces of *O. hispida, O. oppositiflora, O. rugosa, O. ochroleuca, O. fasciculata*. The wavy nature of cell shape was only found on adaxial and abaxial side of *O. mungos*. A combination of two cell shape type (Irregular and Polygonal) was found only on the adaxial and abaxial surface of *O. rugosa* var. *argentea*.

Epidermal cell wall pattern varies among the investigated taxa of genus *Ophiorrhiza*. Irregularly wavy cell wall was present on both adaxial and abaxial sided of *O.tingens* and only on the abaxial side of *O. hispida*. Slightly wavy lobed cell wall and strongly wavy cell wall was observed on both the side of *O. succirubra* and *O. ochroleuca* respectively. Irregularly wavy lobed cell wall was observed on adaxial and abaxial surface of *O. oppositiflora* and *O. fasciculata*. Irregular cell wall is present on both the surface of *O. mungos* and *O. rugosa* var. *argentea* respectively. The combination of two types epidermal cell wall pattern (Irregular & undulating) was observed on both adaxial and abaxial surface of

O. rugosa var. *argentea* and only on adaxial surface of *O. hispida*. Irregularly lobed cell wall was only reported on both surfaces of *O. rugosa.*

Most of the *Ophiorrhiza* species of Assam lacks stomata on the adaxial side, so the leaves are known as hypostomatic in nature. Presence of stomata on both adaxial and abaxial surface of leaves was recorded in *O. hispida*, so it is known as amphistomatic in nature.

Anisocytic type of stomata is the common type found on the abaxial side of most of the *Ophiorrhiza* species of Assam followed by hemiparacytic, anomocytic, paracytic, actinocytic, diacytic and rubiceous type repectively. Single type of stomata (actinocytic and rubiceous) were found in *O. ochroleuca* and *O. mungos* whereas adaxial side of *O. hisp*ida showed the occurrence of only paracytic type of stomata. The combination of two or more types of stomata were observed in *O. tingens*, *O. succirubra*, *O. oppositiflora*, *O. rugosa*, *O. fasciculata*, *O. rugosa* var. *argentea*, *O. rugosa* var. *prostata* and as well as on the abaxial surface of *O. hispida* .

Shape of stomatal pore varies among the studied taxa of *Ophiorrhiza* in Assam. Elliptic shape of stomatal pore was observed in *O. succirubra*, *O. ochroleuca*, *O.rugosa* var. *prostata*. Narrowly elliptic shape was found in *O. oppositiflora, O. rugosa and O. fasciculata.*Broadly elliptic shape of stomatal pore was only found in *O. tingens* where as combination ofnarrowly elongated elliptic shape of stomatal pore was observed in *O. rugosa* var. *argentea*. Narrowly elliptic shape of stomatal pore was found on adaxial surface of *O. hispida* whereas elliptic shape of stomatal pore was observed on the abaxial side of *O. hispida*.

The presence of trichomes and raphides is also an important identifying character of the *Ophiorrhiza* species.

Trichomes were present on both the surface of almost all the species of the genus. Trichomes are only observed on the adaxial side of *O. fasciculata* and *O. rugosa* var. *prostata*. Trichomes were completely absent in *O. ochroleuca*. Needle like raphides are present only on the adaxial surface of *O. fasciculata.*

5.3.2.2 Quantitative foliar epidermal study

Variations in the sizes of epidermal cells, stomata, stomatal pores, and subsidiary cells are observed among the studied taxa. The mean number of epidermal cells per vision on the adaxial side is highest in *O. rugosa var. argentea* (46) and lowest in *O. mungos* (28). The mean number of epidermal cells per vision on the abaxial side is highest in *O.*

tingens (37) and lowest in *O. ochroleuca* (22) (Table 4.2 & Fig 9).

The length of epidermal cell on adaxial side is highest in *O. fasiculata* (76.6 μm) and lowest in *O. tingens* (36.2μm). The breadth of epidermal cell on adaxial side is highest in *O. ochroleuca* (22.5 μm) and lowest in *O. rugosa var. prostata* (15.8μm). The length of epidermal cell on abaxial side is highest in *O. fasiculata* (76.4 μm) and lowest in *O. rugosa* (36.1μm). The breadth of epidermal cell on abaxial side is highest in *O.tingens* (24.1 μm) andlowest in *O. rugosa var. prostata* (15.8 μm) (Table 4.2 and Fig 10).Stomatal index is highest in *O. hispida* (abaxial) (36.67) and lowest in *O. mungos*(28.40) (Table 4.2 & Fig 11). The length of stomata is highest in *O. ochroleuca* (40.3 μm) and lowest in *O. succirubra* (18.1 μm). The breadth of stomata is highest in *O. ochroleuca* (19.8 μm) and lowest in *O. succirubra* (8.7 μm) (Table 4.2 & Fig 12). The length of stomatal pore is highest in *O. ochroleuca* (21.8 μm) and lowest in *O. rugosa var. prostata* (10.8μm). The breadth of stomatal pore is highest in *O. ochroleuca* (6.8μm) and lowest in *O. rugosa var. argentea* (1.6μm) (Table 4.2 & Fig 13). The length of subsidiary cell is highest in *O. ochroleuca* (56.3μm) and lowest in *O. tingens* (29.9μm). The width of subsidiary cell is highest in *O. oppositiflora* (60.9μm) and lowest in*O. tingens* (18.4μm) (Table 4.2 & Fig 14).

5.3.2.3 ANOVA analysis

ANOVA analysis of eight parameters of foliar epidermis demonstrates statistically significant variation among taxa in epidermal size on both upper and lower surfaces, stomatal size, subsidiary cell size and stomatal pore size respectively. ($F= 1405, 87.97, 76.29, 452.2$ respectively; $P < 0.0001$).

5.3.3 Micromorphological significance on leaf architectural studies of the taxa

5.3.3.1 Qualitative Leaf architecture study

Opposite and decussate phyllotaxy is the most common and dominant in the genus *Ophiorrhiza* followed by opposite phyllotaxy which is only recorded in *O. oppositiflora*.The leaf organization is simple in all the investigated taxa of the genus.

Among all the species studied in the genus *Ophiorrhiza,* entire margin was the most common character observed. The investigated taxa of *Ophiorrhiza* exhibited variation in lateral vein patterns, with *O. mungos* having the highest count of lateral veins (18), while *O. rugosa* var. *prostata* exhibited the lowest count (4).

5.3.3.2 Quantitative Leaf architecture study

The primary (1°) vein category is pinnate in all the examined taxa. It is the constant character of members under the genus *Ophiorrhiza*.

Under the 2° vein category, weak brochidodromous features are common among all the investigated taxa.

Under the 2° vein spacing, uniform spacing was the most common and dominant character observed among the species followed by irregular spacing and spacing gradually decreasing towards the base. Uniform spacing was recorded in *O. ochroleuca, O. rugosa* var. *argentea*, *O. rugosa, O. rugosa* var. *prostata, O. mungos, O. hispida, O. oppositiflora.* Spacing decreasing towards the base was recorded in *O. fasciculata* and *O. succirubra*. Only *O. tingens* exhibits irregular 2° vein spacing.

Inter-secondary veins are weak in *O. fasciculata, O. rugosa* var. *argentea, O. ochroleuca* and *O. oppositiflora*. Strong inter-secondary veins are exhibited by *O. succirubra* while inter-secondary veins are absent in *O. tingens, O. rugosa, O. rugosa* var. *prostata, O. mungos* and *O. hispida.*

Under 3° vein category random recticulate was found to be most common and dominant among the studied taxa in Assam followed by alternate percurent and dichotomizing. Random reticulate 3° vein category was recorded in *O. rugosa, O. rugosa* var. *prostata, O. ochroleuca, O. rugosa* var. *argentea, O. mungos, O. hispida, O. oppositiflora. O. fasciculata* and *O. succirubra* exhibits alternate percurrent 3° vein while *O. tingens* recorded with dichotomizing 3° vein category.

Regular polygonal reticulate 4° vein category was found highest amongst the investigated species of *Ophiorrhiza* in Assam followed by dichotomous and alternate percurrent 4° vein category. Regular polygonal reticulate 4° vein category was exhibited by *O. mungos, O. hispida, O. oppositiflora, O. rugosa* var. *prostata, O. succirubra* and *O. rugosa*. *O. tingens, O. rugosa* var. *argentea and O. fasciculata recorded with alternate percurrent* 4° vein category while *O. ochroleuca* recorded with dichotomous 4° vein category.

The areolation pattern amongst the studied taxa was mostly moderately developed followed by well developed areoles. The highest areolation pattern was noted as 5, 4 or more sided category followed by 3-sided category.

The dichotomously branched and freely ending ultimate veins (i.e., F.E.V.S) were recorded as the most common type amongst all studied species of *Ophiorrhiza* in Assam,

followed by curved F.E.V.S, 1 or more branched (1+), 2 or more branched (2+), Y shaped branched and lastly unbranched F.E.V.S. Dichotomously branched in Y shaped free vein endings were observed in *O. rugosa* var. *prostata, O. mungos, O. hispida, O. oppositiflora* while *O. succirubra* exhibits only dichotomous branched and linear types of F.E.V.S. An unbranched free vein ending has been observed in *O. fasciculata*.

5.4 Anatomical significance of the species within the genus

The presence of a singular layer of epidermis is a consistent feature in the stem anatomy of the studied taxa within the genus. The transverse section of stem anatomy exhibited a predominantly circular shape across all investigated taxa, except for *O. fasciculata* and *O. rugosa* var. *argentea*, which shows an oval shape.

Sub epidermal cells were composed of parenchyma cells in *O. ochroleuca, O. mungos, O. rugosa* var. *prostata*, *O. rugosa*, *O. oppositiflora* whereas in *O. fasciculata*, *O. hispida, O. rugosa* var. *argentea*, *O. succirubra* and *O. tingens* sub epidermal cells were composed of collenchymatous cells.

Trichome in epidermis layer was mostly observed in the investigated taxa except in *O.fasciculata* and *O. rugosa.*

Vascular bundle is arranged in continuous patches of ring like structure and pith is composed of parenchyma cells in all the investigated taxa.

Calcium crystals or oxalate was observed inside the parenchyma cells of pith in *O. rugosa, O. succirubra, O. rugosa* var. *argentea*. Needle like raphides were observed in *O. fasciculata, O. rugosa, O. rugosa* var. *argentea*, *O. rugosa* var. *prostata, O. succirubra, O. mungos* and *O. ochroleuca*.

5.5 Studies using Ecological Niche Modeling (ENM) on threatened species

ENM study of two species, viz., *O. hispida* and *O. tingens* was undertaken. Due to various anthropogenic factors and road construction, species are at high risk of extinction. Inorder to protect the plant from future extinction, ENM was conducted for both plants. The NDVI parameter is used as a variable in the modelling to determine the habitat suitability of both species. The ENM in the present study showed overall good results based on the AreaUnder Curve (AUC) value and test.

The training AUC is 0.98 and the test AUC results 0.96 for *O. hispida* which show very good result according to a model. The environmental variable eu9_1_eur shows the

highest gain when used in isolation and has important information by itself.

The training AUC results 0.84 and the test AUC results 0.63 for *O. tingens* which reveals a satisfactory result according to the model. The environmental variable eu5_1_eur shows the highest gain when used in isolation and has important information by itself.

The results would be quite helpful in the management of these species in their natural habitat and provide an effective means of conservation.

Table 5.3 List of the species of *Ophiorrhiza* recorded in present and past studies

Name of thetaxa	**Species distribution recorded by Hooker (1882)**	**Species distributionrecorded by Kanjilal et al. (1939)**	**Species distribution recorded by Deb& Mandal (1997)**	**Species distribution recorded by Barooah & Ahmed (2014)**	**Species distribution recorded during the present work (2018–2022)**
O. mungos	+	+	+	+	+
O. ochroleuca	+	+	+	+	+
O.succirubra	+		+	+	+
O. fasciculata	+	+	+		+
O.oppositiflora	+	+	+	+	+
O. rugosa			+		+
O. rugosa var. *argentea*	+		+		+
O. rugosa var. *prostata*	+	+	+	+	+
O. tingens			+	+	+
O. hispida	+	+	+	+	+

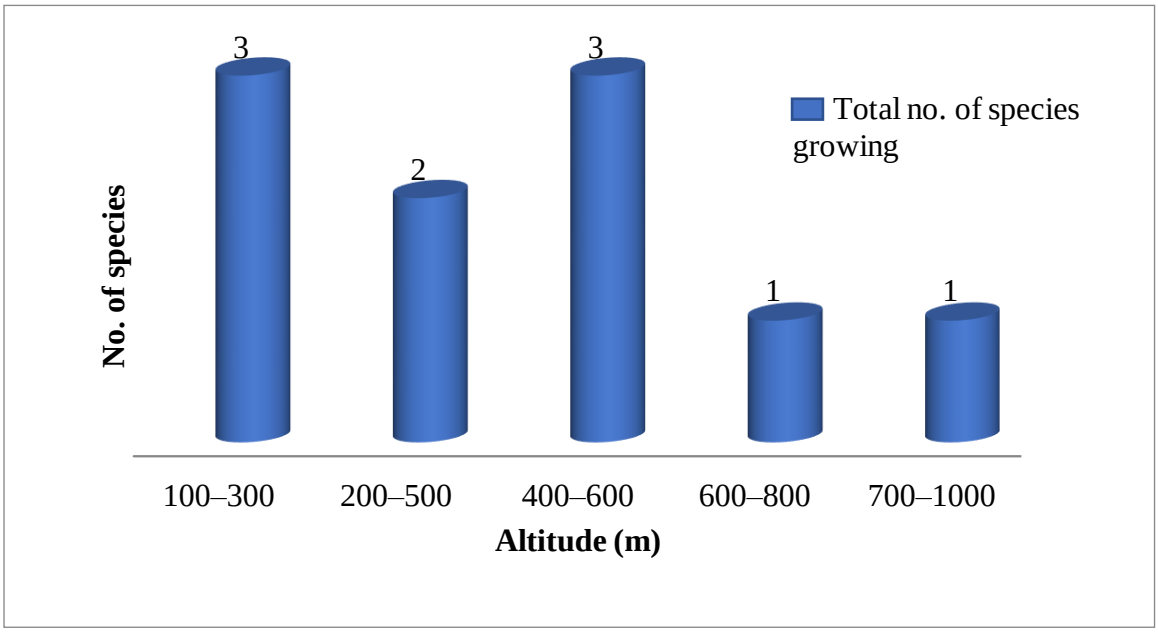

Fig 17 Altitudinal distribution of different species of *Ophiorrhiza*

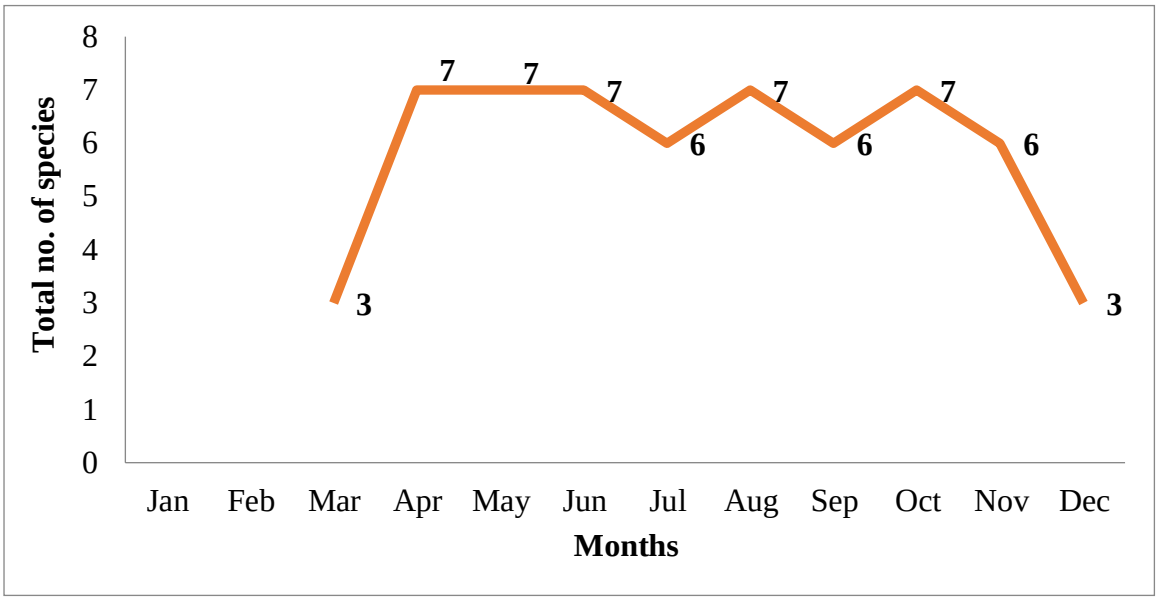

Fig 18 Graphical representation of the month-wise flowering and fruiting in the investigated taxa

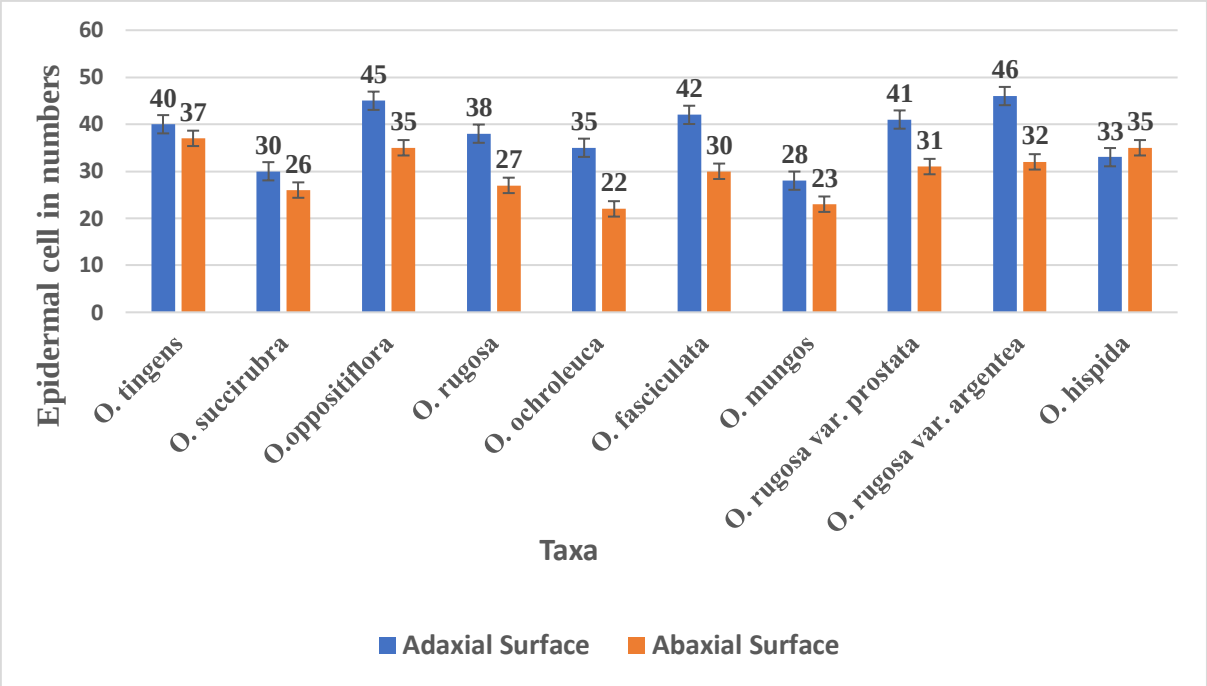

Fig 19 Variation in the number of epidermal cells on both surfaces among the investigated taxa

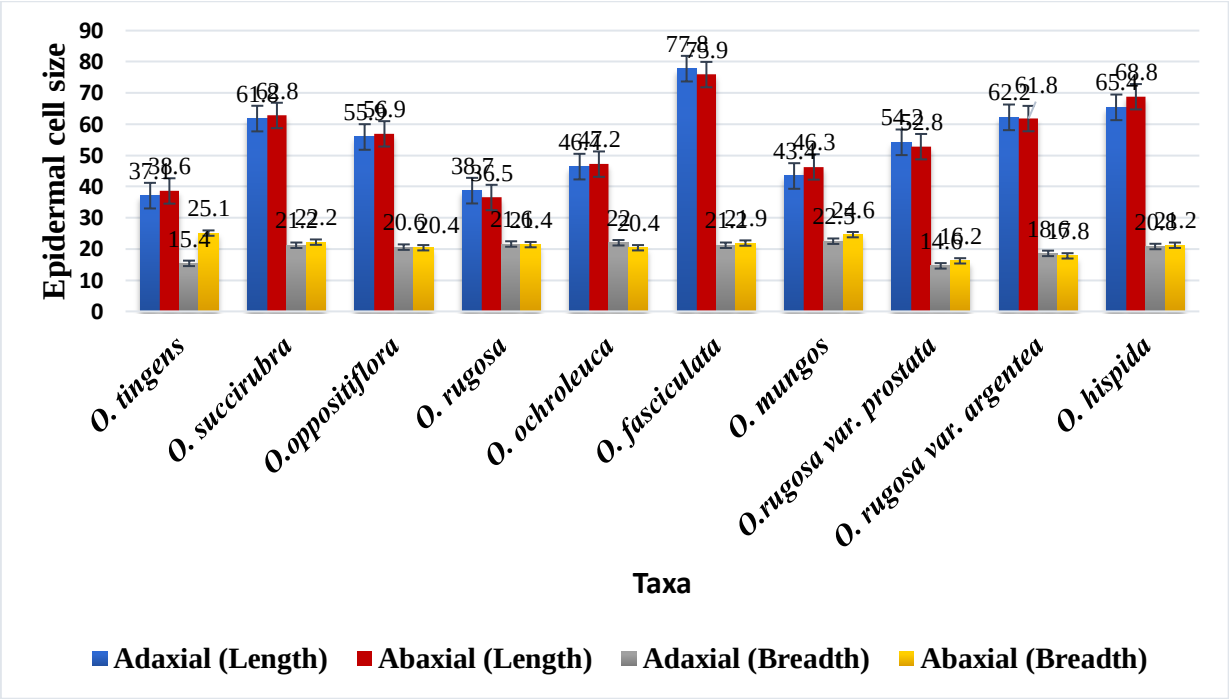

Fig 20 Variation in the size of epidermal cells on both surfaces

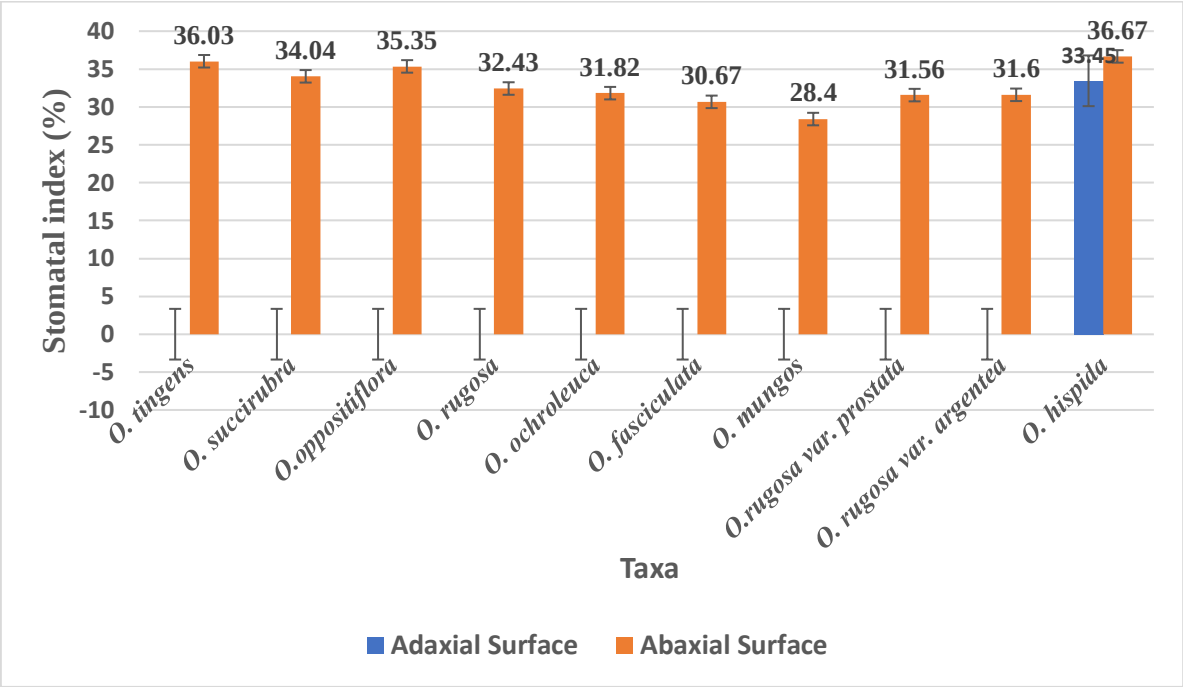

Fig 21 Variation in the stomatal index on both surfaces among the investigated taxa

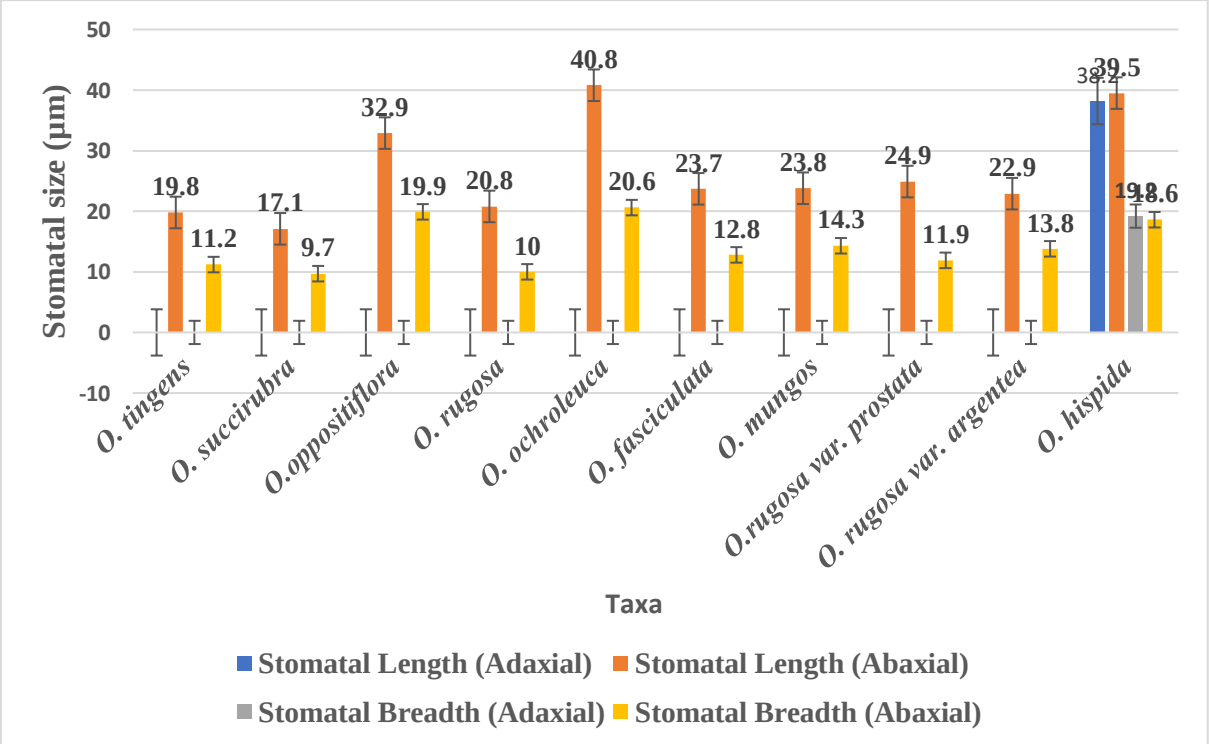

Fig 22 Variation in the stomatal size on both surfaces among the investigated taxa

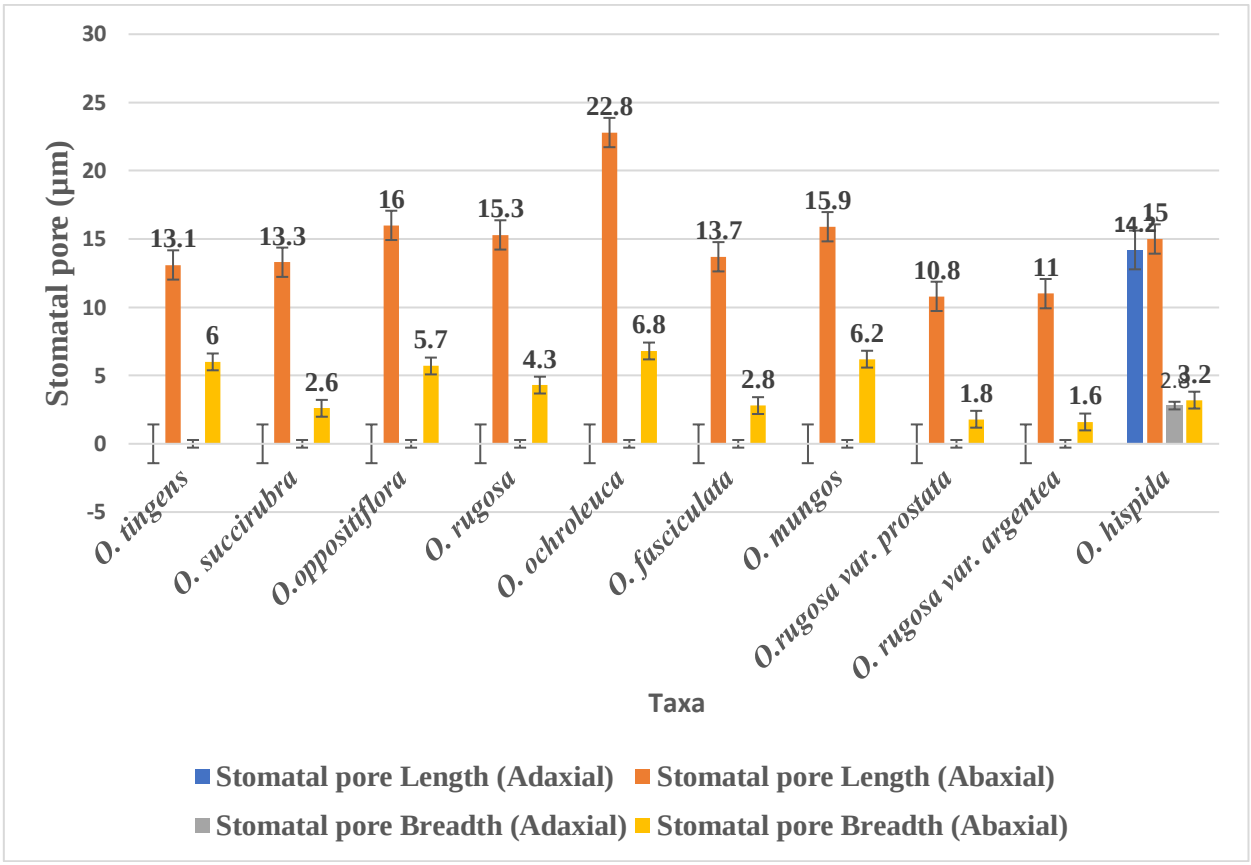

Fig 23 Variation in the stomatal pore size on both surfaces among the investigated taxa

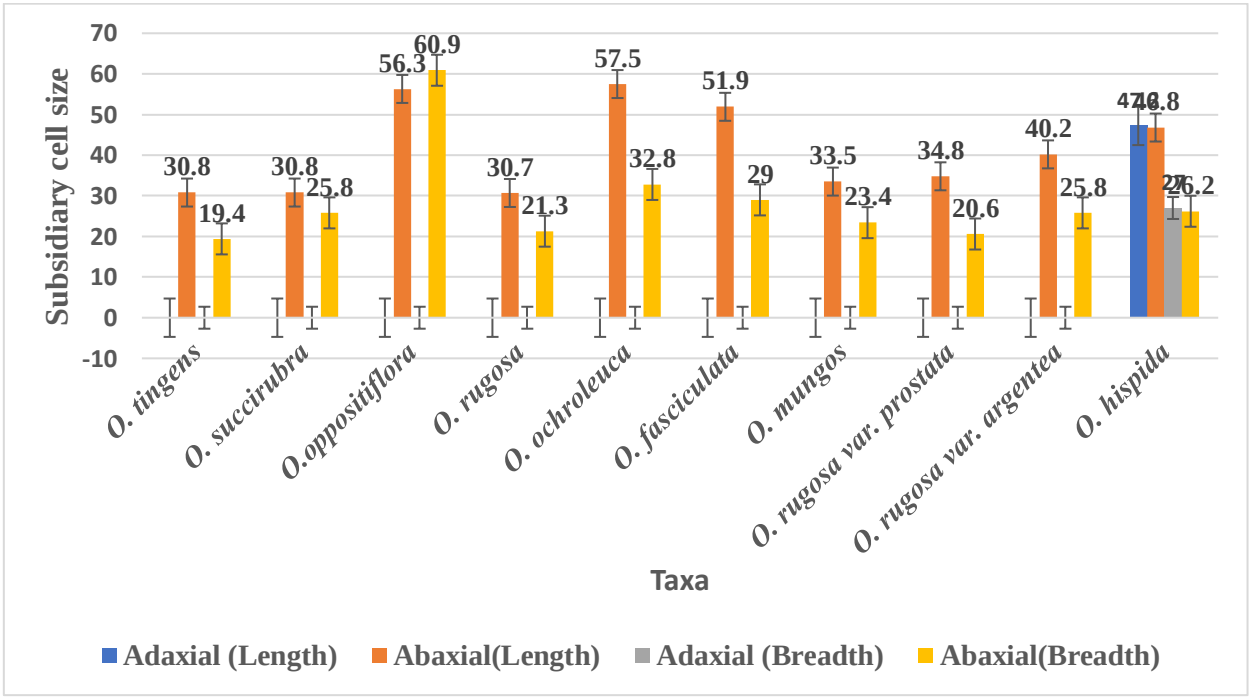

Fig 24 Variation in the subsidiary size on both surfaces among the investigated taxa