CHAPTER 4

4. RESULTS

Plant taxonomy is a large branch of plant biology which traditionally deals with morphological characters of the plants. But in recent times, incorporation of other branches like anatomy, palynology, embryology, cytology along with morphology provides better additional characters and ascertain certain characteristics within a genus and families and also help in determining affinities among the taxa.

In the present work, in addition to external morphology, certain taxonomic attributes like foliar epidermal features, leaf architectures and stem anatomy have been included for proper taxonomic studies and to provide proper taxonomic assessment to the genus.

4.1 Systematic enumeration of the genus *Ophiorrhiza*

The present work is a result of an investigation of the genus *Ophiorrhiza* in Assam. As an outcome of the investigation, a total of 10 taxa were recorded from the different parts of the studied area. The species distribution map of the study area was also presented depicting the places of collection (Fig 1.).

The Genus *Ophiorrhiza* L.

Linneaus, Fl. Zeyl. 239. 1747; Mat. Med. 1:79. 1749; Sp. Pl. 1: 150. 1753; Gen. Pl. 74. 1754; Syst. Nat. 920. 1759; Burman, Fl. Ind. 42. 1768; Juss, Gen. Pl. 143.1789; Brown, Prodr. 1: 450. 1810; Roxburgh, Fl. Ind. 2: 546. 1824; Don, Prodr. 135. 1825; Gaudich in Freycin. Voy. Bot. 97. 1829; DC. Prodr. 4: 415. 1830; Don, Gen. Syst. Gard. Bot. 3: 522. 1834; Wight & Arnold, Prodr. 405. 1834; Gray, Proc. Amer. Acad. 4: 311. 1859; Miquel, Fl. Ind. Bat. 2: 166. 1861; Benth, Fl. Hongk. 147. 1861; Thaites, Enum. Fl. Zeyl. 139. 1864; Benth, Fl. Austral. 3: 407. 1867; Miquel, Ann. Mus. Lugd. Bat. 4: 230. 1869; Hook. f., in Benth. & Hook. f., Gen. Pl. 2: 63. 1873 & Fl. Brit. Ind. 3: 77. 1880; Hance in Trimen, Fl. Ceylon 2: 320. 1895; Prain, Beng. Pl. 1: 410. 1903; Duthie, Fl. Upper Gang. Pl. 1: 384. 1903; Cooke, Fl. Pres. Bomb.1: 596. 1903; Rao, Fl. Pl. Travanc. 207. 1914; Fyson, Fl. Nilgiri & Pulney Hill tops 1: 191. 1915; Gamble, Fl. Pres. Madras 607.1921; Haines, Bot. Bih. Orissa 443. 1922; Ridley, Fl. Malay Penin. 2: 40. 1923; Kanjilal *et al.*, Fl. Assam 3: 42. 1939; Kitam in Fauna, Fl. Nep. Himal. 231. 1955; Bakh. f. in Backer & Bakh. f., Fl. Java 2: 291. 1965; Hara, Fl. E. Himal. 313. 1966; Gandhi in Saldanha *et al.*, Fl. Hassan District 587. 1976; Babu, Herb Fl. Dehra Dun 228. 1977; Hara in Hara & Williams, Enum. Nepal Fl. 2: 206. 1979; Balakr, Fl. Jowai 1: 247. 1981; Manilal & Sivaranjan, Fl. Calicut. 134. 1982; Deb, Fl. Tripura state. 2: 73. 1983; Rao, Fl. Goa. Diu. Daman, Dadra and Nagarhaveli. 2: 214.1985; Sharm. *et al.*, Fl. of

Karnataka Anal. 2: 130. 1987; Subramanian, Fl. Thenmala & its envorins. 164. 1995; Deb & Mondal in Bull. Bot. Surv. India 39: 1-148. 1997; Mohanan & Sivadasan, Fl. Agasthyamala. 340. 2002; Singh *et al.*, Fl. of Mizoram 1: 710. 2002; Chowdhury, Assam's Flora. 231. 2005; Tao & Taylor, Fl. China. 19: 258. 2011; Pal, Fl. Lower Subansiri Dist. Arunachal Pradesh. 1: 710. 2013; Nayar *et al.*, Flowr. Pla. of Western Ghats. 794. 2014.

Description

Herbs, sometimes undershrub, annual or perennial, 6 cm–3m in height; stems sometimes erect, prostrate or decumbent, herbaceous, rarely suffrutescent, pubescent or sometimes glabrous. **Leaves** grow opposite each other, decassate, petiolate or sometimes rarely subsessile and sometimes unequal in pair, 0.6–25 × 0.5–10 cm, elliptic, elliptic–lanceolate, elliptic–oblong, ovate, ovate–lanceolate, obtuse or cordate at base, glabrous or scattered hairy above, usually pubescent, sometimes glabrous on the nerves beneath; lateral nerves 3–19 on either side, subopposite; petioles 0.3–3.5 cm long; stipules persistent or caducous, 1.5–18 mm long, usually narrow, linear–lanceolate from a broad base, sometimes broadly ovate–oblong, or ovate–lanceolate, triangular, rotund or cuspidate, entire or bifid, glabrous. **Inflorescence** axillary and terminal cymes, 0.5–1 cm across, peduncles 0.5–10 cm long, sometimes elongated with fruits. Bracts and bracteoles absent or present, small linear–lanceolate, falling away before the maturation of fruits or sometimes large, linear–oblong to oblong–lanceolate and persistent, pubescent or glabrous. **Flowers** on the branches of peduncles, more or less pedicellate, 0.3–4 cm long, bisexual, pentamerous, white, pinkish white, creamy or greenish, brownish, sometimes sweetly fragrant; hypanthium 0.5–2.2 × 0.4–2.5 mm, ovoid or obovoid; calyx lobes 0.3–5 × 0.2–2 mm, triangular to subulate, ovate to lanceolate, acute or obtuse; corolla 0.2–3.5 cm long, usually infundibuliform, sometimes swollen at base, sometimes constricted at middle; lobes valvate in buds, 0.75–9 × 0.5–5 mm, usually ovate to ovate–lanceolate, sometimes winged or spurred at back. **Stamens** 5, adnate at different levels in the corolla tube, sometimes at the base of the tube and sometime above, inserted or exerted; filaments short or long, sometimes raising the anthers above the throat and sometimes present inside the tube; anthers 2–lobed, linear–oblong, dorsifixed, introrse, dehiscing longitudinally. **Ovary** 2–loculed, many–ovuled; placenta oblong or clavate, ascending from the bottom of each cell. Style filiform, encircled by a large 2–lobed disc at base; stigma usually 2–lobed. **Capsules** strongly laterally compressed with a thickened belt at middle, obcordate, much broader than height, internally divided into 2–locules, lolulicidal, opening by a transverse slit around the apex.

Seeds numerous, minute, angular, wall of the areole usually thick, brown or dark brown.

Ecology: Grows mainly in moist, cool, shady, clayey soil. Mostly found in forest floor, moist hilly slopes, moist shady places, along the water streams, damp shady places along forest margins, in semi-evergreen forest, wet evergreen forest.

4.1.2 Key to the species

1a. Bracts and bracteoles absent ..... ***O. mungos***

1b. Bracts and bracteoles present 2

2a. Bracts and bracteoles long, upto12 mm long… 3

2b. Bracts and bracteoles minute, upto 5 mm long… 4

3a. Inflorescence terminal fascicled and pubescent, stipule lanceolate with broad base..... ***O. fasciculata***

3b. Inflorescence terminal capitates cyme and hispid, stipule oblong–lanceolate with narrow base..... ***O. hispida***

4a. Inflorescence spreading, leaves reddish beneath.....5

4b. Inflorescence not spreading, leaves greenish beneath.....6

5a. Leaves purplish or reddish beneath, peduncle stout..... ….***O. tingens***

5b. Leaves reddish beneath when drying, peduncle slender ..... ***O. succirubra***

6a.Leaves opposite to each other on each node, greenish scattered minute hairy above .....***O.oppositiflora***

6b. Leaves decussate, arranged at one node lie right angle to next pair of leaves at the next node, no greenish scattered minute hair above 7

7a. Stem creeping at base, leaves rugose above and pubescent at lower nerve ……***O. rugosa***

7b. Stem terete, leaves glabrous above and below……..***O. ochroleuca***

1. *Ophiorrhiza. mungos* L.

Linneaus, Sp. Pl. 150. 1753; Roxburgh, Fl. Ind. 2: 544. 1824; De Candole, Prodr. Systemalis Naturalis 4: 415. 1830; Wight & Arnold, Prodr. Flo. Peninsu. Ind. Orient. 404. 1834; Don, Gen. Sys. Gard. Bot. 3: 521. 1834; Thwaites, Enum. Pl. Zeyl. 139. 1864; Miquel in Ann. Mus. Bot. 4(2): 234. 1869; Kurz in Journ. Asiat. Soc. Bengal 46(2):130. 1877; Hook. f., Fl. Brit. India 3: 77. 1880; Trimen, Handb. Fl. Ceylon 2: 320. 1895; King in Journ.Asiat. Soc. Bengal 72(4): 174. 1903; Rao, Flower. Pl. Travanc 206. 1914; Gamble, Fl. Pres. Madras 607. 1921; Burkill in Rec. Bot. Surv. India 10(1): 50. 1924; Kanjilal *et al.*, Fl. Assam 3: 42.1939; Deb in Bull. Bot. Surv. India 3: 312. 1961; Deb, Fl. Tripura State 2: 74. 1983; Sharma *et al.*,

Fl. of Karnataka Analysis. 2: 130. 1987; Deb & Mandal in Bull. Bot. Surv. India 39: 67. 1997; Singh *et al.*, Fl. of Mizoram 1: 711. 2002; Pal, Fl. Lower Subansiri Dist. Arunachal Pradesh 1: 711. 2013; Nayar *et al.*, Flowr. Plants of Western Ghats. 794. 2014.

Type: Sri Lanka, *Herb. P. Hermann* 3: 50, No. 402 (Barcode BM000594692) Lectotype designated by Verdcourt, Regnum Veg. 127: 17 1993.

Vernacular name: Neuli (Assamese).

Description

Herbs, 60–90 cm tall; stem suffruticose, erect, branching, puberulous; internode 6–7 cm long and 4–5 mm in diameter. **Leaves** 3.5–15 × 1–5 cm, blade elliptic–lanceolate, acuminate at apex, narrowed at base, puberulous on the nerves beneath; lateral nerves 7–17 on either side; stipules caducous, 2–6 mm long, triangular, sometimes bifid, glabrous and sometimes puberulous on the margin; petioles 0.4–3.5 cm long, slightly puberulous. **Inflorescence** terminal, subumbellate cymes, 1.2–5.5 cm across, puberulous; peduncles 4–5 mm long, slightly pubescent. **Flowers** 1.2–1.3 cm long, white and sometime pinkish–white, pedicels 0.3–1.4 mm long, puberulous; Hypanthium 0.5–1.6 × 0.4–0.9 mm, ovoid and puberulous; calyx lobes 0.4–1 × 0.3–0.6 mm, subulate, acute; corolla 5–8 mm long, infundibuliform, glabrous outside, villous at the middle within; lobes 0.6–1.3 × 0.5–l mm, ovate, subacute, slightly keeled at back. **Stamens** adnate at the base of corolla; filaments 0.5–2 mm long; anthers 0.6–2.5 mm long, oblong–linear. **Ovary** 0.4–1.4 × 0.2–0.5 mm, obovoid; styles 3/4th of corolla tube, glabrous; stigma bilobed, 0.5–1 mm long, lobes ovate glabrous. **Capsules** 1.2–3 × 3–8 mm, glabrous, locules ovate or ovate–oblong, tip slightly inclined outwards. **Seeds** 0.4–0.5 × 0.3–0.4 mm many, angular, dark brown **(Plate 1 & Fig 3).**

Distribution: INDIA: (Assam, Sikkim, Meghalaya, Nagaland, Manipur, Mizoram, Tamil Nadu, Kerela, Nicober Island). BANGLADESH, NEPAL, JAWA, MALAYA, MYANMAR, SRI LANKA, SUMATERA, THAILAND, VIETNAM.

Phenology: Flowering: April–September, Fruiting: June–October.

Ecology: Grows in moist clayey loam type soil in cool and shady place on the forest floors in the elevation of 400–600 m along with *Melastoma malabathricum* L, *Premna herbacea* Roxb., *Polyura geminata* (Wall. ex G.Don) Hook.f, *Begonia roxburghii* (Miq.) A.DC. etc.

Specimen Examined: Assam, Kamrup (M) district, Pamohi, 03.03.2019, 26°05'84.7" N 91°41'74.7"E, *B.Bhuyan BB0005* (BUBH); Ouguri range, Karbi Anglong, 05.04.2019, 26°01'57.3"N 92°16'17.6"E, *B.Bhuyan BB0009* (BUBH).

Additional specimen examined: INDIA, Madras, *6227* (CAL); *D.B.Deb s.n.* (CAL); Madras, Coimbatore Dist., Manoampalli to Top slip, 25.08.1992, *A. Rajendran96941* (MH); Andaman & Nicobar Island, Kondul Island, 08.12.2012, *S. Prabhu & R.Sathiyaseelan1240* (PBL); Laful, 31.05.2013, *S. Prabhu1453* (PBL); Andaman & Nicobar Island, Katchal Island, 10.03.2012, *S. Prabhu & R. Sathiyaseelan463* (PBL); Rutland, Bada khadi, 26.2.2004, *K. Karthigeyan21366* (PBL); Havelock Island, 05.9.1977, *R. K. Premanath6145* (PBL); Tiltop near Sawai, 26.03.1959, *K. Thothathori9329* (PBL); Arong, 12.08.1973, *N. P. Balakrishnan471* (PBL); Passa, 02.03.1974, *N. G. Nair941* (PBL); Galathea Bay, 23.03.1966, *Thothathori11514* (PBL); Kopenheat, 21.07.1976, *N. P. Balakrishnan3925* (PBL); GT. Nicobar, 27.11.1978, *P. Basu7105* (PBL); GT. Nicobar Island, Laful, 14.05.1980, *D. K. Hore7587* & 08.06.1981, *D. K. Hore8751* (PBL); Great Nicobar, 16 km East-West Road, 15.11.1993, *B. K. Sinha16350* (PBL); Passa, 02.03.1974, *N.G.Nair941* (PBL); Jula, Katchal Island, 21.08.1974, *P. Chakraborty 2147* & 21.04.1974 *P. Chakraborty1119* (PBL); Katchal Island, 27.03.1979, *M. K. Vasudeva Rao7411* (PBL); Galathea Bay, 23.03.1966, *Thothathori & Banerjee11483* (PBL); Tamil Nadu, Manoampalli to Topslip, 25.08.1992, *A. Rajendran96491* (BSID); Kalpong, 23.09.1996, *G.S. Lakra15060* (PBL); Teressa Island, 31.07.2012, *S.Prabhu & R. Sathiyaseelan928* (PBL); Little Nicobar, Menchal, 07.5.2008, *C.Murugan26549* (PBL); Pulopanja, 16.04.2011, *C. Murugan28483* & 02.11.2009, *C.Murugan27862* (PBL); Maharastra, Varandha Ghat, 11.08.2020, *S. Bramhadande3252* (NGCPR); Anaimalai, 25.22.1975, *J.P.Pascal612* (HIFP); Kerela, Trivandum Distt., 04.07.1977, *K.U. Karmer* & *G.B. Nair6165* (U); Ponmundi, 08.6.1976, *C.E. Ridsdale66* (L); Shenkottai division, *K.N. Subramanian1675* (MH); Assam, Ledo road, *G.Juan525* (US); West Bengal, *J. O. Voigt405* (US); Arunachal Pradesh, *A. Pramanik477* & *G.D. Pal573* (ARUN); India, *W. Roxburgh s.n.* (BR). SRI LANKA, *G.Thwaites 1704* (BR), 29.05.1993, *A.D.Weerasooriya & P. Jayasekera2114* (L); *Burman s.n.* (M); *C.P. Thunberg s.n.* (SBT). INDONESIA, *H. Zollinger s.n.* (BR) .CHINA, *A. Henry11674* (K). PHILLIPPNES, *A.D.E. Elmer14223* (BISH); Handipan Ella, 01.9.1981, *G. Thanikaimoni1743* (HIFP); Morapitiya, Kalutara District, 09.9.1975, *D.B. Sumithraarachchi, D. Austin &S. Austin1005* (US).

2. *O. ochroleuca* Hook. f., Fl. Brit. India. 3: 78. 1880; Burkill in Rec. Bot. Surv. India. 10(1): 50. 1924; Kanjilal *et al.*, Fl. Assam 3: 42. 1939; Deb & Mandal in Bull. Bot. Surv. India. 39: 84. 1997; Singh *et al.*, Fl. Mizoram 1: 710. 2002; Pal, Fl. Lower Subansiri Dist. Arunachal Pradesh.1: 710. 2013.

Type: India: Sikkim, alt. 2–5000 ft, s.n., *J.D. Hooker* 5– Ophiorrhiza (K). Lectotype: first-step lectotype designated by Deb & Mondal 1997; second-step lectotype K [Barcode K000031179] designated by Hareesh & Sabu (2022).

O. recurvipetala Bhuyan, S. Baruah & Mehmud Nordic Journal of Botany 39: e03048 (2021)

Type: India, Assam: Dima Hasao district, hilly areas near Jatinga, B. Bhuyan & S. Baruah 0019 (ASSAM; BUBH).

Description

Perennial herb, 50–60 cm tall, branched; stem terete, woody at base, glabrous, green when young, pale brown when mature; internodes 3–4 × 0.3–0.5 cm long. **Leaves** 13.0–15.0 × 5.0–6.5 cm; blade ovate–elliptical, attenuate at base, with caudate apex, glabrous above and below, dark green above and pale beneath; lateral nerves 11–12 pairs on either side, mid vein prominent beneath, glabrous; stipules caducous, triangular at base, minute; petioles 3.5–4.0 cm long, glabrous, slender. **Inflorescence** terminal and axillary trichotomous helicoid cyme, 3–4 cm across; peduncle 5–7 cm long, slender, slightly pubescent; bracts and bracteoles minute, 0.1–0.2 mm long, linear, pubescent; pedicels 1–2 mm long, pubescent. **Flowers** creamy white, 1.0–1.2 cm long, glabrous. Hypanthium obovoid, 1.5–1.6 × 1.6–1.9 mm, puberulous; calyx lobes 0.4–0.8 mm, acute, pubescent; corolla tubular, glabrous outside, densely pubescent within the tube except at the base; corolla lobes 1.8–3.0 × 0.4–0.9 mm, linear, oblong, strongly recurved, reflexed, hairy within. **Stamen**s adnate, inserted at 3/4th of corolla tube; filaments 4–5 mm long; anthers 3–4 mm long, creamy white. **Ovary** 0.3–1 × 0.2–0.5 mm, obovoid; style filiform, 04–0.5 mm long, glabrous; stigma bilobed, 0.3 mm long, glabrous. **Capsule** obovoid in outline, 0.3–0.4 × 0.5–0.6 cm pubescent. **Seeds** many, small, angular **(Plate 2 & Fig 4).**

Distribution: INDIA**: (**Assam, Arunchal Pradesh, Mizoram). CHINA, MYANMAR, VIETNAM.

Phenology: Flowering: October– December, Fruiting: November–December.

Ecology: It grows in damp swampy area near hill slopes in the elevation of 700–1000 m along with *Floscopa scandens* Lour., *Rungia repens* (L.) Nees, *Digitaria sp.* etc.

Specimen examined: Assam, Kamrup (M) district, Pamohi, 19.04.2019, 26°04'36.9"N 91°42'34.0"E, *B.Bhuyan BB0013* (ASSAM); Cachar, Lailapur, 02.12.2020, 24°30'51.7"N 92°47'23.1"E, *B.Bhuyan BB0017* (BUBH).

Additional specimen examined: India, Mikir Hills, Karbi Anglong, 07.02.1977, *S.K.Borthakur69537* (ASSAM); Luchai Hill, Khaitum, 23.01.1963, *D.B.Deb31214* (ASSAM); NEFA, Lohit, 02.12.1957, *R.S.Rao10893* (ASSAM); Luchai Hill, Khaitum, *D.B.Deb31235* (ASSAM); Assam, Namchung, Luckimpore (Lakhimpur), 18.04.1885, *C.B.Clarke37954* (US); Subansiri, 12.11.1964, *A.R.K. Sastry40538* (L); Meghalaya, Tura Mountain, Garo Hills, 08.2.1950, *W.N. Koelz24391* (MICH); Khasia, *R.L.Kenan s.n.* (W); Khasia, *T. Thomson5* (NY); Sikkim, *J.D.Hookers.n.* (K) (Lecto); Khasia, 1859, *JD Hooker & Thomson s.n.* (P) (Isosyntype); Sikkim, *J.D.Hooker s.n.* (L); Khasia, *J.D.Hooker & Thomson s.n.* (L); Assam, *F Jenkins s.n.* (L); East Bengal, *H Griffith 2867* (L); Khasia, *J.D. Hooker s.n.* (CAL); Sikkim. *Griffith* s.n. (CAL); Tanliaka, *T. Anderson685* (CAL); Lapva, Dongbe, *G.King* s.n. (CAL); Lopchu, *G.King* s.n. (CAL). West Bengal: Darjeeling, Rishap, *C.B.Clarke9131* (BM); Rishap, *C.B.Clarke12255* (CAL); Rishap, *C. B. Clarke* s.n. (CAL); Lebong, *J.S.Gamble3744* A (K); Kalimpong, *J.S.Gamble* s.n.(CAL); Mongpoo, *C.B. Clarke36182A* (BM); Pashok, *W.W. Smith471* (CAL); Rungbee, *W.W.Smith727* (CAL); Rungbee, *W.G. Craib117* (CAL); Rungbee, *G.H.Cave* s.n. (E); Rangpoo, *K. Biswas9877* (CAL); Khasia, G. King's Collector s.n. (DD); Garo Hills, Tura, *C.B.Clarke43094 B* (K); Shillong, *C.B.Clarke44521* (BM, CAL); Jowai, King's Collector s.n. (BSIS, MH); Garo Hills, Tura, *N.E. Parry820* (K); Garo Hills, Tura, Walter *N. Koelz 24391* (L); Khasia hills collector of Bot. Garden, Calcutta s.n.. (CAL); Assam, Cachar, 1873, *R.L. Keenan* s.n. (K); Sibsagar, *C.B.Clarke* s.n. (CAL); Golaghat *King's Collector* s.n. (CAL); Arunachal Pradesh, Duffla hills, *King's Collector* s.n. (CAL); Abor hills, *I.H. Burkill36192* (CAL); Abor hills, Lalik valley *I.H.Burkill* s.n. (CAL); Abor hills, Upper Renging camp, *I.H. Burkill* s.n. (CAL); Kameng Dist, Kocharigaon to Chardwar, *G. Panigrahi5902* (CAL); Lohit Dist., Dreyi to Badaru, *R.S. Rao 10893* (CAL); Naga hills, Perenni, *N.L. Bor6453* (K, DD). Manipur.Ainadhar, *K.C.Malick950* (BSIS); Nungba to Oinamlong, *K.C. Malick1257* (BSIS); Mizoram. Kheitum, *D.B.Deb31220* (ASSAM). MYANMAR: Bhamo Division, *G.E.S. Cubitt* s.n. (CAL); Khempti, Daru Uka, *S.M. Toppin* s.n. (CAL); Bhamo, along Ledo Road, 02.5.1945, *J.R. McMillen251* (US); Bhamo, *T. Thomson & J.D. Hooker5* (NY, E); *J.D. Hooker & T Thomson s.n.* (M).

3. *O. succirubra* King ex Hook. f., Fl. Brit. India 3: 82. 1880; Clarke in Journ. Linn. Soc. Bot. 25:31. 1887; Hara, Fl. E. Himalaya 314.1966; Mukherjee *et al.*, in Rec. Bot. Surv. India 20(2); 120.1973; Balakr, Fl. Jowai 1: 248. 1981; Deb, Fl. Tripura State 2: 75. 1983; Chauhan *et al.*, Fl. of Namdapha 190. 1996; Deb & Mandal in Bull. Bot. Surv. India 39: 120. 1997;

Singh *et al.* Fl. of Mizoram, 1: 713. 2002; Pal, Fl. of Barak Valley, Assam 1: 429. 2013; Pal, Fl. Lower Subansiri Dist. Arunachal Pradesh 1: 714. 2013.

***Type*:** Mungpo, *J.D. Hooker Ophiorrhiza*. *17* Holotype CAL (Barcode CAL0000010914); K (Barcode K000740544); Sikkim, *J.D. Hooker*, Isosyntype P (Barcode P02273404).

Description

Herbs, 50–70 cm tall; stems erect, sometimes woody at base, branched, glabrous, internodes 4–5 cm long and 0.3–0.5 cm in diameter. **Leaves** 4–22 × 2–7 cm, elliptic to lanceolate, acuminate at apex, acute at base, glabrous, reddish beneath on drying; mid rib prominent at abaxial surface, lateral nerves 8–12 on either side; petioles 1.2–2.8 cm long, glabrous; stipules 5–6 mm long, entire, bifid, glabrous. **Inflorescence** terminal, coryrmbose cymes, 3–3.2 cm across, puberulous; peduncles 2–3 cm long, puberulous, bracts and bracteoles persistent, 0.5–0.8 cm long, linear to lanceolate, glabrous. **Flowers** 1.2–1.5 cm long, white; infundibuliform; pedicels 1.5 mm long, glabrous or puberulous; hypanthium 1–1.75 × 1.5–2 mm, broad at base, puberulous; calyx lobes 1.2 × 0.75 mm, triangular in shape, obtuse, puberulous; corolla lobes 2–2.5 × 1–1.5 mm, ovate, acute apex, shortly keeled at back. **Stamens** 5, adnate at the middle of corolla tube or slightly below, inserted; no hairs within the corolla tube, filaments 1.3 mm long; anthers 3 mm long. **Ovary** 0.5–1.2 × 1.4–1.7 mm, obovoid, glabrous; stigma bilobed, 0.1–0.2 mm long, pubescent. **Capsule** 2–3 mm × 6–8 mm, puberulous, tip slightly inclined outwards. Seeds many, angular **(Plate 3 & Fig 5).**

Distribution: INDIA: (Assam, Sikkim, Meghalaya, West Bengal). MYANMAR, CHINA, NEPAL, TIBET.

Phenology: Flowering: March–May, Fruiting: March–June.

Ecology: Grows on moist shady places and on clayey soil type at elevation of 100–200 m along with *Begonia roxburghii* (Miq.) A.D.C., *Melastoma melastoma* L., *Stachytarpheta* sp. etc.

Specimen examined: Assam, Kamrup (M) district, Garbhanga RF, 08.04.2019, 26°02'42.8"N 91°42'53.0"E, *B.Bhuyan BB0012* (ASSAM); Lakhimpur dist, Bokulbari, 04.02.2019, 27°25'48.0"N 94°11'36.2"E, *B.Bhuyan BB0003* (BUBH).

Additional specimen examined: Naga Hills, Kohima, *D. Prain* s.n. (K); Sikkim, *J.D. Hooker17* (K); Sikkim, *W.J. Treutler339* (K); Sikkim, *J.D. Hooker s.n*. (L) & (CAL); Sikkim, *W.J. Truetler339* (K); Darrang, Bhalukpung, 25.04.1914, *U. Kanjilal6611* (ASSAM); Karimganj, Longai Reserve Forest, 18.04.2005, *P.S. Das90* (ASSAM); Umrong Dam, *R.S. Baruah115584* (ASSAM); Arunachal Pradesh, Hapoli, 21.04.1965, *A.R.K. Shastry 42118*

&16.04.1965, *A.R.K. Shastry 42023* (ASSAM); Lakhimpur, Dullung Reserve Forest, 19.09.2011, *N.Odyuo* & *D.K.Roy123166* (ASSAM); Lakhimpur, Dullung Reserve Forest, 07.05.2011, *N.Odyuo122212* (ASSAM); Cachar, Barail WLS, 04.06.2012, *H.A.Barbhuiya915* & 25.04.2011, *H.A.Barbhuiya568* (ASSAM); Jorhat, Gibbon WLS, 10.06.2010, *R. Daimari116058* & *116079* (ASSAM); Nowgong, Doboka RF, 27.08.1964, *N.P.Balakrishnan39479* (ASSAM, CAL); Assam, 31.03.1964, R.M. Dutta s.n. (ASSAM); Arunachal Pradesh, *S.S.Dash31064*, *R.Gogoi21339*, *A.K.Sastri42118* (ARUN); Tirap Dist, Lansang Forest, *D.B. Deb21622* (ASSAM); Sikkim, *G. King s.n.* (CAL). West Bengal, Darjeeling dist, Rungbee, *C.B. Clarke 12160* (CAL, BM); Sormpahar, *C.B.Clarke27563 A* (CAL); Mungpoo, *C. B. Clarke36462* (BM); Rumbhijhora, *W.W. Smith351* (CAL); Sonada, *G. H. Cave s.n.* (E); Darjeeling, *S.K. Mukherjee873* (CAL); Meghalaya, Garo hills, Phulbari, *W.N.Koelz25112* (L); Assam, Nowgong dist, Doboka Reserve forest, *N.P Balakrishnan39479* (CAL); Arunachal Pradesh. Lohit dist, Mawaito Nathai, *J. Joseph48831* (CAL); Tirap dist, Lansang forest (Kothong), *D.B.Deb21622* (CAL, ASSAM). Nagaland, Kohima, *C. B. Clarke41050* (CAL); Kohima, *C. B. Clarke41062A* (K); Kohima, *D. Prain* s.n. (CAL). Mizoram, Mizo Hills, *R.M. Datta33809* (CAL). MYANMAR: Tenasserim division, Moolyet, *G. Gallatly184* (CAL).

4. *O. fasciculata* D. Don. Prodr.136.1825; Don, Gen. Syst. Gard. Bot. 3: 521. 1834; Hook.f., Fl. Brit. India. 3: 83. 1880; Clarke in Journ. Linn. Soc. Bot. 25: 31. 1889; Duthie, F1.Upper Gang. P1. 1: 384. 1903; Burkill in Rec. Bot. Surv. Ind. 4: 112. 1910; Lacaita in Journ. Linn. Soc. Bot. 43: 470.1916; Haines, Bot. Bih. Orissa 443.1922; Kanjilal *et al.*, Fl. Assam 3: 42.1939; Kitam in Fauna Fl. Nep. Himal. 231. 1955; Deb in Bull. Bot. Surv. India. 3: 312.1961; Hara, Fl. E. Himal. 313. 1966; Babu, Herb. F1. Dehra Dun 228. 1977; Hara in Hara & Williams, Enum. Nepal 2: 206. 1979; Balakr, Fl. Jowai 1: 249. 1981; Deb & Mandal in Bull. Bot. Surv. India 39: 44. 1997.

Type: Nepal, Suembu, *Buchanan* s.n. Holotype BM (Barcode BM000521916); CAL (Barcode CAL0000010899).

O. bracteolata R. Br. (in Wall. Cat. 6228A. 1832, nom nud.) ex G. Don, Gen Syst. Gard. Bot. 3: 521. 1834; Walp. Rep. 2: 503. 1843.

Type: Nepal, Wallich, 1821, *6228* Holotype CAL (Barcode CAL0000010971).

Vernacular name: Akhap-Abor (Siang dist, Arunachal Pradesh).

Description

Perennial herb, 10–30 cm tall; stems erect, woody at base, branched, pubescent; internode 2.0–2.5 long and 3–4 mm in diameter. **Leaves** 3–13 × 2–5.5 cm long, ovate–lanceolate, acute apex, tapering at base, glabrous above, pubescent on the nerves beneath, membranous; lateral nerves 5–15 on either side; petioles 1–4 cm long, slender, pubescent; stipules 3–12 mm long, lanceolate with broad base, acute, entire, pubescent. **Inflorescence** terminal, fascicled, 1–4 cm across, 3–5 branched, pubescent; peduncles 2–8 cm long, elongating in fruit, slender, pubescent. **Flowers** 1.5–2 cm long, white, bracts persistent, 0.5–1 cm long, lanceolate, pubescent, pinkish; bracteoles persistent, 0.3–0.6 cm long, narrowly lanceolate, pubescent, pinkish; pedicels 1–2 mm long, pubescent; hypanthium obovoid, pubescent; calyx lobe ovate, acute at apex, pubescent; Corolla tube 1.3–1.8 cm long, infundibuliform; tube slender, puberulous outside, glabrous; lobes 1.5–2.2 × 1.2–1.7 mm, broadly ovate–oblong, acute. **Stamens** adnate to the base of corolla or slightly above, inserted; filaments 1.4–1.7 mm long; anthers 1.6–1.7 mm long, linear oblong. **Ovary** 1.5 × 1.25 mm, obovoid; style 1.25–1.5 mm long; stigma bilobed, 1.8–2.3 mm long, glabrous. **Capsule** 1–2 mm × 5–7 mm, puberulous, with straight tip. Seeds many, angular **(Plate 4 & Fig 6).**

Distribution: INDIA: (Assam: Dima Hasao, Western Himalaya, Sikkim, West Bengal, Orissa, Khasi Hills and Mizo hills). MYANMAR, NEPAL, BHUTAN.

Phenology: Flowering and fruiting: October–November.

Ecology: Grows on moist soil in rocky slopes and mountain at the elevation of 600–800 m along with *Amomum subulatum* Roxb., *Lecanthus peduncularis* (Royle) Wedd., *Begonia roxburghii* (Miq.) A.D.C. etc.

Specimens examined: Assam, Dima Hasao district, Halflong, Jatinga forest, 04.11.2021, 25°06'50.79"N 93°02'16.62"E, *B.Bhuyan BB0026* (BUBH).

Note: The species was recorded in the Kanjilal's Assam Flora volume 3 without any descriptions and information of the species and the authors refer Hooker's Flora of British India of Vol. III (1882) for its taxonomic enumeration and distribution. In the flora of British India by Hooker recorded the species from the state Meghalaya, Sikkim and Bhutan. However, it is to be mentioned that the Khasi hills was once in the integral part of erstwhile Assam and falls under the state Assam but now Khasi Hills comes under present political boundary of Meghalaya. On scrutiny of revision work on genus *Ophiorrhiza* Rubiaceae in Indian subcontinent by Deb and Mondal (1997) mentioned the distributional record of *O. fasciculata* from different states but not from Assam. Barooah and Ahmed (2014), in their book

Plant diversity of Assam did not mentioned about the species. The species is a new distribution report for the state and it is established (Bhuyan & Baruah 2022).

Additional specimen examined: INDIA: Walong, Khasia, *C.B. Clarke43780* (US); Arunachal Pradesh, Siang dist., Koppu to Geling, 27.03.1958, *G.K Murthy13082* (ASSAM); Tura, 12.12.1960, *G. Panigrahi22409*, (ASSAM); Tura, 29.08.1962, *D.B.Deb28859* (ASSAM); Mizoram, Mizo Hills, 30.08.1965, *R.M.Dutta33501* (ASSAM); Meghalaya, Pynursla, 12.03.2012, *R. Kumar124590* (ASSAM); Garhwal, Ukhimath, *M.A. Rau38770* (CAL, L); Orissa, Kalahandi dist, Goyal–Khojghati, *H.F.Mooney3501* (K, L); West Bengal, Badamtam, *K Biswas* s.n. (US); Meghalaya, Pynursla, *Ramesh Kumar124590* (ASSAM); Khasia, *J. D.Hooker1622* (K); *J.D.Hooker* s.n. (BR); Sikkim, J.D. Hooker s.n. (L); Uttar Pradesh, Almora, Kumaon-Sarju valley, *J.F. Duthie2989* (BM); Kopkote, *J.F. Duthie s.n.* (K); Boramgaon. Gori valley, *Inayat24494* (CAL); Jeolikote, *N. Gill73* (CAL, LWG); Dogaun, *N. Gill648* (CAL, LWG); Dogaun, *Bis Ram2291* (DD, E); Thanakpur, *T.A. Rao11539* (BSD); Barun Maiti, *C.M. Arora45527* (BSD); Dafio Dhuru, *C.M. Arora49516* (CAL); Mussoorie, *J. F.Duthie566* (CAL); Garhwal dist. Bhainkil kota range, Inayat 25908 (DD, K); Batwatebari, *M.A. Rau6377* (BSD); Naraikoti, *M.A.Rau 6477* (BSD); Ukhimath, *M.A.Rau38770* (CAL,BSO, L); Sikkim, Cheerrakhud, *C.B.Clarke42815* (CAL); Raiotdong, *C.B.Clarke42815* (CAL); Sangachelling, *I.H. Burkill32120* (BSIS); Temi, *W.W.Smith2922* (CAL). West Bengal. Darjeeling, Pankabari, *S. Kurz* s.n. (CAL); Rungbee, *C.B. Clarke8566* (CAL, BM); Rishap, *C.B. Clarke8704* (CAL); Tista, *C.B. Clarke11815* (CAL); Rungbee, *C.B. Clarke12355* (BM); Ryang, *C.B.Clarke13765* (BM); Choonbuttee, *C.B.Clarke 26568 (*BM); Terai, *C.B.Clarke 26724 A* (CAL); Darjeeling, *C.B. Clarke26936* (K); Budum Jhom, *C.B. Clarke27064* (CAL); Runjeet, *C.B. Clarke 27143B* (CAL); Terai, *J.S. Gamble866B* (K); Kurseong, *C.B. Clarke36535* (BM); Lubdah, Prain's Collector s.n. (CAL); Tista valley, *Ribu829* (CAL); Rungio, *W.W. Smith290* (CAL); Mungpoo, *Kari1627* (CAL); Rungpo, *I. H. Burkill34069* (BSIS); Mirik, G.H. Cave s.n. (E); Rungpo, G.H. Cave s.n. (E); Kalimpong, H.J.C. Kinghorn 7 (CAL); Kullong, *C.B.Clarke40007A* (CAL); Mawphlong, *C.B. Clarke45076C* (CAL); Khasi Hills, G. Mann s.n. (CAL); Tura Top, *G. Panigrahi22409* (CAL); Arunachal Pradesh. Siang dist., Koppu to Geling, G.K. Murthy 13082 (CAL); Manipur, Konglatonghi, *A.A. Bullock571* (K); Mizoram, Mizo Hills, *R. M. Datta 33540* (CAL). Orissa, Kalahandi dist., Goyal-Khojghati,, *H.F. Mooney3501* (K, L); Koraput dist., Joypore Estate, Bhalupodar Valley, *H.F.Mooney3886* (DD), NEPAL: Hamilton s.n. (CAL); Kathmandu, *K. Prashad* s.n. (CAL); Kathmandu, *Kalka Prasad* s.n. (CAL); *N Wallich6228*

(P, K); Pokhara, *T.B. Shrestha & M. Bistha1754* (US); Gokarna, *P.Pradhan & R. Thapa4530* (US).

5. *O. oppositiflora* Hook. f., Fl. Brit. Ind. 3: 80. 1880; Kanjilal *et al.*, Fl. Assam 2: 42. 1939; Deb & Mondal in Bull. Bot. Surv. India 39: 86. 1997; Singh *et al.*, Fl. of Mizoram 1: 713. 2002; Pal, Fl. Lower Subansiri Dist. Arunachal Pradesh.1: 712. 2013. **Type:** Khasi Hills, 1873, *C.B. Clarke 21878* Holotype K (Barcode K000031232).

Description

Herbs annual, 80–100 cm tall; stems erect, woody at base, unbranched, scabrid; internode 4–5 cm long and 3–5 mm in diameter. **Leaves** opposite, 8–15 × 1–6.5 cm, ovate–lanceolate, acuminate at apex, acute at base, greenish scattered minute hairy above, pubescent on the nerves beneath; lateral nerves 8–11 on either side; petioles 1.8–2.5cm long, rusty pubescent; stipules persistent, 2–10 mm long, entire or bifid, pubescent. **Inflorescence** terminal and opposite in the leaf axils, corymbose cyme, 1–2.5 cm across, not spreading, pubescent; peduncle 1.5–2 cm. **Flowers** 0.8–1.1cm long, white; bracts and bracteoles deciduous, minute, 1 mm;pedicles 0.5–1.2 mm long, pubescent; hypanthium 0.75–1 × 0.5–0.75 mm, obovoid, pubescent; calyx lobes 0.5–0.7 × 0.3 mm, ovate–lanceolate, obtuse at apex, pubescent; corolla 0.5–0.9 mm long, infundibuliform; glabrous outside, villous at the middle of the tube within or glabrous; lobes 1.5–1.8×1–1.15 mm, oblong, slightly curved inward, obtuse at apex, keeled at back. **Stamens** adnate to the tube, slightly above the base of the corolla, inserted; filaments 2–2.5 mm long; anthers 1.5–2 mm long. **Ovary** 0.5–0.7 × 0.4–0.6 mm, obovoid;style half as long as corolla, glabrous; stigma bilobed, 1.5–1.8 mm long, glabrous. **Capsule** 1.5–2 × 3–6 mm, glabrous, locules ovate–oblong, tip slightly inclined outwards; Seeds irregularly angular, glabrous, brown **(Plate 5 & Fig 7)**.

Distribution: INDIA: (Assam, Meghalaya, Arunachal Pradesh, Nagaland, Tripura). BANGLADESH, CHINA, HAINAN, MYANMAR.

Phenology: Flowering: March–May, Fruiting: May–September.

Ecology: Grows on moist and damp soil in forest foothills and found in the elevation of c.60–200 m along with *Hydrocotyle javanica* Thunb., *Psychotria denticulata* Wall. etc.

Specimen examined: Assam, Kamrup Metro district, Garbhanga Reserve Forest, 17.5.2019, 26°05'35.7"N 91°44'10.8"E *B.Bhuyan BB0015* (ASSAM**);** Rani Reserve Forest, 19.02.2020, 25°51'42.5"N 91°20'23.2"E, *B.Bhuyan BB0020* (BUBH).

Additional specimen examined:

INDIA: Assam: *Prain798* (L); Dekho river, *G. Reporter on Economic Products11049* (US); Mikir Hills, 17.06.1963, *D.B.Deb35053* (ASSAM); Kamrup, Garbhanga Forest, 13.06.1964, *A.S.Rao38798* (ASSAM); Jirang Bazar, 24.03.1957, *G.Panigrahi9533* (ASSAM); Deygram village, 17.05.1957, *G.Panigrahi9388* (ASSAM); Nowgong, Diphu forest, 24.08.1939, *R.N. De18670* (ASSAM); Singale Bamm Jangahl, *Prain's Collector 798* (L); Meghalaya, Khasia, 1873, *C.B. Clarke21878B* (K); Khasia, 1873, *Rathn21878A* (K); Khasia, Mamloo, 12.5.1886, *C.B. Clarke43803* (US); Lawbah river bank, 21.07.1957, *G.K.Deka 10104* (ASSAM); Nongpoh, 03.5.1945, *W.N.Koelz22629* (MICH); Cherapunjee, 03.5.1952, *W.N.Koelz29639 &* 07.8.1952, *W.N.Koelz31047* & 27.6.1952, *W.N.Koelz30374* (MICH); Cherapunjee, 24.7.1952, *T.R.Chand6224* (MICH); Manipur, Kazuri river, 10.05.1997, *A.A. Mao102428* (ASSAM); Mizoram, Pualreng WLS, 04.12.2010, *S.K. Singh120992* (ASSAM); Arunachal Pradesh, *R. Gogoi24536* & *B.B.Thomson35067* (ARUN); Meghalaya. Khasi & Jaintia Hills, *G. Galatly* s.n. (CAL); Shillong, *King's collector s.n.* (CAL); Nongpoh, *N. Koelz22629* (L); Cherrapunji, N. Koelz 22629 (L); Cherrapunji, *N. Koelz 29639* (L) &*N. Koelz 30370* (L); *Rupchand 6224* (L); *N. Koelz31047* (L); Loobah River bank, *G. K. Deka10104* (CAL); Umsing, Noonmati, *J. Joseph37564* (ASSAM). Assam. Kamrup dist., Garbhanga forest, *R. S. Rao38798* (CAL, L); Mikir Hills, *G. Panigrahi9329* (CAL); Deygram, *G. Panigrahi 9388* (CAL); Dulong Reserve Forest, *G. Panigrahi11313* (CAL); Jorhat to Sibsagar, *C.B. Clarke38034* (CAL, BM). Arunachal Pradesh. Kameng dist., Chardwar, *G. Panigrahi 5473* (CAL); Nagaland. Dikho River bank, *G. Watt11049* (CAL, BSIS); Themokidima, *G. Watt11664* (CAL, BSIS); Tripura, Gorjee Reserve forest, *R. S. Rao 8961* (CAL, ASSAM, L). MYANMAR: Myitkyina dist. Tagwinchaung, *Gokhant 12415* (DD).

6. *O. rugosa* Wall. in Roxb. Fl. Ind. 2:547. 1845; DC, Prodr.4: 416.1830; Don, Gen. Syst. Gard. Bot. 3: 522. 1834; King & Gamble in Journ. Asiat. Soc. Beng. 72: 175. 1903; Ridley, Fl. Mal. Penins. 2: 40. 1923: Hara, Fl. E. Himal. 314. 1966 in synon. *O. harrisiana* Heyne in Wt. & Arn.Prodr. 405. 1834; Hook.f., Fl. Brit. India. 3: 78. 1880; Cooke, Fl. of the Presid. of Bom. 1: 596. 1901; Subramanium, Fl. of Thenmala. 164: 1995; Deb & Mandal in Bull. Bot. Surv. India. 39: 107.1997; Nayar *et al.*, Fl. Pl. of West. Ghats, India. 1: 2014.

Type: Nepal, 1821, Wall.Cat. *6235*, Holotype CAL (Barcode CAL0000010979); K (Barcode K001123369).

Description

Herbs perennial, 10–40 cm long; stem creeping at the base, unbranched, slender, pubescent; internode 1–1.5 cm long. **Leaves** 2–12 × 1–4.5 cm, ovate to lanceolate, apex obtuse to acute, tapering at the base, shining rugose and scabrous above, pubescent on the nerves on the abaxial side, lateral nerves 5–12 on either side; petioles 0.5–2 cm long, puberulous; stipules persistent, 0.4–0.6 cm long, filiform, sometime bifid. **Inflorescence** terminal corymbose or compound helicoid cyme, 1.2–3.3 cm across; branched, pubescent; peduncles 2.8–4 cm long, elongating with the maturity of fruits, pubescent. **Flowers** 1–2 mm long, pinkish white, infundibuliform; bracts and bracteoles deciduous, 2 mm long, linear; hypanthium 0.6–1 × 0.4–1.7mm, obovoid, puberulous; calyx lobes 0.4–1 × 0.25–1 mm, subulate, acute, pubescent; corolla 4–10.2 mm long, infundibuliform, slightly broader at base, puberulous outside, villous at the middle within; lobes 0.7–2.3 x 0.5–1.55 mm, triangular to lanceolate, slightly curved inward, acute at apex, slightly keeled at back. **Stamens** 5, adnate slightly above the base of corolla, inserted; filaments 0.2 cm long; anthers 0.1 cm long. **Ovary** 0.5–1.2 x 0.4–1mm, obovoid style as long as corolla tube, $3/4^{th}$ of the flower, pubescent; stigma 2–lobed, 0.3–1mm long, glabrous. **Capsules** 1.8–2 × 3.8–4.2 mm, puberulous, tip straight. Seeds irregularly angular **(Plate 6 & Fig 8)**.

Distribution: INDIA: (Assam, Sikkim, West Bengal, Bihar, Orissa, Maharastra, Goa). BANGLADESH, CAMBODIA, CHINA, MALAYA, MYANMAR, NEPAL, SRI LANKA, THAILAND, TIBET, VIETNAM.

Phenology: Flowering: April–October; Fruiting: April–November

Ecology: Grows on moist soil in shady places of rocky slopes at 200–500 m above m.s.l. along with *Nephrolepis cordifolia* (L.) C.Presl, *Diplanzium esculentum* (Retz.) Sw. *Digitaria setigera* Roth etc.

Specimen examined: India, Assam, Lakhimpur district, Dulung Reserve Forest, 17.03.2019, 27°26'35.9"N 94°10'25.4"E**,** *B.Bhuyan BB0010* (ASSAM); West Karbi Anglong, Khanduli, 04.05.2021, 25°44'13.6"N 92°27'35.8"E, *B.Bhuyan BB0027* (BUBH).

Note: For the first time viviparous germination was observed in the species in the present study area. **(Plate 11)**

Additional specimen examined: INDIA: *J.D.Hooker & T.Thomson s.n.* (BR); Khasia, *J.D.Hooker & T.Thomson* s.n.(VT), Silent Valley, 12.06.1975, *J.P.PascalJPP0559* (HIFP); Megarvalli–Nalur, 07.10.1961, *G.ThanikaimoniGT0472* (HIFP); Sikkim, *Griffth 2861* (CAL); Khasia, *J.D. Hooker & J.J.* s.n. (CAL); Arunachal Pradesh, *Ritesh Kr Choudhury18222* (ARUN); Sri Lanka, Ceylon, 07.3.1973, *Bernardi14131* (US); Maskeliya, 22.6.1972, *F.Hepper4462* (US); Singaraja forest, 20.7.1971, *W.Meijer911* (US); Kandy district, 29.11.1972, *L.H.Cramer, S.Balasubramanium & D. Tirvengadum3932* (US); Pinnawela, *N.Balakrishnan556* (US); Myanmar, *W. Griffth121* & *Helfer2857* (K); Mount Sillet, *N Wallich6229a* (K); Burna and Malay, *W Griffth2857* (K); Nepal, Taksindu & Kharikhola, 23.7.1996, *M.L.Banerji1878* (USF); Nepal, 1821, *N.Wallich6235* (CAL, S, K); Nepal, Nerain Hetty, *Buchanan s.n.* (BM); *N. Wallich s.n.* (BM).

Keys to the varieties

1a.Leaves narrowly lanceolate, broadly acuminate apex, lateral nerve 6–11 either side, shinny white beneath..... *O. rugosa* var. *argentea.*

1b.Leaves broadly ovate, subacute apex, lateral nerve 5–7 either side, greenish beneath..... *O. rugosa* var. *prostata*.

7. *O. rugosa* var. *argentea* (Hook. f.) Deb & Mondal in Bull. Bot. Surv. India. 24: 228. 1982; Deb, Fl. Tripura State 2: 75. 1938. *O. harrisiana* var. *argentea* Hook f., Fl. Brit. Ind. 3: 78. 1880.

Type: Sylhet, Wall. Cat. *W. Gomez* s.n. 6229, Holotype CAL (Barcode CAL0000010965); K (Barcode K000031201).

O. argentea Balakr, Fl. Jowai 1: 247.1981; Chauhan *et al.*, Fl. of Namdapha 190. 1996; Deb & Mondal in Bull. Bot. Surv. India. 109. 1997; Singh *et al.*, Fl. of Mizoram 1: 713. 2002; Nayar *et al*., Flowr. Pla. of Western Ghats. 796. 2014.

Type: Syllet, Wall. Cat. 6229 B, Holotype CAL, (Barcode CAL0000010964).

Description

Herbs, 30–40 cm long; stem erect from creeping base, sparsely puberulous, branched; internode 5–6 cm long and 4–6 mm in diameter. **Leaves** opposite and decussate, 4–12 × 3–5 cm, ovate–narrowly lanceolate, broadly acuminate at apex, attenuate or acute at base, shining white beneath, glabrous above; mid vein distinct, pubescent, lateral nerves 6–11 on either side; petioles 0.5–1.5 cm long, sparsely puberulous; stipules 0.4–0.6 cm long, subulate, entire or bifid, persistent. **Inflorescence** terminal, 1.5–3 cm across; peduncles 2.5–3 cm long,

glabrous or puberulous; bracts and bracteoles present, minute, linear 1–2 mm long. **Flowers** 0.6–1 cm long, 0.1–0.2 cm in diameter, white with creamy yellow tinge or pinkish–white to rosy red; pedicels 0.5–1 mm long, slightly puberulous; hypanthium 1–1.25 × 0.75–1 mm; calyx lobes 0.7 × 0.4 mm; corolla 5–8 mm long, infundibuliform, glabrous outside, villous at the middle within; lobes 0.7–1.2 × 0.6–1 mm, broadly acute; **Stamens** 5, adnate slightly above the base of corolla, inserted; filaments 1–1.5 mm long; anthers 1.2–1.7 mm long. **Ovary** 0.7–1 × 0.6–0.8 mm; disc 0.35–0.6 mm high; style 3.7–6.2 mm long, pubescent; stigma 0.5–1.2 mm long, lobes ovate to narrowly ovate, glabrous. **Capsules** 2–2.2 × 4–5 mm, glabrous; seeds angular, brown **(Plate 7 & Fig 9)**.

Distribution: INDIA: (Assam, Sikkim, Meghalaya, Andaman & Nicobar Islands, Karnataka). NEPAL, MYANMAR. THAILAND, BANGLADESH, SRI LANKA.

Phenology: Flowering: April–August**,** Fruiting: May–November

Ecology: Grows on moist shaded areas near the water streams and forest floor at elevation of about 200–400 m.s.l. along with *Diplanzium esculentum* (Retz.) Sw., *Ichnanthus pallens* (Sw.) Munro ex Benth, *Torenia crustacea* (L.) Cham. & Schltdl. etc.

Specimen examined: Assam, Lakhimpur district, Dulung Reserve Forest, 16.3.2019, 27°28'21.3"N 94°13'15.6"E, *B.Bhuyan BB0009* (ASSAM); Morigaon, Neili, Amguri, 17.3.2019, 26°04'38.5"N 92°17'17.5"E *B.Bhuyan BB0011* (BUBH).

Additional specimen examined: INDIA: Aizwal Road, 02.09.1957, *R.S Rao 9111* (ASSAM); Khasi Hills, 03.07.1937, *G.K. Deka15366* (ASSAM); South Garo Hill, 05.06.2014, *D.K. Roy130136* (ASSAM); Dawki Forest, 03.05.1943, *G.K.Deka21709*& 01.03.1938, *G.K.Deka16452* (ASSAM); Meghalaya, Khasi Hills, Cherrapunji, *Schlagiantweit s.n.* (BM); Khasi Hills, *J.D. Hooker & T.Thomson s.n.* (CAL, K, BM); Mausmai, *C.B. Clarke43738 A* (CAL); Jherria Ghat, *D.Hooper34712* (CAL); Pynursla, *A.S. Rao47489* (CAL). Assam. Cachar, *J.C. Prugla47* (CAL); Lakhimpur, *A. Meebold5693* (CAL); Kata Khal R. F., *R.S.Rao911* (CAL).Tripura. Sipaijala, *D.B.Deb1772A* (CAL). Arunachal Pradesh, *I.H.Burkill37380* (CAL); Kameng, Sissini, *G.Panigrahi6242 & 6306* (CAL). Nagaland. Ghaspani, *N.L.Bor 18482* (L).Mizoram Lungleh, *A.T.Gage 188* (CAL). Lushai Hills, *N.E.Parry30* (CAL). Andaman & Nicobar Islands, Great Nicobar hills, *M.A.Ali47* (CAL). Karnataka, North Canara, Kutgal, *W.A.Talbot628* (CAL); Suddshalli Karwar, *L.J.Sedgwick* & *T.R.D.Bell 6628* (CAL, K); North Canara, Sirsi, *L.J.Sedgwick* & *T.R.D.Bell 7035* (CAL). BANGLADESH: Montes Sillet. *Silva, F. de, Blinkworth, R.* & *Gomez, W* s.n. (GZU); *N.Wallich6229A* (W); *N.Wallich6229B* (CAL). MYANMAR: BorongaIsland, Arracan,

Mingoohills, *S.Kurz* s.n. (CAL, BM); Kachinhills, *Shaik Mokim* s.n. (CAL). TENASSARIM: Eastern Tenassarim, *A.F.G.Kerr 21609* (BM).

O. rugosa* var. *prostrata (D.Don) Deb & Mondal in Bull. Bot. Surv. India 24: 228. 1982.

O. prostrata Don, Prodr. Fl. Nep. 136. 1825; DC, Prodr.4: 415.1830; Don, Gen. Syst. Gard. Bot. 3: 522. 1834; Sant & Marchant in Bull. Bot. Surv. India 3(2): 109. 1961; Hara, Fl. E. Himal. 313. 1966 (Wall. Cat. Citation erroneous).

Type: Nepal, 1813, *B. Hamilton s.n.* BM *(n.v.)*.

O. harrisonii Don, Gen. Syst. Gard. Bot. 3: 523. 1834; Trimen, Fl. Ceylon 2: 321. 1895; Cooke, Fl. Pres. Bombay 1: 596. 1903; Gamble, Fl. Press. Madras 607. 1921; Haines, Bot. Bihar Orissa 443. 1922.

Type: Malacca, *S. Harris* s.n. Herb. *Heyne* s.n. in Wall. Cat. *6236*, Holotype CAL (Barcode CAL0000010967).

Description

Herbs attaining height of 17–40 cm long; stem prostrate, rooting at lower nodes, glabrous or rarely puberulous. **Leaves** 1.5–5 × 1–2 cm, broadly ovate, obtuse to subacute at apex, rounded or subcordate at base, glabrous; lateral nerves 5–7 on either side; petioles 0.5–1 cm long, glabrous or puberulous; stipules 0.3–0.6 cm long, filiform from a triangular base, entire or bifid. **Inflorescence** 1–2 cm across; peduncle 2.5–3 cm long, glabrous; bracts and bracteoles present, minute, linear 1 mm long. **Flowers** 8–10 mm long, pale pink; pedicels 0.5–1 mm long; hypanthium 0.6–1 × 0.5–9 mm. Calyx lobes 0.6–1 × 0.3–0.7 mm; corolla 7–9 mm long, infundibuliform, glabrous outside, villous at the throat within; lobes 1.25–1.75 ×0.75–1 mm. **Stamens** 5, adnate to slighty above the base of corolla; filaments 1.75–2 mm long; anthers 1.75–2 mm long. **Ovary** 0.5–0.8 × 0.4–0.7 mm, disc 0.5–0.75 mm high; style 4.5–7 mm long; stigma 0.3–0.5 mm long, lobes ovate–lanceolate. **Capsule** 2–2.2 × 4–4.5 mm, glabrous. Seeds 0.2 × 0.3 mm, glabrous, brown. **(Plate 8 & Fig 10).**

Distribution: INDIA: (Assam, Bihar, Orissa, Maharashtra, Goa, Tamil Nadu, Kerala). NEPAL, BHUTAN, SRI LANKA, MALAY, MYANMAR.

Phenology: Flowering: April–November; Fruiting: May–December

Ecology: Grows on moist and clayey soil in forest floor at elevation of about 100–300 m.s.l. along with *Thottea* sp., *Lycopodiella cernua* (L.) Pic.Serm., *Cyathula prostrata* (L.) Blume etc.

Specimen examined: Lakhimpur dist, Kadam Dirgha, Kakoi Reserve Forest, 17.3.2019, 27°23'34.7"N 94°05'44.1"E *B.Bhuyan BB0008* (BUBH); West Karbi Along, Amlong,

30.03.2020, 25°47'56.2"N 92°35'24.0"E *B.Bhuyan BB0021* (BUBH).

Additional specimen examined: INDIA: Peninsular India, *R.Wight1345* & *R.Wight1344* (M); East Bengal, *Griffth2860* (MNHN); Andaman, *W.Hooker2857* (MNHN); Nilgiri, *Thomson s.n.* (MNHN); Bihar, Saranda forest, *Srivastava75210* (LWG); Orissa, Baripada, Meghasni forest, *S.L.Kapoor73359* (E, LWG). Andhra Pradesh. Godavary Jungles, *R.W. Indu* s.n. (CAL); Tamil Nadu: Kanyakumari, Kilavirumalai, *A.N. Henry48134* (CAL, MH); Madras, *Blatter & Hallberg203* (CAL); Madura, *K.C.Jacob17640* (CAL, MH); Nilgiri, *Thomson* s.n. (CAL); Siruvani, *A. N. Henry511* (CAL, MH); Kerala, Palghat, Silent Valley *E.Vajravelu26058* (CAL, MH); *R.Ansari51489* (CAL, MH); Trivandrum, Bonaccord Estate, *J. Joseph44492* (CAL, MH); South Malabar, Dhoni, *C.E.C.Fischer1996* (CAL); Donmudi Hills, *E. Barnes1190* (K); Karnataka, Garsappa falls, *A.Meebold9931* (CAL); Castle Rock, *L.S.Sedgwick2736* (CAL); North Canara, Yellapur, *R.W. Indu* s.n. (K); South Canara, Sullia, *C.A.Barber2130* (CAL,MH); Gundier, *A. Meebold9932* (CAL); Balchalley State forest, Augumbe, *K.S.Srinivasan* s.n. (BSIS); Maharashtra. Katlekan evergreen forest, *J. Fernandes1940* (CAL); Poona, Kalapani forest, *B.V. Reddi96020* (ESI).Goa. *N. P. Singh 124588 (*BSI); Usgao, *R. S. Raghavan103424 A* (BSI). NEPAL: Gokarna, *P. Pradhan & R. Thapa4530* (CAL). BHUTAN: Trashmangstchu: *F. Ludlow, G. Sherriff & J. H. Hicks 20482* (BM). MYANMAR: Kachin Hills, Kingting, *S. Mokim* s.n. (CAL); Juonugoo, *A. Reeuger* s.n. (CAL): MALAYA: Malacca, S. Haris s.n. ex Wall. Cat. 6236 (CAL, K). NEPAL: Kharikhola, 23.7.1966, *M.L.Banerji1878* (USF); *Buchanan s.n.* (NHMUK). CAMBODIA: Kampot, 11.8.1919, *E.Poilane304* & *324* (MNHN). PHILIPINES: Dumaguete, 1908, *A.D.E. Elmer9582* & *A.D.E. Elmer9134* (VT); Luzon, *A.D.E. Elmer6456* (MNHN); NEW GUINEA: *Schlechter13977* (BG); New Guinea, 1902, *R. Schlechter13977* (BR). CHINA: Tonkin, 1939, *W.T. Tsang29319* (MNHN). THAILAND, *N.R.Bunnag48 (*TCD) & *F.G.Arthur6162* (TCD).

8. *O. tingens* C.B. Clarke ex C.E.C. Fischer in Kew Bull. 33. 1940; Deb, Fl. Tripura State 2:76. 1983; Deb & Mondal in Nayar & Sastry, Red Data Book Ind. Pl. 2: 231. 1988; Deb & Mandal in Bull. Bot. Surv. India. 39: 124.1997.

Type: Naga Hills, Kohima, 1740 m, *C.B. Clarke 41121* Holotype K (Barcode K000031237); Khasia, *C.B. Clarke 40695A*; Isotype CAL (Barcode CAL0000010950).

Description

Herbs annual, attaining height of 20–40 cm tall, sometime; stem greenish, somewhat woody below, internode 2–3 cm long and 3 mm in diameter. **Leaves** 7–11 x 4–6 cm, opposite and

decussate, ovate or elliptic lamina shape, subcaudate apex at apex, tapering at base, margin entire, green and scabrous above; mid vein prominent beneath, lateral nerves 9–11 on either side, lateral nerve hairy beneath, abaxial purplish in colour; petioles 0.5–1 cm long, puberulous; stipules persistent, acicular, sometimes with broad base, sometimes bifid, 0.2–0.3 cm long. **Inflorescence** terminal, corymbose cymes, 1–1.5 cm across, slightly puberulous; peduncles 2–2.5 cm long, puberulous;bracts and bracteoles minute, 0.1 cm long. **Flowers** 0.5–0.6 cm long, infundibuliform, white, pedicels 0.2–0.3 cm long, puberulous; Hypanthium 0.6–0.9 cm, obovoid, puberulous; calyx lobes minute, 0.1 cm long, brownish, obtuse apex, puberulous; corolla 0.1–0.2 cm long, glabrous outside, villous at the middle corolla tube; lobes 0.7–0.8 × 0.2–0.3 mm, ovate, subacute. **Stamens** 5 adnate at the base of corolla or slightly above, inserted below the viscous ring, 0.2 or 0.3 cm long, brown. **Ovary** 0.4–0.6 × 0.4–0.7 mm, disc 0.5–0.6 mm high; stigma bilobed, style hairy, $3/4^{th}$or $1/4^{th}$of the corolla tube, 0.1 or 0.3 cm long. **Capsule** pubescent, 0.4 x 0.2 cm, locule ovate, slightly inclined outward. Seeds many, 4–5 angled **(Plate 9 & Fig 11).**

Distribution: INDIA: (Assam (Karbi Anglong, Nagaon), Meghalaya, Nagaland). BANGLADESH, MYANMAR.

Phenology: Flowering: March–July, Fruiting: June–August.

Ecology: Mainly grows in moist and shady places, nearby forest foot hills in the elevation of 400–600 m.s.l. along *Lycopodiella cernua* (L.) Pic. Serm., *Ixora sp*., *Pteris semipinnata* L. etc.

Specimen examined: Assam, West Karbi Anglong, Amlong, 04.04.2021, 25°47'47.4"N 92°33'51.5"E, *B.Bhuyan BB0023* (ASSAM); Hamren, 06.04.2021, 25°51'20.9"N 92°34'56.3"E, *B.Bhuyan BB0024* (BUBH).

Additional specimen examined: INDIA: Assam, *F. Jenkins s.n.* (L); Naga Hills, 1936, *N.L.Bor19818* (ASSAM); Khasia, Mungpo, 04.10.1885, *C.B.Clarke40695 A* (CAL); Byrnihat, 09.05.1885, *C.B.Clarke38076D* (CAL); KhasiaHills, 06.09.1982, *M.Gangopadhyay11692* (CAL); Kohima, Naga Hills, 01.6.1950, *W.N. Koelz25193* (MICH); Konoma, 01.04.1896, *King's collector246* (L), Naga Hills, Kohima, *C.B. Clarke41121A* (K); Khasia, 02.04.1886, *C.B. Clarke43268* (K); Kohima, Kegwema Road, 13.05.1895, Reporter on Economic Products to the Govt. of India *11416* (P); Naga Hills, *D. Prains.n.* (P); Nagaland, Japvo, *G. Reporter on Economic Products11476* (US); East Bengal, *H. Griffth2865* (L).

9. *O. hispida* Hook.f., Hook. f., F1. Brit. India. 3: 83.1880; Kanjilal *et al*., Fl. Assam 3: 42. 1939; Balakr, Fl. Jowai 1: 249. 1981; Deb & Mondal in Nayar & Sastry Red Data Book Ind. Pl. 2: 223. 1988; Chauhan *et al.*, Fl. of Namdapha 191. 1996; Deb & Mondal in Bull. Bot. Surv. India 39: 59. 1997.

Type: Khasia, Cherrapunjee, 13.08.1850, *J.D. Hooker & T. Thomson20*, Holotype K (Barcode K000031215).

Description

Herbs, 10–40 cm long; stems procumbent, branched, hispid; internode 1.5–1.8 cm long and 2–3 mm in breadth. **Leaves** 2–16 × 2–4 cm, ovate–lanceolate, acute or obtuse at apex, base obtuse, hispid; lateral nerves 7–13 on either side; petioles 0.6–1.7 cm long, hispid; stipules 5–6mm long, oblong–lanceolate, acuminate, hispid at margin. **Inflorescence** terminal capitate cymes, 2 cm across, subglobose, dense flowered, hispid; peduncles 0.5–1.5 cm long, stout, hispid. **Flowers** 5–6.5 mm long, reddish; bracts and bracteoles similar, persistent, concealing the flowers, 0.4–0.5 × 0.1–0.2 cm, lanceolate, acute at apex, hispid; hypanthium 0.1 × 0.75 mm obovoid, hispid; calyx lobes 0.7–1.2 × 0.5–0.6 mm, ovate–lanceolate, acute, hispid; corolla 4–5.25 mm long, shortly infundibuliform, broad at base, hispid outside, villous at the throat within; lobes 1.2–1.5 × 0.7–1.2 mm, ovate–oblong, spreading, acute, hispid outside. **Stamens** adnate to the throat of corolla or slightly below, inserted or slightly exserted; filaments 0.8–1 mm long, glabrous; anthers 1–1.2 mm long, oblong–linear. **Ovary** 0.7–1 × 0.6–0.8 mm, obovoid to subglobose; disc styles 1–1.5 mm long, glabrous; stigma bilobed, 1–1.25 mm long, lobes oblong–lanceolate, acute at apex, glabrous. **Capsules** 1.5–2.5 × 3.5–6 mm, hispid, locules ovate–oblong **(Plate 10 & Fig 12).**

Distribution: INDIA: (Eastern Himalaya, Assam). BANGLADESH.

Phenology: Flowering: August–October, Fruiting: November–December

Ecology: Grown in shady damp places nearby streams in the elevation of 200–400 m.s.l along *Pteris* sp., *Nephrolepis cordifolia* (L.) C. Presl., *Eranthemum* sp., *Floscopa scandens* L., *Selaginella chrysorrhizos* Spring etc.

***Specimen examined*:** Assam, Lakhimpur dist, Dullung Reserve Forest, 20.08.2021, 27°41'16.5"N 94°11'38.4"E *B.Bhuyan BB0027* (BUBH).

Additional specimen examined: INDIA: Khasia, Cherrapunji, *J.D.Hooker & T.Thomson 20* (K); Lakhimpur, Digboi, 1937, *N.L. Bor13930* (ASSAM); Lakhimpur, Digboi, 18.06.1938, *G.K. Deka 16964* (ASSAM); Khasi & Jantia Hills, Narpuh Reserve Forest, 21.07.1957, *G.K. Deka10105* (ASSAM); Cachar, Bhuban Hill, 08.09.1978, *R.B. Majumdar73057* (ASSAM);

Cachar, Lailapur to Aizwal road, 19.09.1978, *B. Majumdar73492* (ASSAM); Lakhimpur, Makum, 12.04.1885, *C.B. Clake37830* (K, CAL); Namsung, C.B. Clarke 37931 (K,CAL). Myanmar: Kachin Hills, Kritoo, E. Pttinger42 (CAL); Chindwin Bhamo, S. Toppin 3123 & 3125 (CAL); Katha dist, Kadu hills J.H. Lace 5334 (CAL, E).

The following section includes the species distributional map depicting species collection site (Fig. 2) and photo-illustration plates and line drawing of the 10 investigated taxa documented in the present work **(Plate 1–11 & Fig 3–12).**

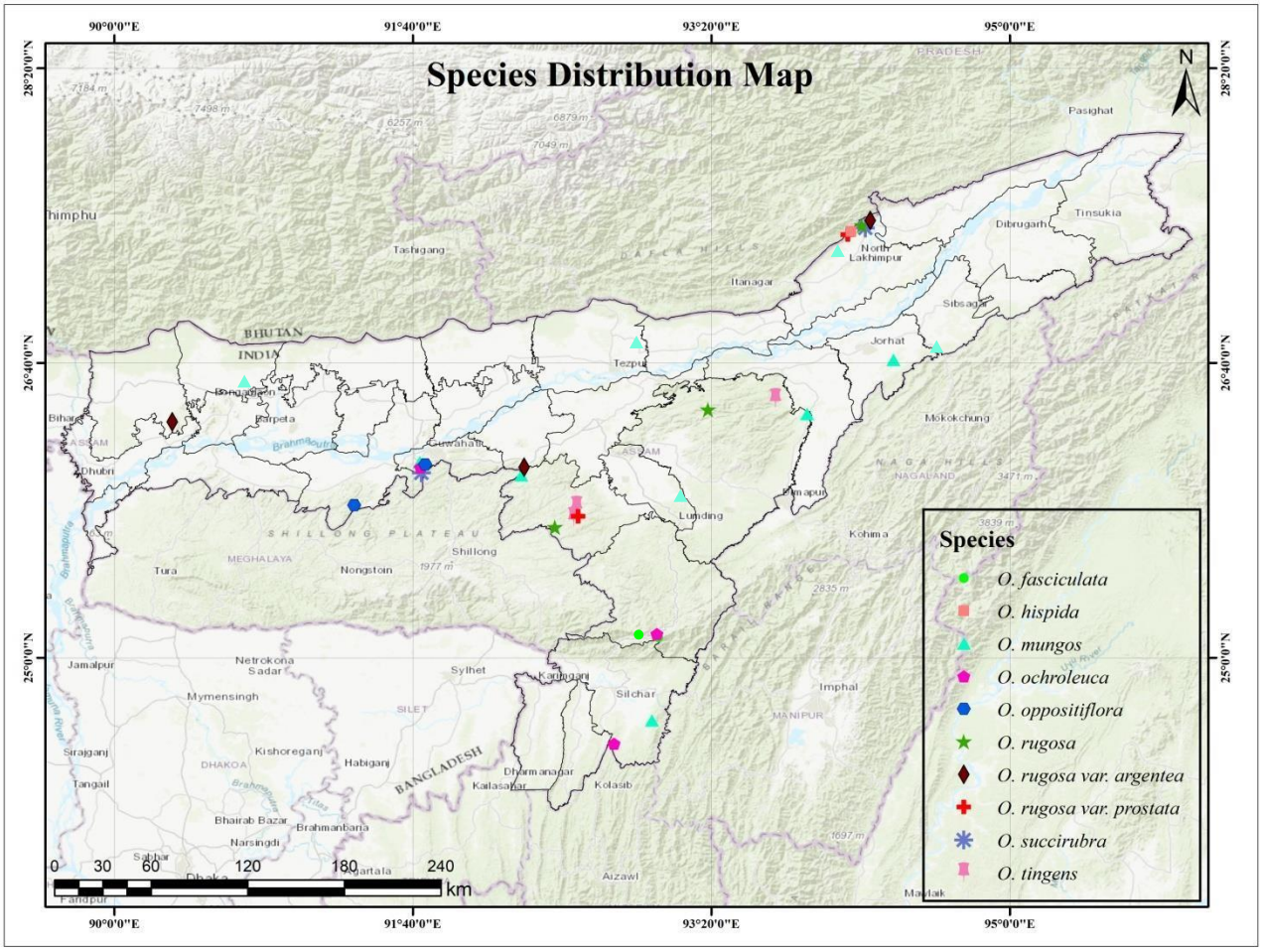

Fig. 2 Distribution map of the collected species

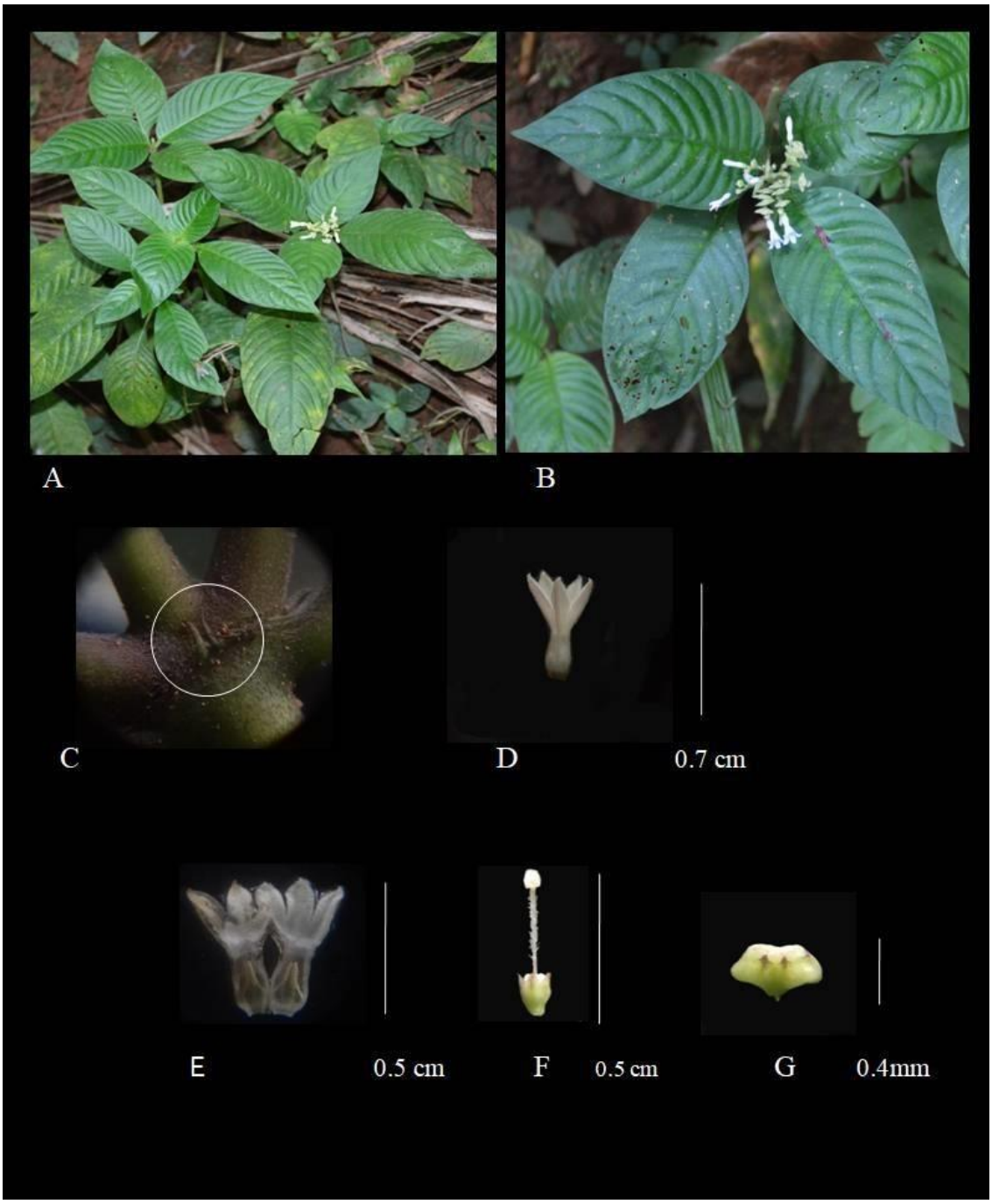

Plate 1 ***Ophiorrhiza mungos.*** A & B- Habit; C- Stipule; D-Single flower; E- Split open flower; F- long style; G- Capsule.

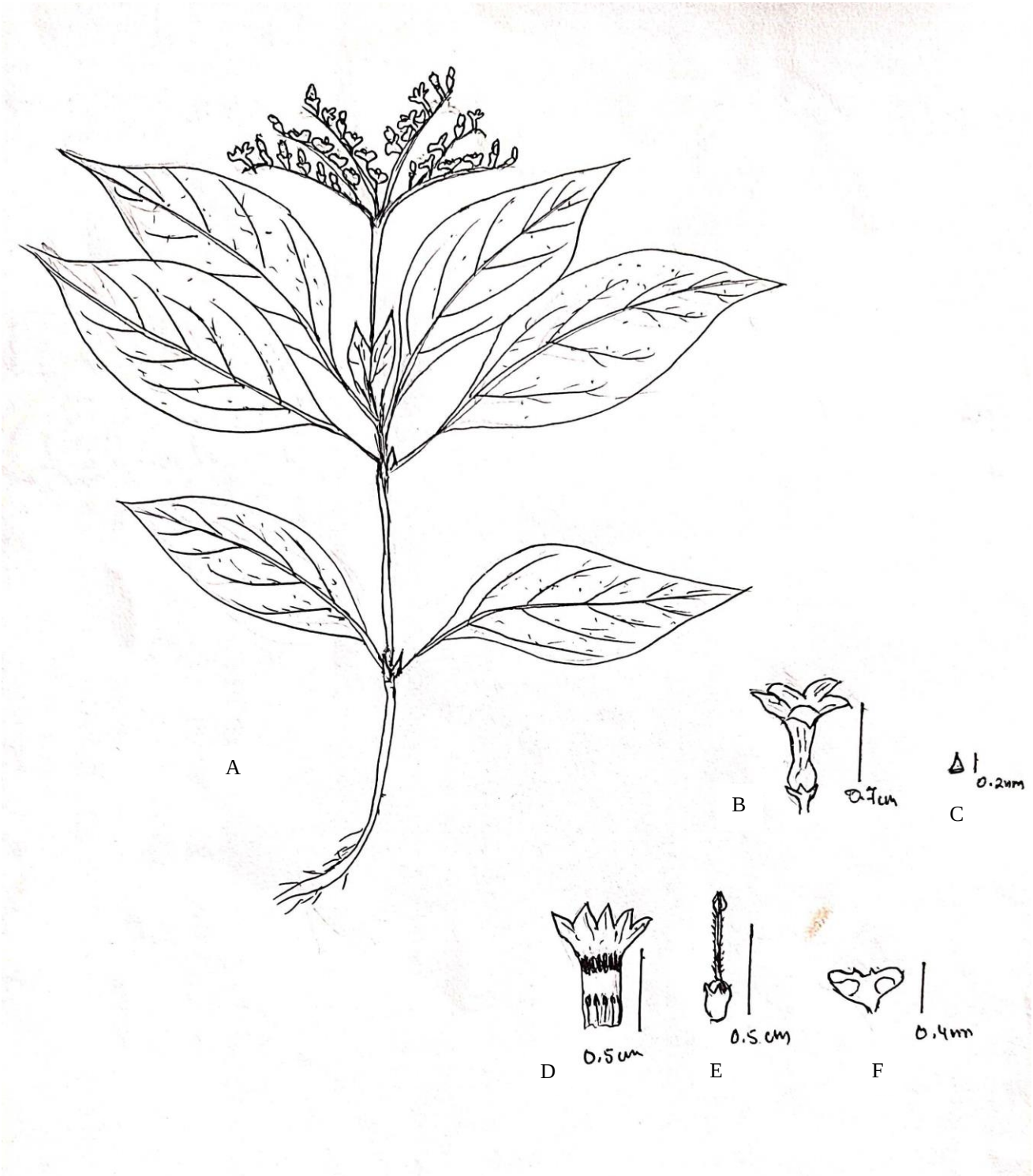

Fig 3 Illustration of ***Ophiorrhiza mungos.*** A- Plant; B- Flower; C- Stipule; D- Split open flower; E- Long style; F- Capsule.

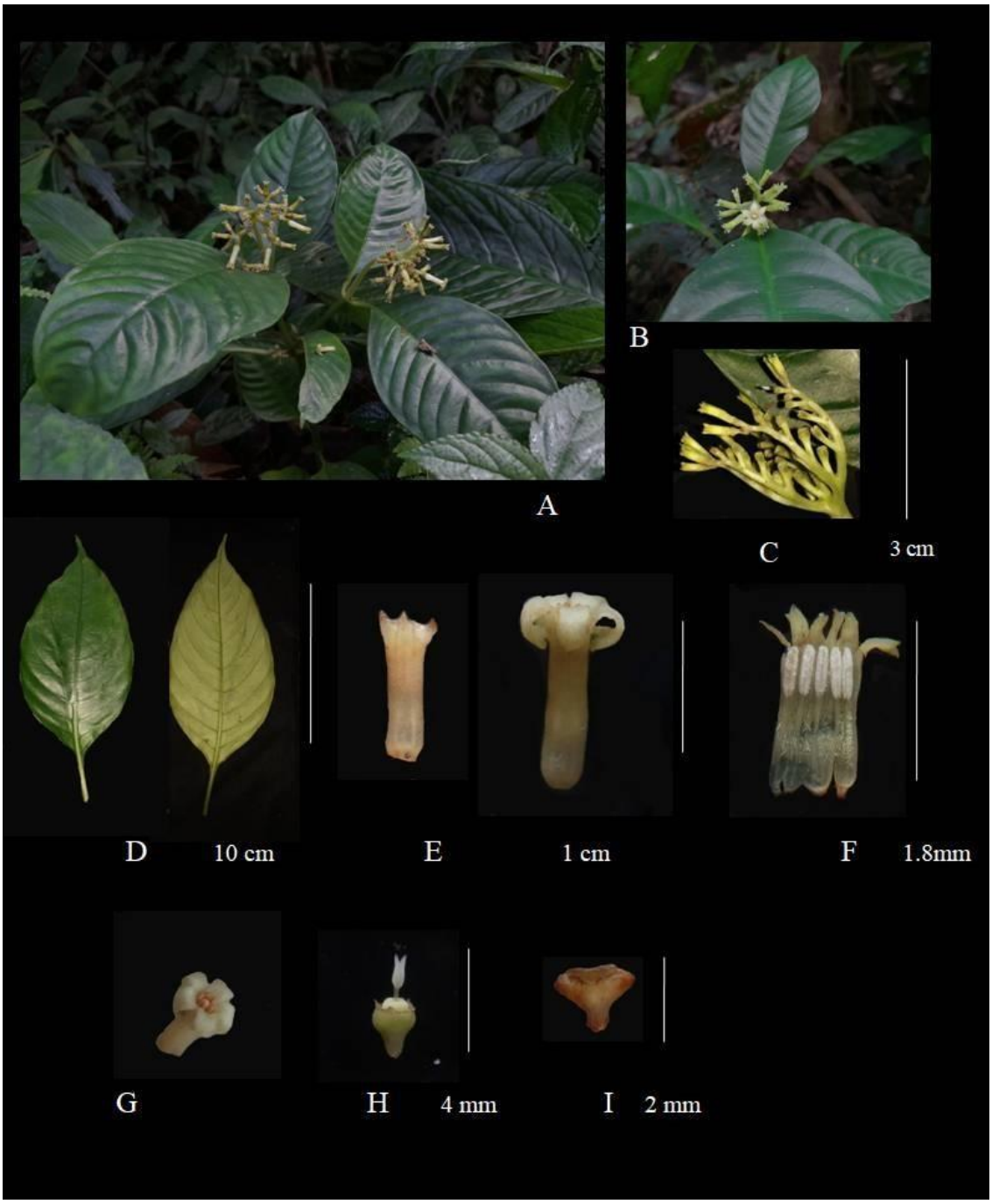

Plate 2 ***Ophiorrhiza ochroleuca***. A-Habit; B & C- Inflorescence; D- Leaves; E- Flower; F- Split open flower; G- Front view of flower; H- Short style gynoecium; I- Capsule.

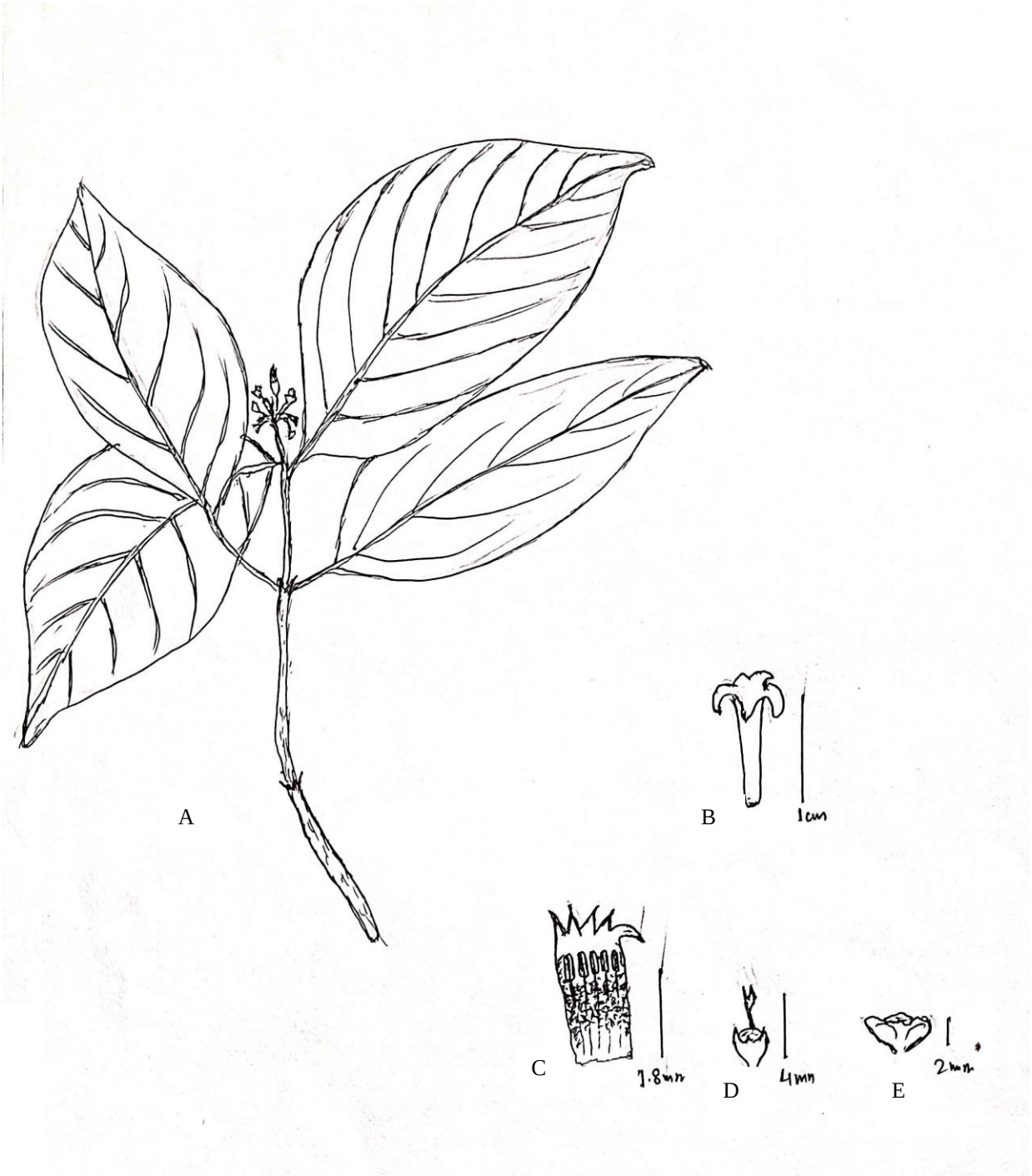

Fig 4 Illustration of ***Ophiorrhiza ochroleuca.*** A- Plant; B- Flower; C- S- Split open flower; D- style; E- Capsule.

Plate 3 ***Ophiorrhiza succirubra***. A-Habit; B- Inflorescence; C- Stipule; D- Flower; E- Front view of flower; F- Split open flower; G- Short style gynoecium; H- Capsule.

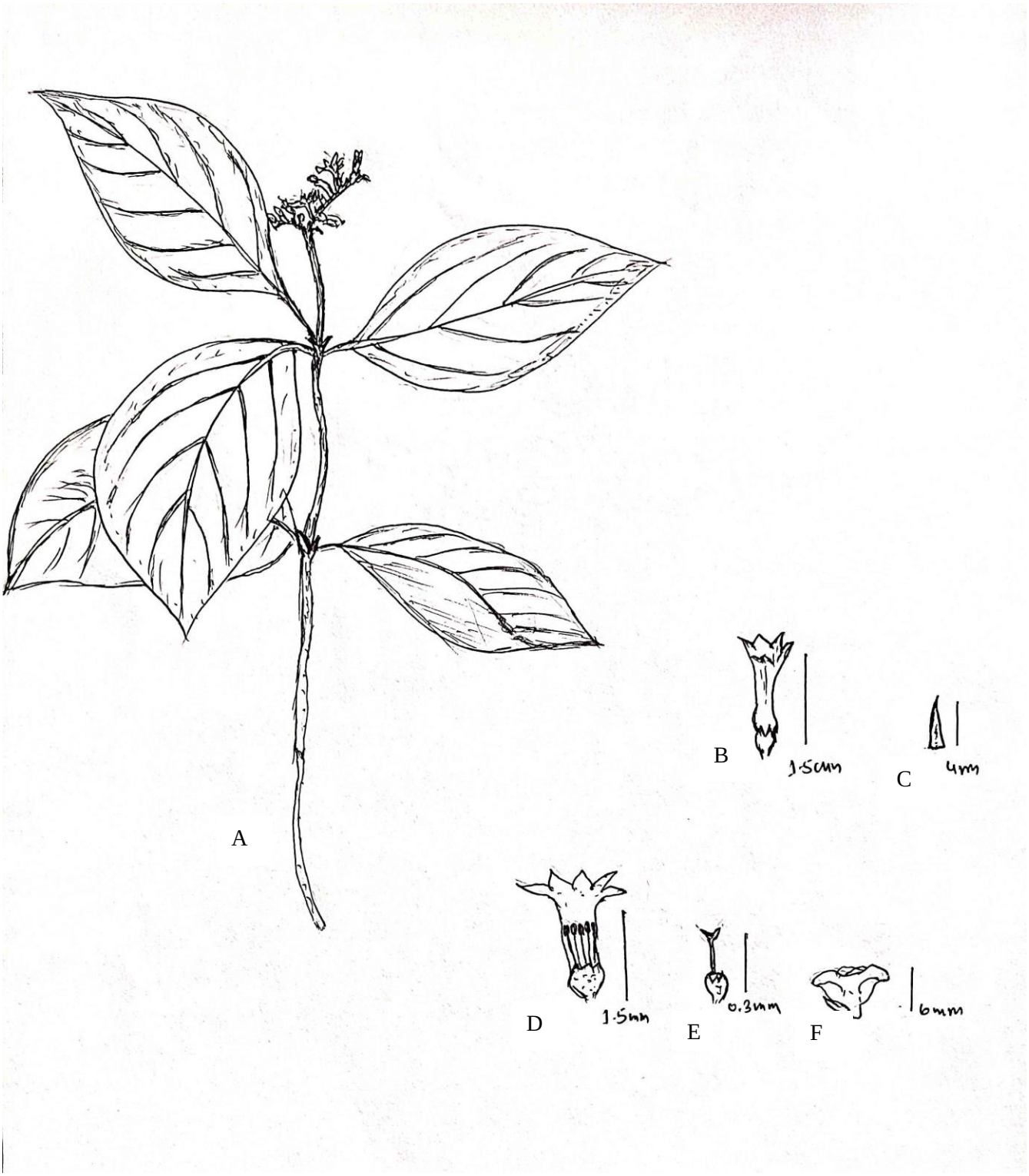

Fig 5 Illustration of ***Ophiorrhiza succirubra.*** A- Plant; B- Flower; C- Stipule; D- Split open flower; E- Style; F- Capsule.

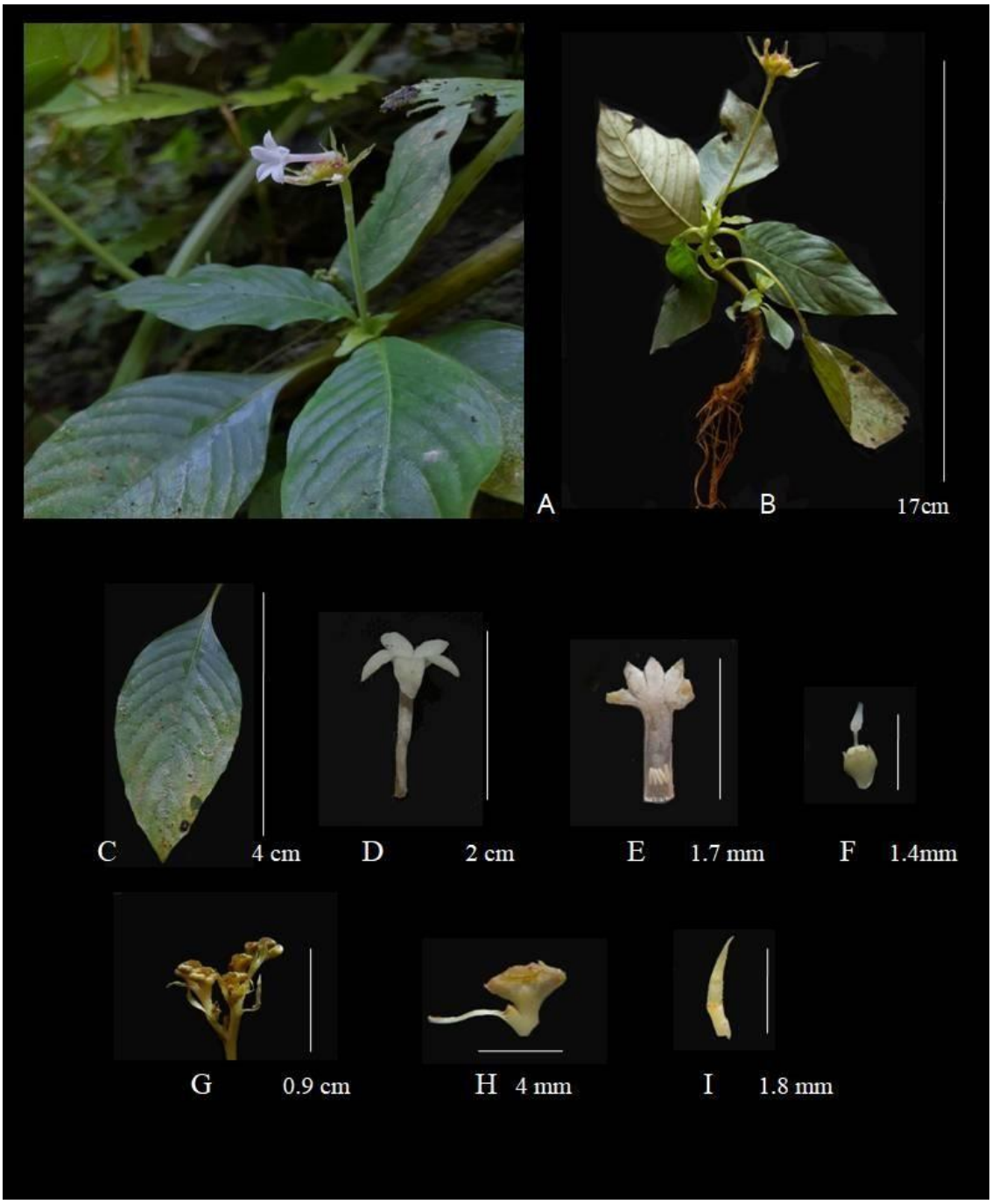

Plate 4 ***Ophiorrhiza fasciculata***. A & B- Habit; C-Leaf; D- Flower; E- Split open flower; F- Short style gynoecium; G- Infloresecence with capsule; H- Capsule with bracts; I- Bracts

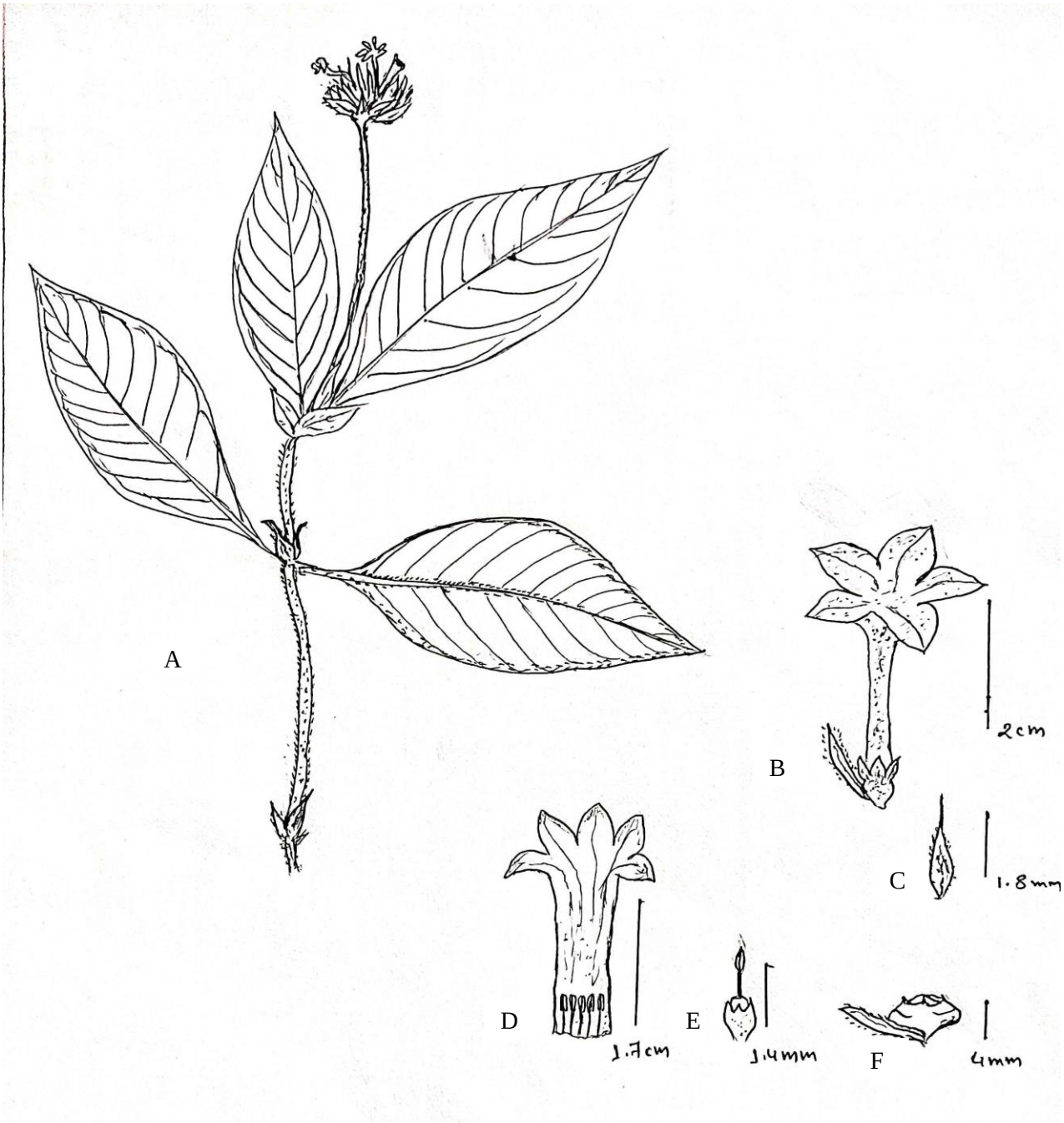

Fig 6 Illustration of ***Ophiorrhiza fasciculata.*** A- Plant; B- Flower; C- Bract; D- Split open flower; E- Style; F- Capsule with bracts.

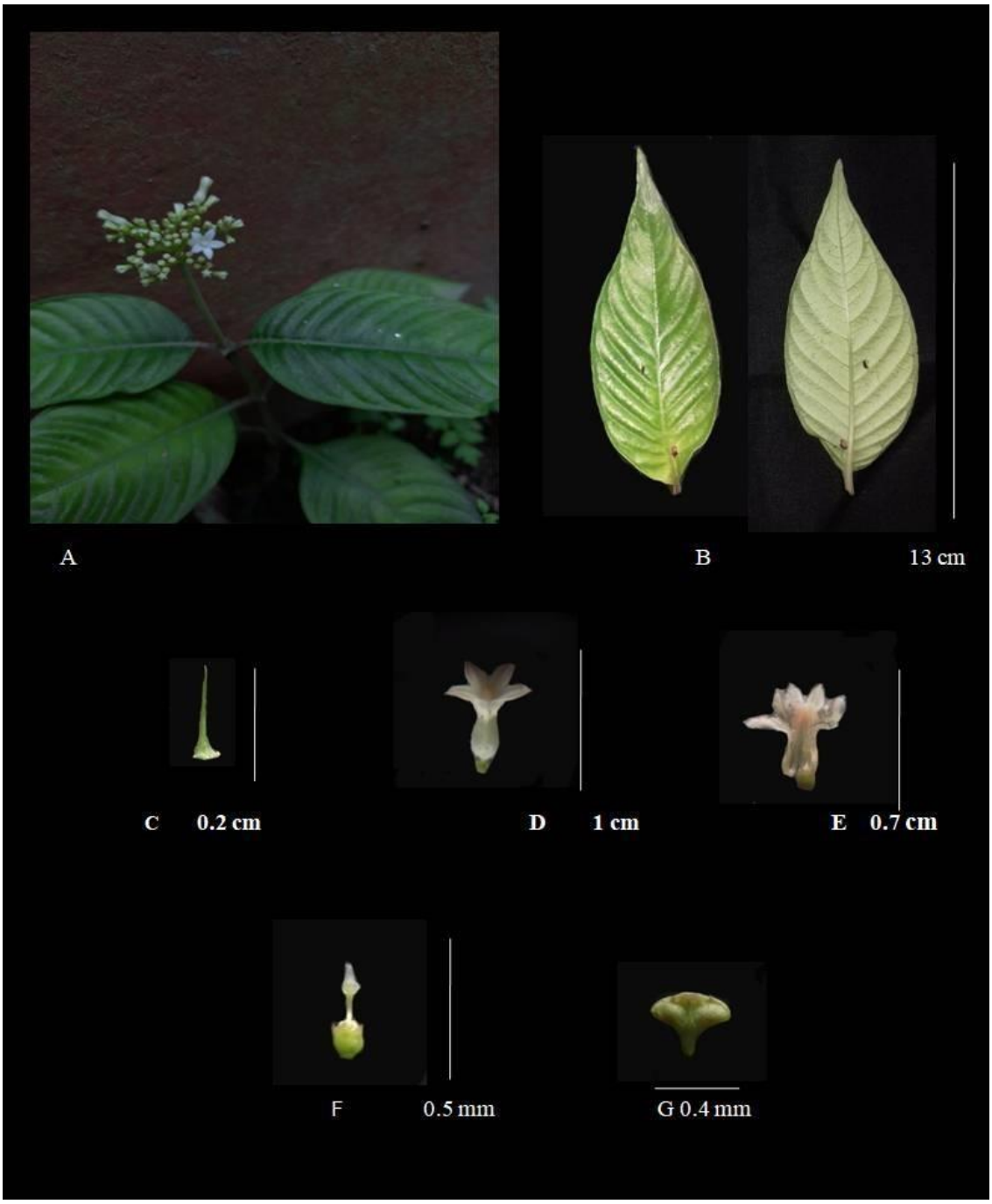

Plate 5 ***Ophiorrhiza oppositiflora***. A- Habit; B- Leaves; C- Stipule; D- Flower; E- Split open flower; F- short style gynoecium; G- Capsule.

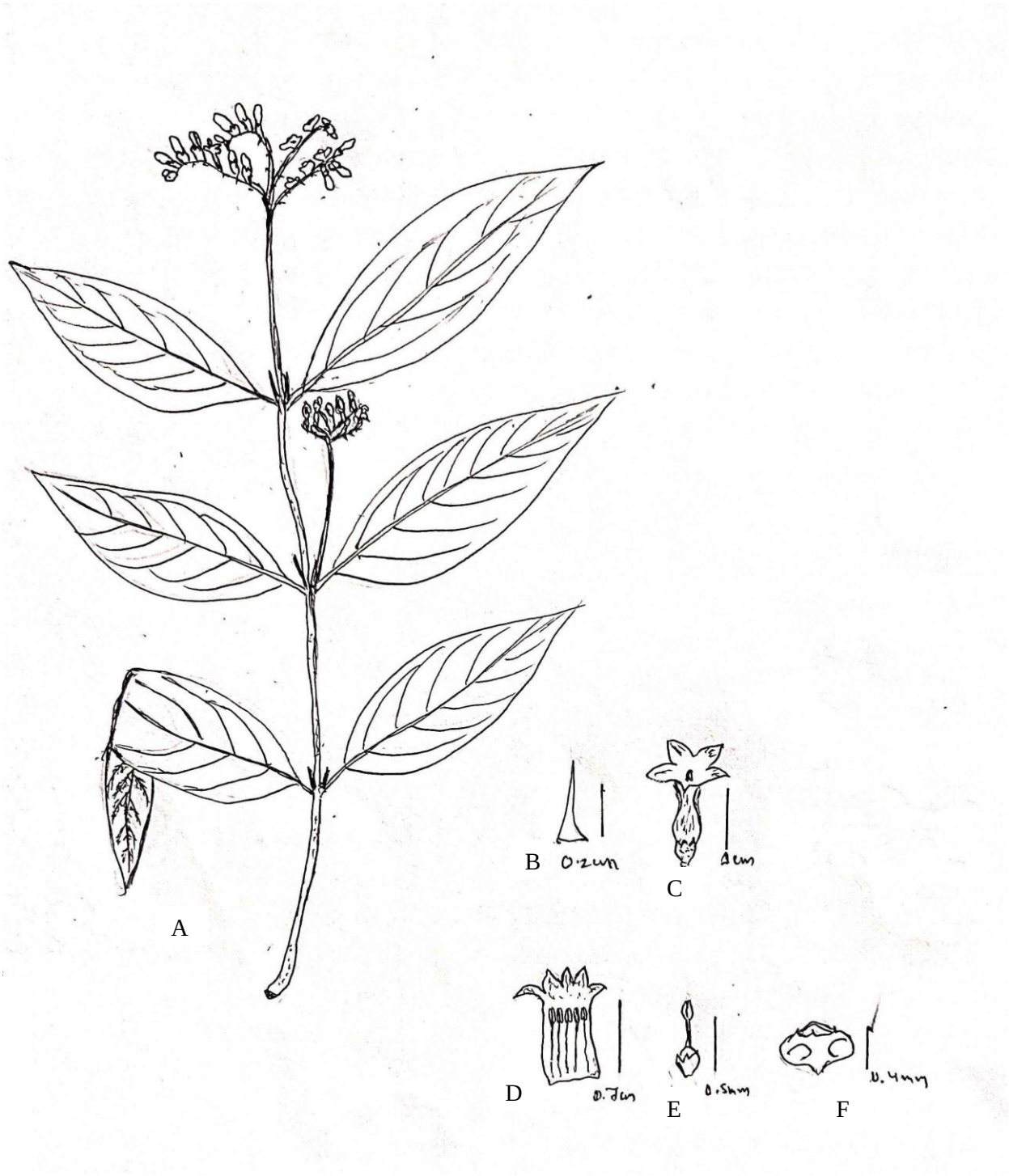

Fig 7 Illustration of ***Ophiorrhiza oppositiflora.*** A- Plant; B- Stipule; C- Flower; D- Split open flower; E- Style; F- Capsule.

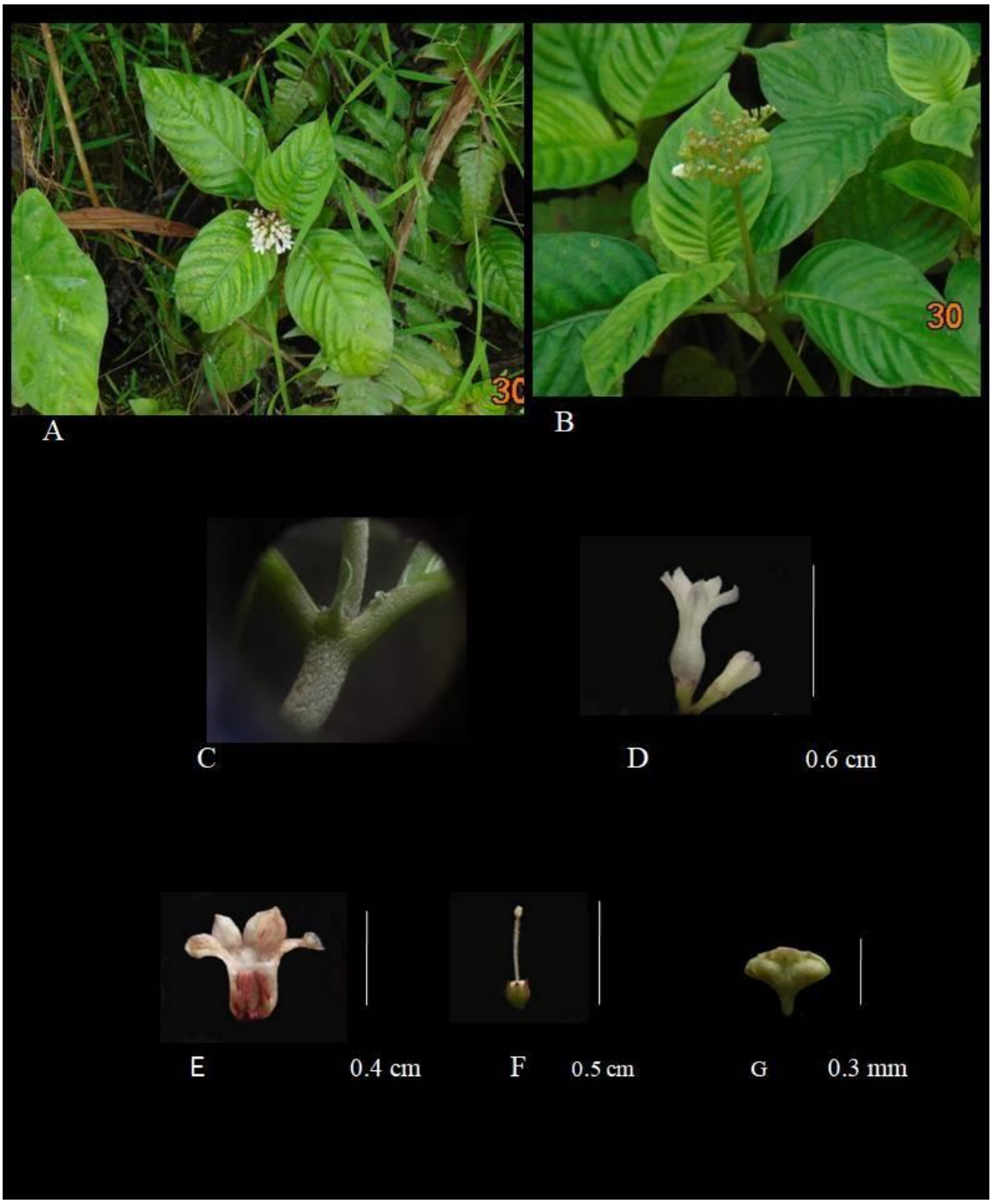

Plate 6 ***Ophiorrhiza rugosa***. A & B- Habit; C-Interpetiolar stipule; D- Flower; E- Split open flower; F- Long style gynoecium; G- Capsule.

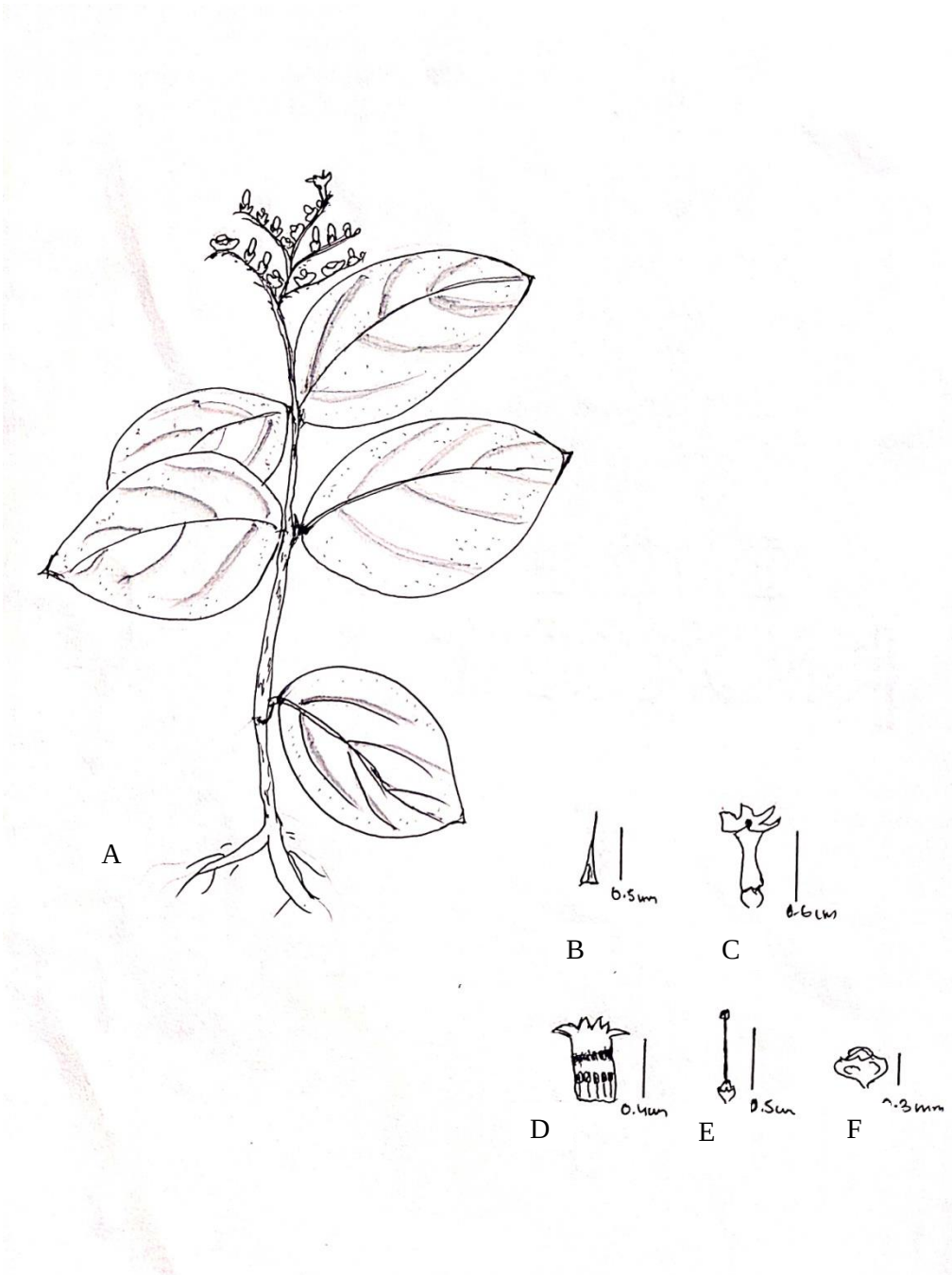

Fig 8 Illustration of ***Ophiorrhiza rugosa*.** A- Plant; B- Stipule; C- Flower; D- Split open flower; E- Long tyle;F- Capsule.

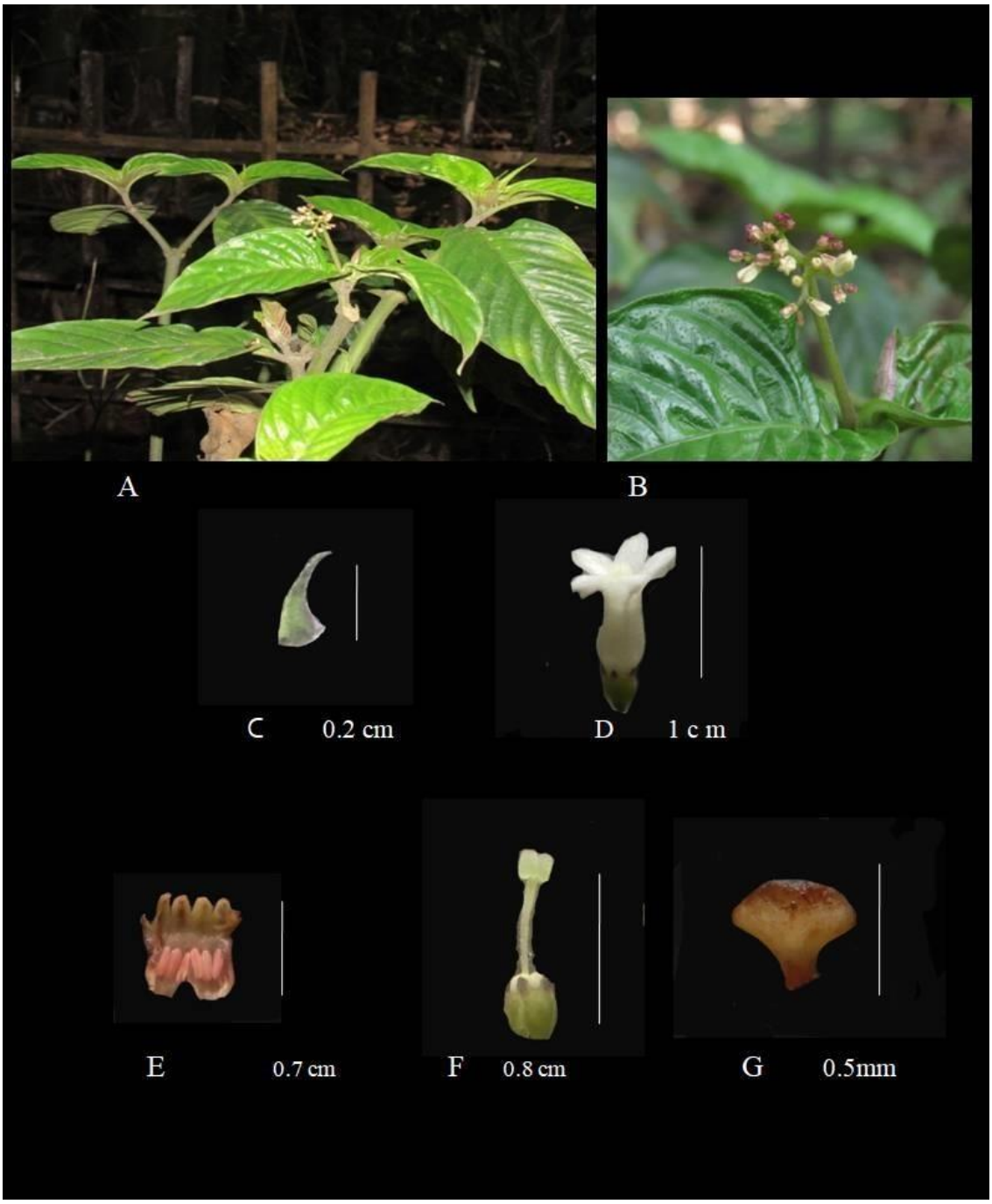

Plate 7 ***Ophiorrhiza rugosa* var. *argentea***. A- Habit; B- Inflorescence; C- Stipule; D- Flower; E- Split open flower; F- Long style; G- Capsule.

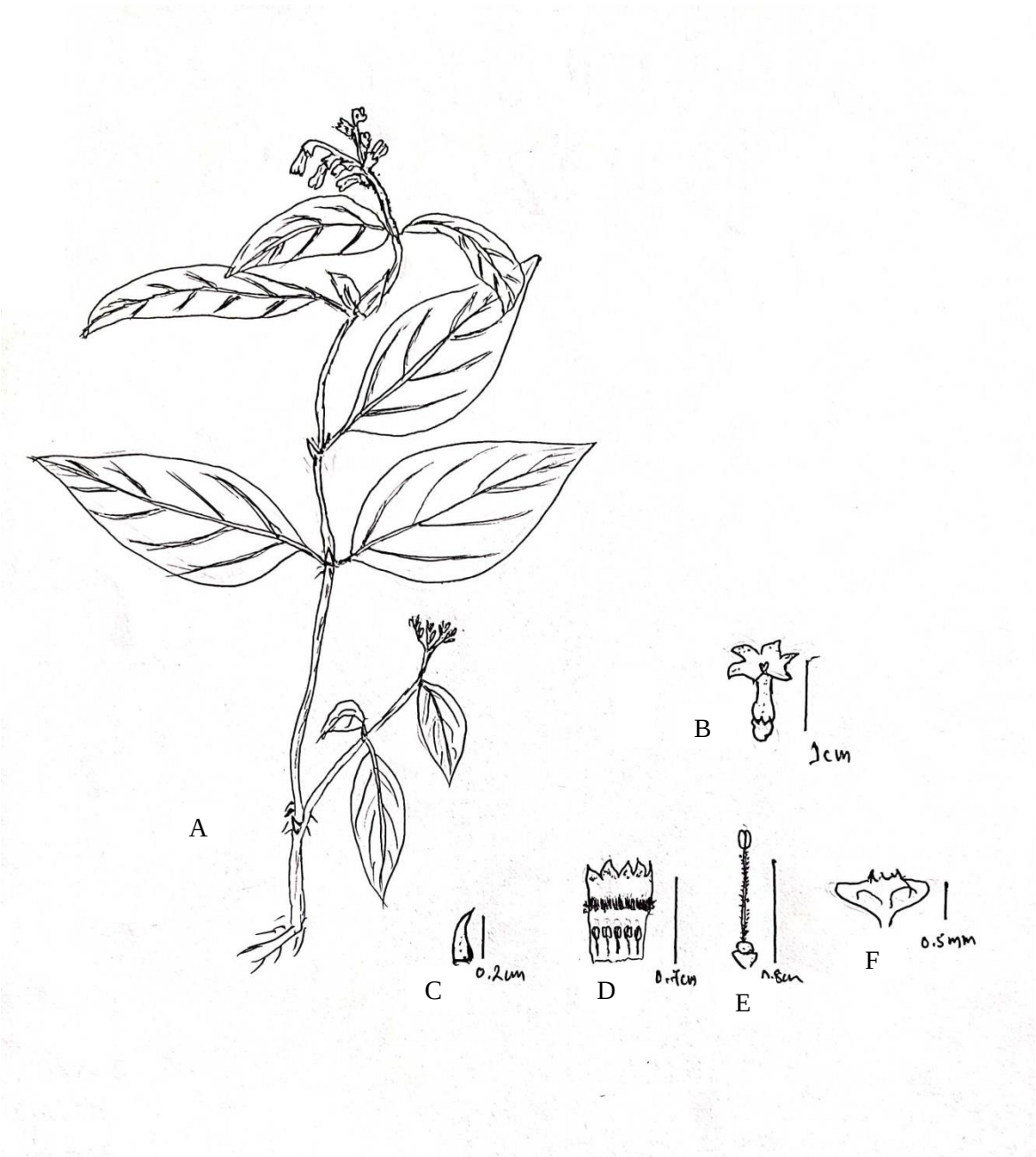

Fig 9 Illustration of ***Ophiorrhiza rugosa* var. *argentea*.** A- Plant; B- Flower; C- Stipule; D- Split open flower; E- Long style; F- Capsule.

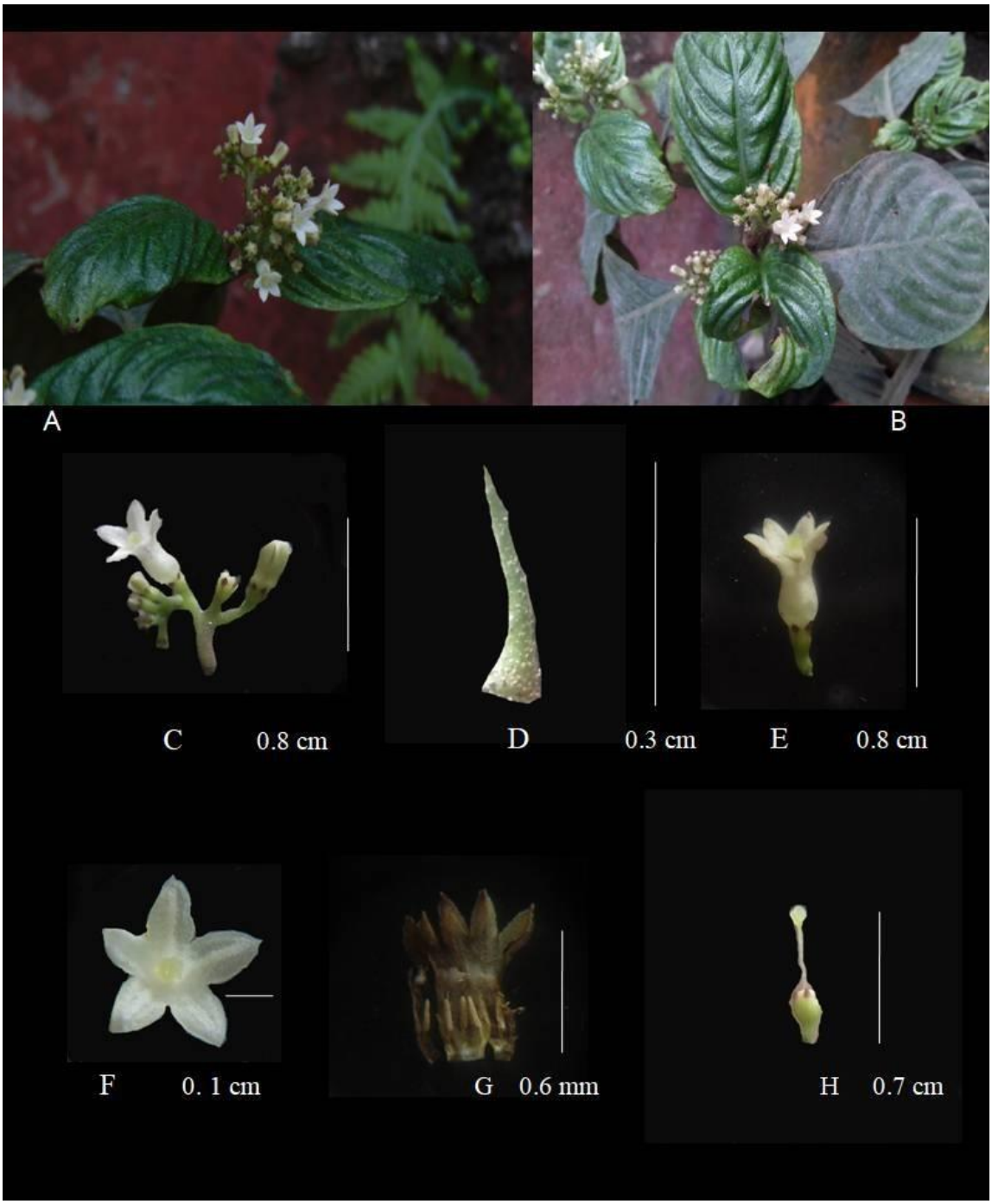

Plate 8 ***Ophiorrhiza rugosa* var. *prostata***. A & B- Habit; C- Inflorescence; D- Stipule; E- Single flower; F- Front view of flower; G- Split open flower; H- Long style gynoecium

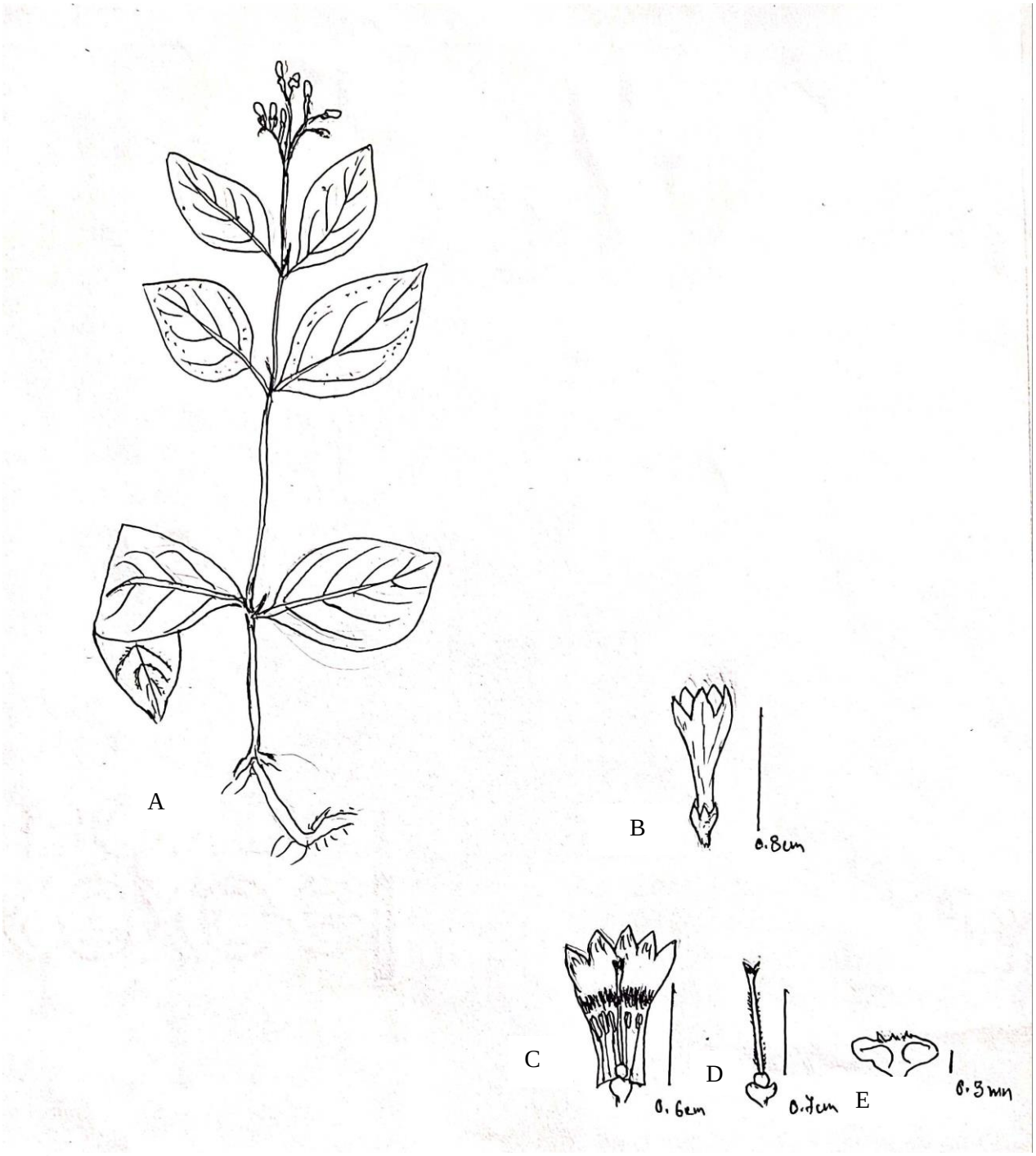

Fig 10 Illustration of ***Ophiorrhiza rugosa*** **var.** ***prostata*****.** A- Plant; B- Flower; C- Split open flower; D- Style; E- Capsule.

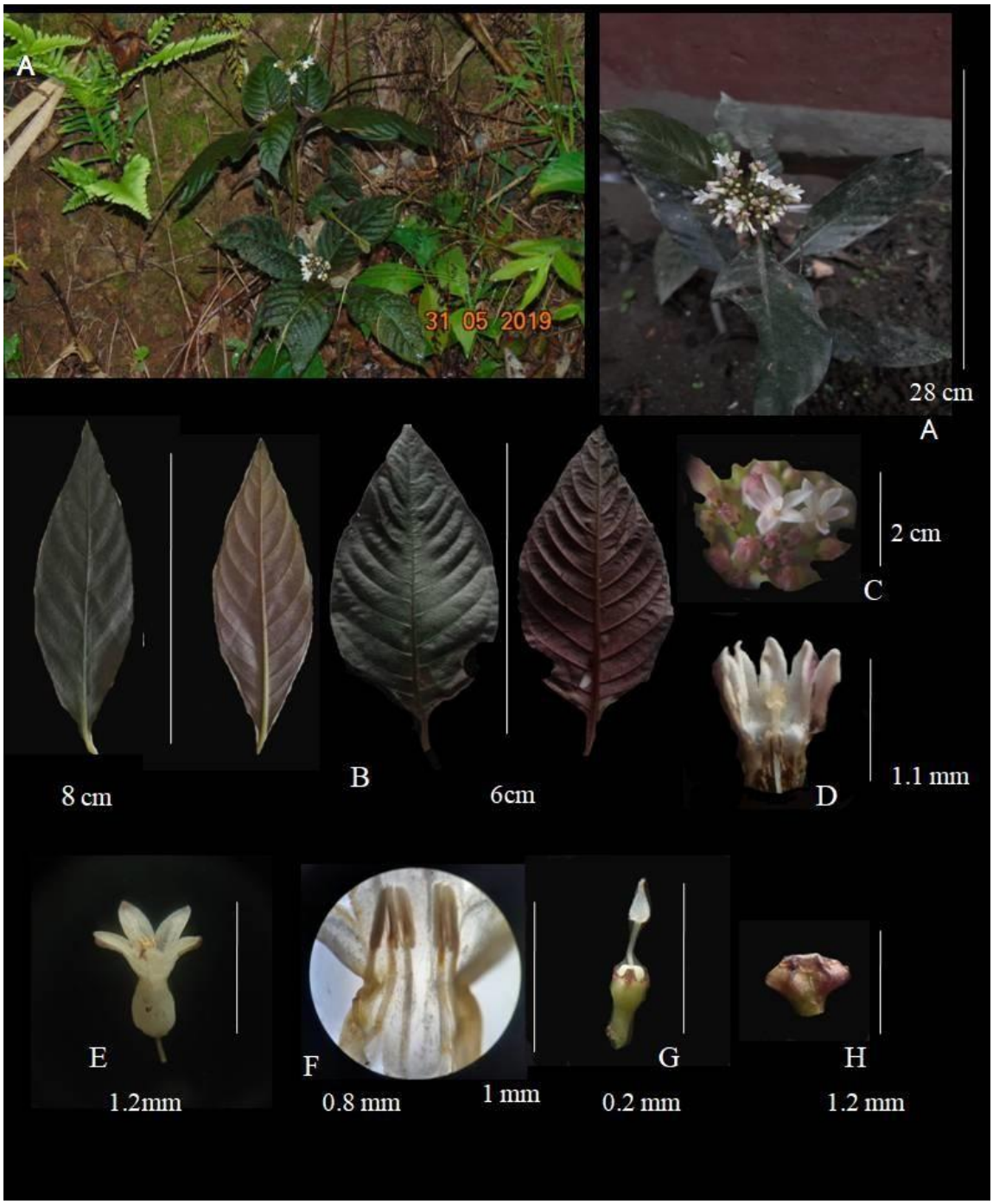

Plate 9 ***Ophiorrhiza tingens***. A- Habit; B- Elliptic and ovate leaves; C- Flower with long style; D- Split open flower long style; E- Single flower with short style; F- Split open flower with long filament; G- short style gynoecium; H- Capsule.

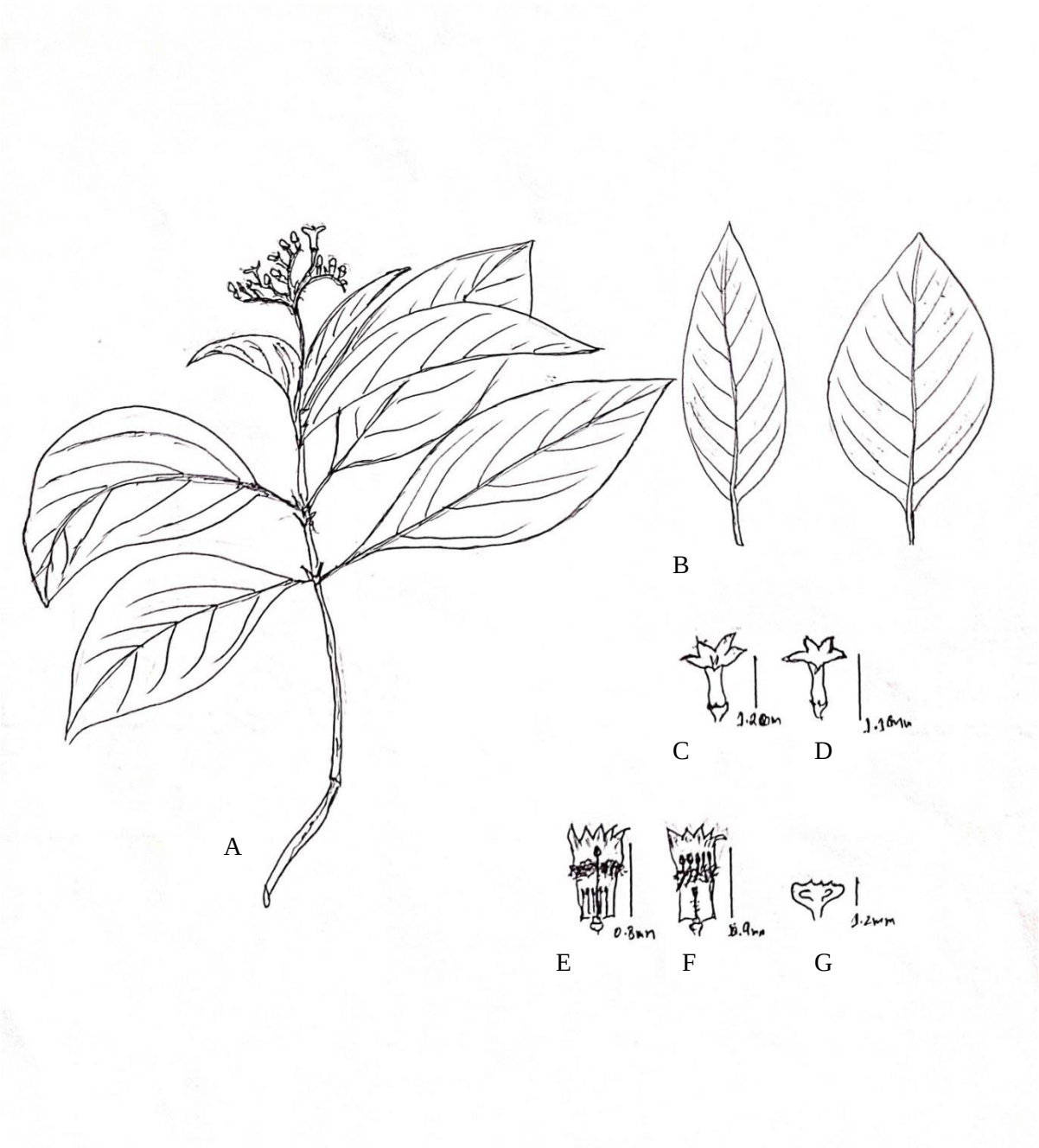

Fig 11 Illustration of ***Ophiorrhiza tingens*.** A- Plant; B- Elliptic and ovate leaves; C- Flower with long style; D- Flower with short style; E- Split flower with long style; F- Split flower with short style; G- Capsule.

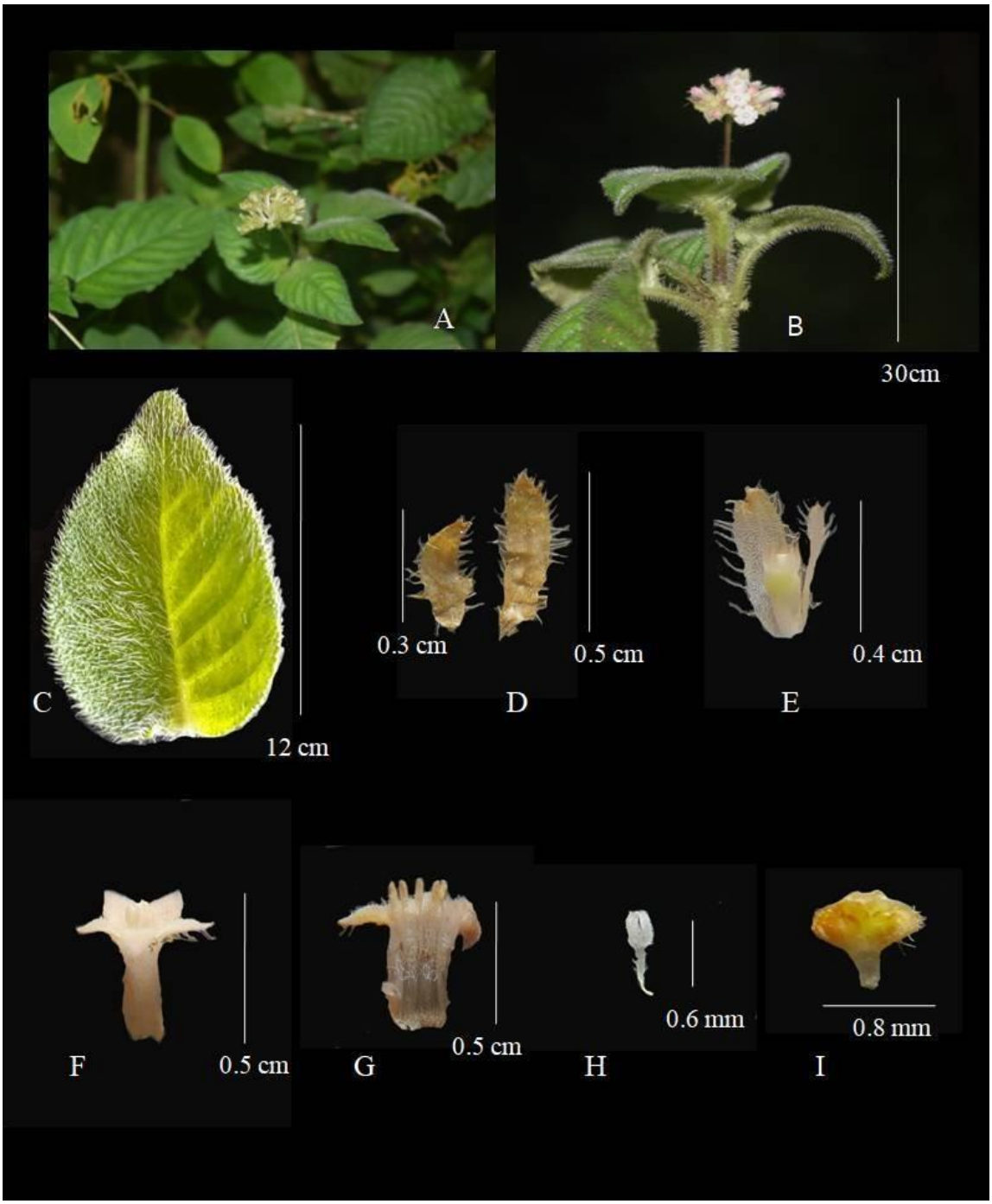

Plate 10 ***Ophiorrhiza hispida.*** A- Habit; B- Inflorescence; C- Leaf; D- Bracts; E- Bracts with calyx; F- Singleflower; G- Split open flower; H- gynoecium; I- Capsule.

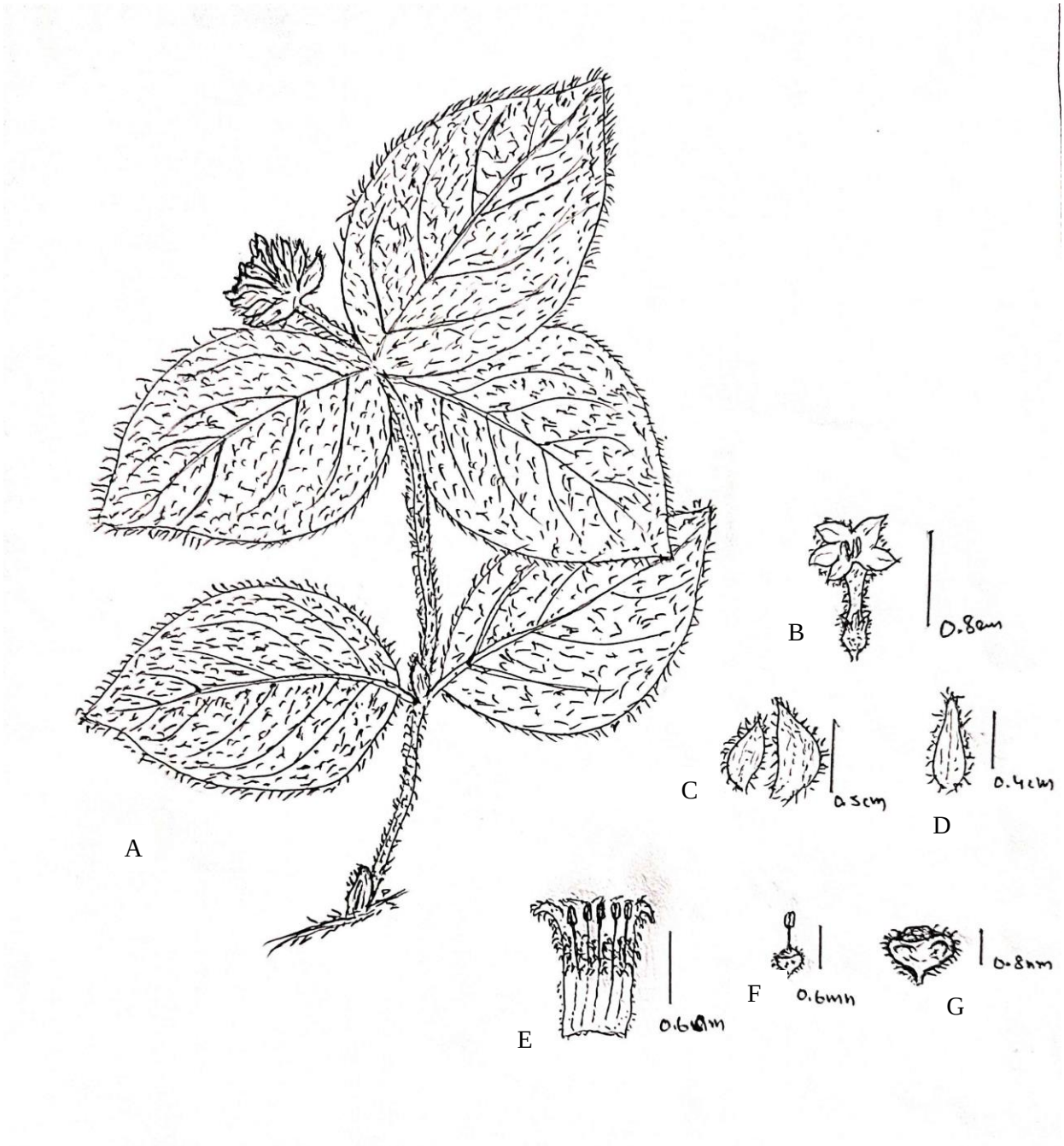

Fig 12 Illustration of ***Ophiorrhiza hispida.*** A- Plant; B- Flower; C- Bracts; D- Stipule ; E- Split open flower; F- Short style; G- Capsule.

Plate 11 **Viviparous germination in *Ophiorrhiza rugosa.*** A- Plant with inflorescence from the collection site; B- Fruit showing viviparous germination; C- Viviparous seedlings; D- Viviparous seedlings arising from single capsule.

Foliar epideramal study

In this study, qualitative characteristics of the foliar epidermis and stomatal types have been examined and are presented in Table 4.1 and the mean values of the quantitative data have been calculated and are presented in Table 4.2. Most members of the *Ophiorrhiza* species are hypostomatic. The presence of raphides and trichomes, the distribution and nature of stomata, epidermal cells are found to be significant features in some members of the genus. A comparative study of epidermal studies among the taxa other than morphology would help in the proper taxonomic assessment of the taxa.

The results observed under the light microscope and scanning electron microscope has been presented in Plate no. 12 – 22. Based on the foliar epidermal characters, taxonomic keys were prepared.

4.2 Foliar epidermal study

4.2.1 Key to the species on the basis of foliar epidermal features

1a. Leaves are hypostomatic..... 2

1b. Leaves are amphistomatic.....***O. hispida.***

2a. Shape of the epidermal cell is polygonal in nature.....3

2b. Shape of the epidermal cell is irregular in nature 4

3a. Shape of the stomatal pore is broadly elliptical….....….***O. tingens.***

3b. Shape of the stomatal pore is elliptical.....5

4a. Trichomes present 6

4b.Trichomes absent.....….***O. ochroleuca.***

5a. Epidermal cell wall pattern is only one type, epidermal cell shape is slightly wavy lobed…….***O. succirubra.***

5b. Epidermal cell wall pattern is two types, epidermal cell shape is irregular and strong wavy in shape..... .***O. rugosa* var. *argentea***.

6a. Stomata are paracytic type, stomatal index is 28.40….....***O. mungos.***

6b. Stomata are paracytic and anisocytic type, stomatal index is 31.56..... .***O. rugosa* var. *prostata.***

7a. Irregularly wavy lobed epidermal cell wall 8

7b. Irregularly lobed epidermal cell wall.....***O. rugosa.***

8a. Raphides are present.....***O. fasciculata.***

8b. Raphides are absent .....***O. oppositiflora.***

4.2.2 Foliar epidermal characters of the studied species

1. *Ophiorrhiza mungos* L. Sp. Pl.: 150 (1753)

Leaves are hypostomatic in nature. Stomata were observed only on the lower side of the leaves. Polygonal types of epidermal cells are recorded on both the adaxial and abaxial surfaces. Epidermal cell wall patterns are irregular in shape on both the adaxial and abaxial surfaces of the leaves. The number of epidermal cells on the adaxial surface ranges from 25–30. The length of the epidermal cells on the adaxial surface ranges from 42.1–48.8 µm and the breadth ranges from 20.2–25.3 µm. On the abaxial surface, the most common stomata are paracytic type are recorded. The shapes of the stomatal pores are narrowly elliptic in nature. The number of epidermal cells on the abaxial surface ranges from 20–25. The length of the epidermal cells on the abaxial surface ranges from 45–48.5 µm and breadth ranges from 22.5–26.8µm. The length of the subsidiary cells on the abaxial surface ranges from 32–35.2 µm and breadth ranges from 22.3–25.4 µm. The length of the stomata on the abaxial surface ranges from 23.2–24.8 µm and the breadth ranges from 13.2–15.8 µm. The length of the stomatal pore on the abaxial surface ranges from 15.8–16.5 µm and the breadth ranges from 5.8–6.9 µm. The stomatal index of the species is 28.40. Unseriate types of trichomes are observed in the species **(Plate 12).**

2. *Ophiorrhiza ochroleuca* Hook.f. Fl. Brit. India 3: 78 (1880)

Leaves are hypostomatic in nature, stomata are observed only on the abaxial surface. Irregular types of epidermal cells are recorded on both the adaxial and abaxial surfaces. The epidermal cell wall patterns are strongly lobed on both the surfaces of the leaves. The numberof epidermal cells in adaxial surface ranges from 30–35. The length of the epidermal cells on the adaxial surface ranges from 40.5–46.6 µm and the breadth ranges from 20.4–23.6 µm. Onthe abaxial surface, the most common stomata are anomocytic and anisocytic type and shape of the stomatal pore are elliptic in nature. The number of epidermal cells on the abaxial surface ranges from 20–22. The length of the epidermal cells on the abaxial surface ranges from 45.2–47.5 µm and the breadth ranges from 18.2–20.5 µm. The length of the subsidiary cells in abaxial surface ranges from 55–57.5 µm and breadth ranges from 30.2–33.8 µm. The length of the stomata on the abaxial surface ranges from 35.8–42.8 µm and the breadth ranges from 18.2–21.5 µm. The length of the stomatal pore on the abaxial surface ranges from 20.8–22.8 µm and the

breadth ranges from 5.2–6.9 µm. The stomatal index of the species is 31.82 **(Plate 13)**.

3.*Ophiorrhiza succirubra* King ex Hook.f, Fl. Brit. India [J. D. Hooker] 3(7): 82 (1880)

Leaves are hypostomatic in nature, stomata are observed only on the abaxial surface. Polygonal types of epidermal cells are recorded on both the adaxial and abaxial surfaces. The epidermal cell wall patterns are slightly wavy-lobed in nature on both surfaces of the leaves. The number of epidermal cells on the adaxial surface ranges from 29–31. The length of theepidermal cells on the adaxial surface ranges from 59.2–62.2 µm and the breadth ranges from19.5–22.8 µm. On the abaxial surface, the most common stomata are anisocytic types. Theshapes of the stomatal pores are elliptic in nature. The number of epidermal cells in theabaxial surface ranges from 24–27. The length of the epidermal cells on the abaxial surfaceranges from 60.1–62.8 µm and breadth ranges from 20.8–22.3 µm. The length of the subsidiary cells on the abaxial surface ranges from 28.2–31.2 µm and breadth ranges from23.8–26.1 µm. The length of the stomata on the abaxial surface ranges from 15.9–18 µm andbreadth ranges from 8–10.2 µm. The length of the stomatal pore on the abaxial surface rangesfrom 12.5–13.5 µm and the breadth ranges from 2–2.8 µm. The stomatal index of the speciesis 34.04. Uniseriate types of trichomes were observed in the species **(Plate 14 & Plate 24 E).**

4. *Ophiorrhiza fasciculata* D.Don Prodr. Fl. Nepal.: 136 (1825)

Leaves are hypostomatic in nature; stomata are observed only on the abaxial surface. Irregular types of epidermal cells are recorded on both the adaxial and abaxial surfaces. Epidermal cell wall patterns are irregularly wavy-lobed in nature on both surfaces of the leaves. The number of epidermal cells on the adaxial surface ranges from 35–45. The length of the epidermal cells on the adaxial surface ranges from 70.1–77.2 µm and the breadth ranges from 16.5–22.2 µm. On the abaxial surface, the most common stomata are paracytic, along with diacytic types. The shapes of the stomatal pores are narrowly elliptic in nature. The number of epidermal cells on the abaxial surface ranges from 35–38. The length of the epidermal cells on the abaxial surface ranges from 70.2–76.2 µm and the breadth ranges from18.2–22.5 µm. The length of the subsidiary cells on the abaxial surface ranges from 48–52.8 µm and the breadth ranges from 25–29 µm. The

length of the stomata on the abaxial surface ranges from 20.5–24 µm and breadth ranges from 10.8–13.8 µm. The length of the stomatal pore on the abaxial surface ranges from 10–14 µm and the breadth ranges from 1.5–2.8 µm. The stomatal index of the species is 30.67. Unicellular types of trichomes and needle raphides are observed on the upper surface of species. **(Plate 15 & Plate 24 A; 24 B)**

5. *Ophiorrhiza oppositiflora* Hook.f. Fl. Brit. India 3: 80 (1880)

Leaves are hypostomatic in nature, stomata are observed only on the abaxial surface. Irregular types of epidermal cells are recorded on both the adaxial and abaxial surfaces. Epidermal cell wall patterns are irregularly wavy lobed in nature on both surfaces of the leaves. The number of epidermal cells on the adaxial surface ranges from 42–46. The length of the epidermal cells on the adaxial surface ranges from 52–56 µm and the breadth ranges from 18.5–21.2 µm. On the abaxial surface, the most common stomata are anisocytic, along with diacytic and anomocytic types are recorded. The shapes of the stomatal pores are narrowly elliptic in nature. The number of epidermal cells on the abaxial surface ranges from 32–36. The length of the epidermal cells on the abaxial surface ranges from 55–57.2 µm and breadth ranges from 19–22.2 µm. The length of the subsidiary cells on the abaxial surface ranges from 55.2–57.4 µm and the breadth ranges from 58.2–61.9 µm. The length of the stomata on the abaxial surface ranges from 30.9–32.9 µm and the breadth ranges from 18.9–20.2 µm. The length of the stomatal pore on the abaxial surface ranges from 15–17 µm and breadth ranges from 4.5–6.2 µm. The stomatal index of the species is 35.5 Peltate types of trichomes are observed in the species **(Plate 16 & Plate 24 C).**

6.*Ophiorrhiza rugosa* Wall., Fl. Ind. (Carey & Wallich ed.) 2: 547 (1824)

Leaves are hypostomatic in nature. Irregular types of epidermal cells are recorded on both theadaxial and abaxial surfaces. Epidermal cell wall patterns are irregularly lobed in nature on both the adaxial and abaxial surfaces of the leaves. The number of epidermal cells on the adaxial surface ranges from 36–38. The length of the epidermal cells on the adaxial surface ranges from 36–39.8 µm and the breadth ranges from 20.2–22.3 µm. On the abaxial surface, the most common stomata are of the actinocytic type are recorded. The shapes of the stomatal pores are narrowly elliptic in nature. The number of epidermal cells on the abaxial surface is ranges from 25–28. The length of

the epidermal cells on the abaxial surface ranges from 34–37.5 µm and breadth ranges from 20.5–21.9 µm. The length of the subsidiary cells on the abaxial surface ranges from 28–31 µm and breadth ranges from 20.3–22.4 µm. The length of the stomata on the abaxial surface ranges from 18.2–20.8 µm and breadth ranges from 9.2–10.8 µm. The length of the stomatal pore on the abaxial surface ranges from 13.8–15.5 µm and breadth ranges from 3.8–4.8 µm. The stomatal index of the species is 32.43. Uncinate types of trichomes are observed in the species. **(Plate 17 & Plate 24 D)**

7. *Ophiorrhiza rugosa* var. *argentea* (Wall. ex G.Don) Deb & Mondal Bull. Bot. Surv. India 24: 228 (1982 publ. 1983)

Leaves are hypostomatic in nature, stomata are observed only on the lower surface of the leaves. Irregular, wavy types of epidermal cells are recorded on both the adaxial and abaxial surfaces. Epidermal cell wall patterns are irregular and strongly wavy in shape on both surfaces of the leaves. The number of epidermal cells on the adaxial surface ranges from 38–48. The length of the epidermal cells on the adaxial surface ranges from 59.1–64.2 µm and the breadth ranges from 13.5–19.2 µm. On the abaxial surface, paracytic and anisocytic types of stomata are recorded. The shapes of the stomatal pores are narrowly elongated and elliptic in nature. The number of epidermal cells on the abaxial surface ranges from 32–35. The length of the epidermal cells on the abaxial surface ranges from 59–63.3 µm and breadth ranges from 17.2–20.7 µm. The length of the subsidiary cells on the abaxial surface ranges from 38.3–45.8 µm and breadth ranges from 24–28.3 µm. The length of the stomata on the abaxial surface ranges from 22.5–24.9 µm and breadth ranges from 11.8–14.2 µm. The lengthof the stomatal pore on the abaxial surface ranges from 9–12 µm and the breadth ranges from 1.2–2.µm. The stomatal index of the species is 31.06. Unicellular types of trichomes and unicinate trichomes were recorded on both the lower and upper sides of the species **(Plate 18 & Plate 23 D).**

8. *Ophiorrhiza rugosa* var. *prostrata* (D.Don) Deb & Mondal Bull. Bot. Surv. India 24: 228 (1982 publ. 1983)

Leaves are hypostomatic in nature, stomata are observed only on the lower side of the leaves. Polygonal types of epidermal cells are recorded on both the upper and lower surfaces. The epidermal cell wall patterns are irregular in shape and somewhat wavy on both surfaces of the leaves. The number of epidermal cells on the adaxial surface ranges from 39–44. The length of the epidermal cells on the adaxial surface ranges from 52.6–60.2 µm and the breadth ranges from 11.5–16.8 µm. Paracytic and anisocytic types of stomata are observed on the lower surface of the leaves. The shapes of the stomatal pores are narrow and elliptic in nature. The number of epidermal cells on the abaxial surface ranges from 30–33. The length of the epidermal cells on the abaxial surface ranges from 51.3–59.5 µm and the breadth ranges from 15.2–18.8.µm. The length of the subsidiary cells on the abaxial surface ranges from 33.3–40.8 µm and breadth ranges from 18.3–25.3 µm. The length of the stomata ranges from 23.5–25.3 µm and breadth ranges from 11.2–13.2 µm. The length of the stomatal pore on the abaxial surface ranges from 10–12.3 µm and the breadth ranges from 1.5–2.3µm. The stomatal index of the species is 31.56. Unicellular types of trichomes with a broad base were observed on the upper surface. **(Plate 19 & Plate 23 C)**

9. *Ophiorrhiza tingens* C.B.Clarke ex C.E.C.Fisch., Bull. Misc. Inform. Kew 1940: 33 (1940)

Leaves are hypostomatic in nature, stomata are observed only on the abaxial surface. Polygonal types of epidermal cells are recorded on both the adaxial and abaxial surfaces. The epidermal cell wall patterns are irregularly wavy in nature on both surfaces of the leaves. The number of epidermal cells on the adaxial surface ranges from 40–42. The length of the epidermal cells on the adaxial surface ranges from 35–38.2 µm and the breadth ranges from 14.2–16.3 µm. On the abaxial surface, the most common stomata are the actinocytic type along with the hemiparacytic type. The shapes of the stomatal pores are broadly elliptic in nature. The number of epidermal cells on the abaxial surface ranges from 35–38. The length of the epidermal cells on the abaxial surface ranges from 36.1–39.2 µm and the breadth ranges from 22.1–26.2 µm. The length of the subsidiary cells on the abaxial surface ranges from 28.2–31.8 µm and breadth ranges from 17.1–19.8 µm. The length of the stomata on the abaxial surface ranges from 18.2–20.2µm and breadth ranges from 10–12.2 µm. The length of the stomatal pore on the abaxial surface ranges from 12.2–14 µm and the breadth ranges

from 5–6.5 µm. The stomatal index of the species is 36.03. Uncinate and uniseriate types of trichomes were observed in the species. **(Plate 20 & Plate 24 F)**

10. *Ophiorrhiza hispida* Hook.f., Fl. Brit. India [J. D. Hooker] 3(7): 83 (1880)

Leaves are amphistomatic in nature; stomata are observed on both the adaxial and abaxial surfaces of the leaves. Irregular types of epidermal cells are recorded on both the adaxial and abaxial surfaces. The epidermal cell wall patterns are irregularly wavy in nature on both surfaces of the leaves. The number of epidermal cells in the adaxial surface ranges from 30–35. The length of the epidermal cells on the adaxial surface ranges from 60.1–67.2 µm and the breadth ranges from 14.5–20.2 µm. On the adaxial surface, anisocytic stomata along with multiseriate trichomes were observed. The shapes of the stomatal pores on the adaxial side are narrowly elliptic in nature. The length of the subsidiary cells on the adaxial surface ranges from 45–50.8 µm and breadth ranges from 24–28µm. The length of the stomata on the adaxial surface ranges from 37.6–40.2 µm and the breadth ranges from 18.4–20.1 µm. The length of the stomatal pore on the adaxial surface ranges from 13–15.4 µm and the breadth ranges from 2.3–3.7 µm. The stomatal index on the adaxial side is 33.45

On the abaxial surface the most common stomata are anisocytic along with hemiparacytic and paracytic types are recorded. The shapes of the stomatal pore are elliptic in nature. The no. of epidermal cells in abaxial surface is ranges from 34–36. The length of the epidermal cells in abaxial surface ranges from 68.2–70.2 µm and breadth ranges from 17.2–21.5 µm.The length of the subsidiary cells in abaxial surface ranges from 45-50.8 µm and breadth ranges from 24–28µm. The length of the stomata in abaxial surface ranges from 37.9–41. µm and breadth ranges from 17.6–20.1 µm. The length of the stomatal pore in abaxial surface ranges from 12–16 µm and breadth ranges from 2.5–3.8 µm. The stomatal index on abaxial surface is 36.67. Unicellular and multicellular types of trichomes are observed in the species **(Plate 21, 22 & Plate 23 A & B).**

Table 4.1 Qualitative foliar epidermal characters of the investigated taxa

Name of thetaxa	**Surface**	**Shape of epidermalcell**	**Epidermal cell wall pattern**	**Types of stomata**	**Shape of stomatal pore**	**Trichomes**	**Raphides**
Ophiorrhiza mungos	Adaxial	Polygonal	Irregular	-	-	-	-
	Abaxial	Polygonal	Irregular	Pa	Narrowly elliptic	Present	-
Ophiorrhiza ochroleuca	Adaxial	Irregular	Strongly lobed	-	-	Absent	-
	Abaxial	Irregular	Strongly lobed	Ani, Ano	Elliptic	Absent	-
Ophiorrhiza succirubra	Adaxial	Polygonal	Slightly wavy lobed	-	-	-	-
	Abaxial	Polygonal	Slightly wavy lobed	Ani,Ano	Elliptic	Present	-
Ophiorrhiza fasiculata	Adaxial	Irregular	Irregularly wavy lobed	-	-	Present	Present
	Abaxial	Irregular	Irregularly wavy lobed	Pa, dia, Ano	Narrowly elliptic	-	-
Ophiorrhiza oppositiflora	Adaxial	Irregular	Irregularly wavy lobed	-	-	Present	-
	Abaxial	Irregular	Irregularly wavy lobed	Ani, dia	Narrowly elliptic	Present	-
Ophiorrhiza rugosa	Adaxial	Irregular	Irregularly lobed	-	-	-	-
	Abaxial	Irregular	Irregularly lobed	Pa, Act	Narrowly elliptic	Present	-
O. rugosa var.*argentea*	Adaxial	Irregular ,wavy	Irregular, strongly wavy lobed	-	-	Present	-
	Abaxial	Irregular ,wavy	Irregular, strongly wavy lobed	Pa, Ani	Narrowly elongated, elliptic	-	-
O. rugosa var. *prostata*	Adaxial	Polygonal	Irregular, undulating	-	-	Present	-
	Abaxial	Polygonal	Irregular, undulating	Pa, Ani	Elliptic	Absent	-
Ophiorrhiza tingens	Adaxial	Polygonal	Irregularly wavy	-	-	-	-
	Abaxial	Polygonal	Irregularly wavy	Ani, hemi	Broadly elliptic	Present	-
Ophiorrhiza hispida	Adaxial	Irregular	Irregular, undulating	Ani	Narrowly elliptic	Present	-
	Abaxial	Irregular	Irregularly wavy	Ani, Hemi, Pa	Elliptic	Present	-

Ani- Anisocytic, Pa- Paracytic, Hemi- Hemiparacytic, Dia- Diacytic, Ano- Anomocytic

Table 4.2 Quantitative mean value of foliar epidermal characters of the investigated taxa

Name of thetaxa	Surface	No. of epidermal cell	Epidermal cell size		Stomatal size		Subsidiary cell size		Stomatal pore		Trichome size		(S.I.) (%)
			ECL (µm)	ECW (µm)	SL (µm)	SW (µm)	SCL (µm)	SCW (µm)	SPL (µm)	SPW (µm)	TL (µm)	TB (µm)	
O. mungos	Ad	28	42.5± 0.96	21.6± 0.84	-	-	-	-	-	-	-	-	-
	Ab	23	45.7± 0.87	23.4± 1.09	23.1± 1.34	13.6± 0.90	32.5± 0.85	22.4± 0.92	14.9± 1.07	6.2± 0.61	44.5± 0.89	37.4± 3.59	28.4
O. ochroleuca	Ad	35	45.4± 1.22	22.3± 1.01	-	-	-	-	-	-	-	-	-
	Ab	22	46.6± 0.89	22.5± 1.02	40.3± 1.36	19.6± 0.77	56.3± 0.89	32.8± 0.82	21.8± 0.88	5.8± 1.04	-	-	31.82
O. succirubra	Ad	30	61.8± 1.02	21.4± 0.78	-	-	-	-	-	-	122.1 ±2.35	46.5± 0.87	-
	Ab	26	61.6± 0.93	21.4± 0.63	18.9± 1.55	8.7±0 .77	30.3± 1.21	25.2± 0.77	12.9± 0.92	2.4± 0.50	98.8± 1.64	31.7± 1.03	34.04
O. fasiculata	Ad	42	76.6± 1.01	21.7± 1.06	-	-	-	-	-	-	28.3± 1.12	38.2± 1	-
	Ab	30	76.4± 1.04	21.9± 1.05	23.3± 0.88	11.5± 0.96	50.9± 0.85	28.3± 0.76	12.8± 1.03	2.6± 0.53	-	-	30.67
O. opposit iflora	Ad	45	54.8± 1.04	21.1± 0.85	-	-	-	-	-	-	129.4 ±1.33	46.6± 0.84	-
	Ab	35	55.5± 1.32	21.1± 0.86	32.4± 1.16	18.5± 0.95	55.3± 0.85	60.9± 0.80	15.7± 0.83	4.9± 0.78	132.8 ±2.03	44.4± 0.96	35.35
O.rugosa	Ad	38	38.7± 0.61	21.6± 0.88	-	-	-	-	-	-	60.3± 0.98	26.9± 0.79	-
	Ab	27	36.1± 1.08	21.4± 0.87	21.06 ±0.41	09.8± 0.81	30.2± 0.64	20.9± 0.99	14.4± 0.74	4.2± 0.60	-		32.43
*O. rugosa*var. *argentea*	Ad	46	61.5± 0.98	17.4± 0.94	-	-	-	-	-	-	61.9± 0.93	21.2± 0.62	-
	Ab	32	61.1± 0.96	17.8± 0.77	22.6± 0.76	12.7± 0.78	39.6± 0.64	25.5± 0.74	11.5± 1.09	1.6± 0.31	67.4± 0.99	26.05 ±1.08	31.06
O. rugosa var. *prostata*	Ad	41	52.9± 1.34	15.5± 0.79	-	-					-		-
	Ab	31	51.4± 0.83	15.8± 0.55	23.7± 1.17	11.9± 0.73	33.1± 1.25	19.9± 0.74	10.8± 0.67	1.8± 0.46	65.5± 1.36	25.02 ±0.90	31.56
O. tingens	Ad	40	36.2± 1.37	15.0± 0.77	-	-	-	-	-	-	80.04 ±1.28	31.9± 0.98	-
	Ab	37	37.6± 0.87	24.1± 0.92	18.4± 1.02	12.2± 0.93	29.9± 0.90	18.4± 0.73	13.7± 0.78	5.9± 0.60	85.6± 1.35	36.5± 0.75	36.03
O. hispida	Ad	33	64.1± 1.16	21.3± 1.12	37.2± 0.83	19.2± 0.87	47.2± 0.79	27.1± 0.87	13.2± 0.80	2.8± 0.46	75.4± 1.12	28.1± 0.96	33.45

	Ab	35	68.9± 1.12	21.4± 0.75	39.5± 0.87	19.6± 0.97	46.8± 0.82	26.2± 0.86	14.6± 0.89	3.2± 0.68	143.8 ±1.43	21.1 ± 0.68	36.67

Ad- Adaxial, Ab- Abaxial, ECL- Epidermal cell length, ECW- Epidermal cell Width, SL- Stomatal length, SW- Stomatal Width, SCL- Subsidiary cell length, SCW- Subsidiary cell width, SPL- Stomatal pore length, SPW- Stomatal pore width, TL- Trichome length, TB- Trichome breadth.

4.2.3 ANOVA Test

The quantitative values of parameters of leaf epidermis of both the surfaces have been subjected to ANOVA test and the results are presented in table no. 4.3.

Table 4.3 Results of one way ANOVA for different micro-morphological measurement of leaves among the investigated taxa

Sl. No.	Micro-morphological measurements	F	df	p-value
1	Epidermal cell length (Adaxial)	1256	9, 80	P<0.0001
2	Epidermal cell length (Abaxial)	1405	9, 80	P<0.0001
3	Epidermal cell breadth (Adaxial)	87.97	9, 80	P<0.0001
4	Epidermal cell breadth (Abaxial)	76.29	9, 80	P<0.0001
5	Stomatal length (Abaxial)	452.2	9, 80	P<0.0001
6	Stomatal breadth (Abaxial)	186.2	9, 80	P<0.0001
7	Subsidiary cell length (Abaxial)	1076	9, 80	P<0.0001
8	Subsidiary cell breadth(Abaxial)	618.1	9, 80	P<0.0001
9	Stomatal pore length (Abaxial)	107.8	9, 80	P<0.0001
10	Stomatal pore breadth (Abaxial)	73.24	9, 80	P<0.0001

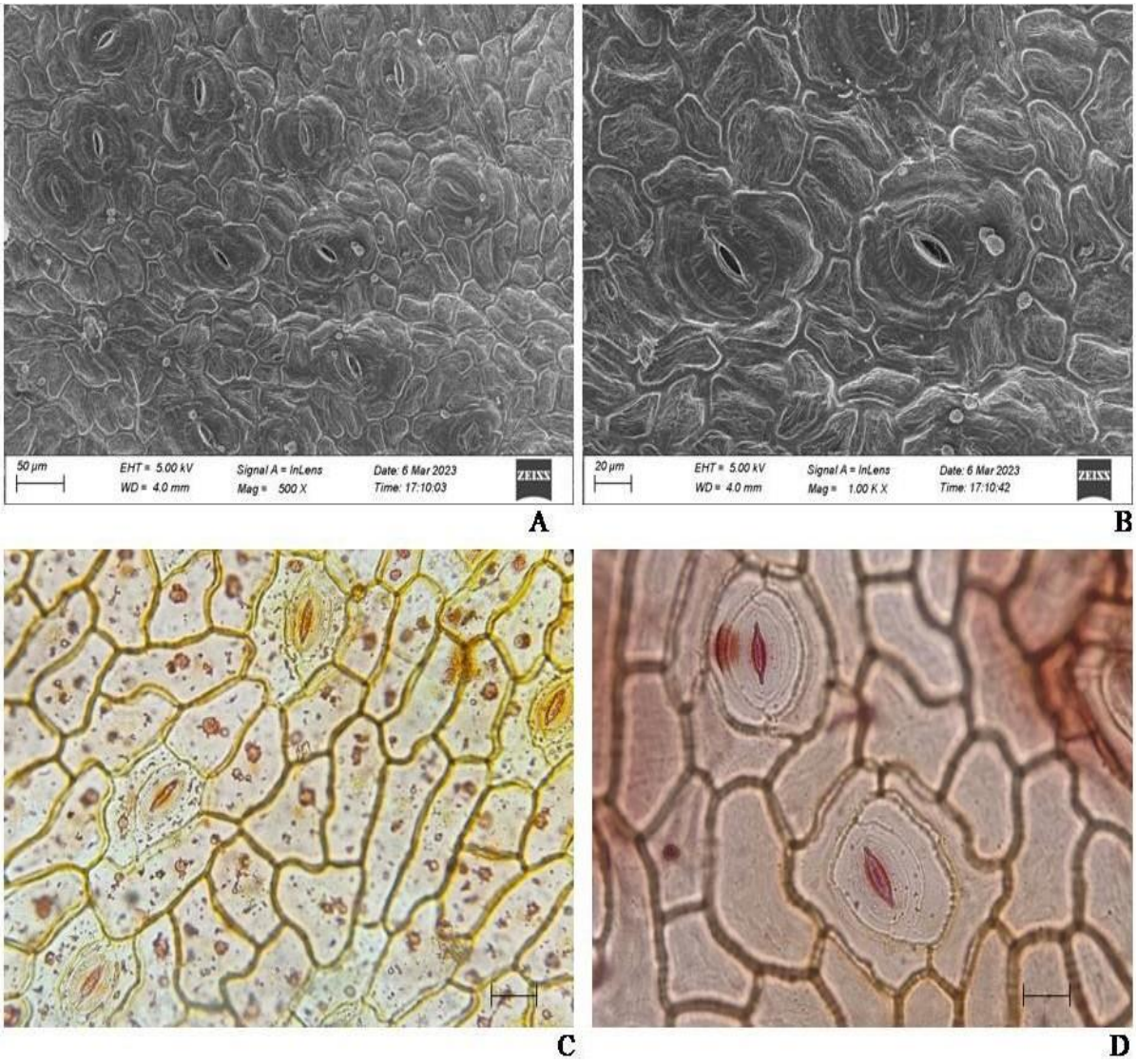

Plate 12 Foliar Epidermal study of *O. mungos*. A- Abaxial surface in SEM; B- Magnified stomata in abaxial surface; C- Abaxial surface showing stomata LM; D- Magnified stomata in abaxial surface. (Scale:C-30µm; D-15µm).

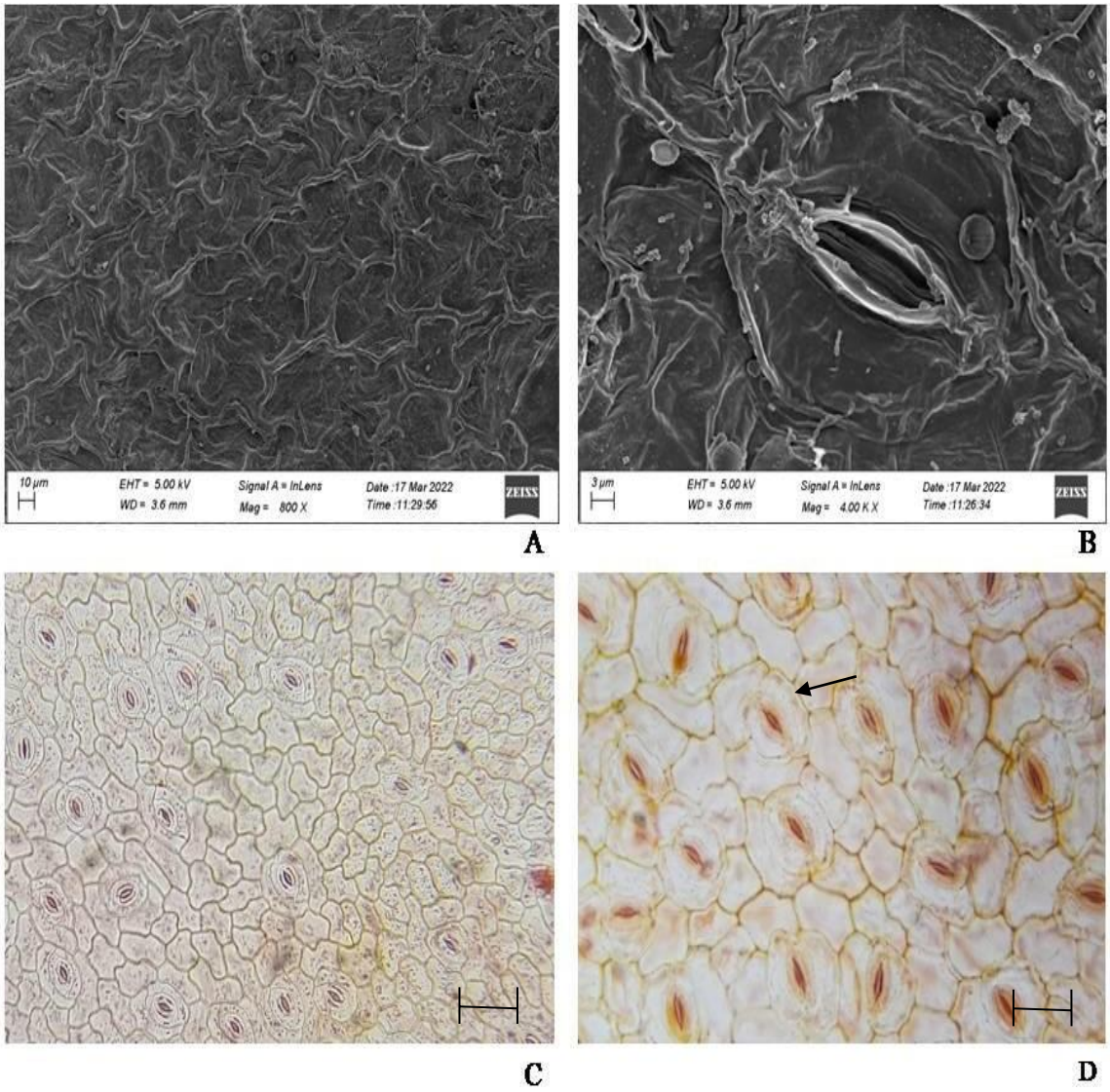

Plate 13 Foliar epidermal study of *O. ochroleuca.* A- Adaxial surface in SEM; B- Magnified stomata in abaxial surface; C & D- Abaxial Stomata in LM. (Scale: C- 20µm; D- 10 µm). (Anisocytic Stomata is marked in fig D).

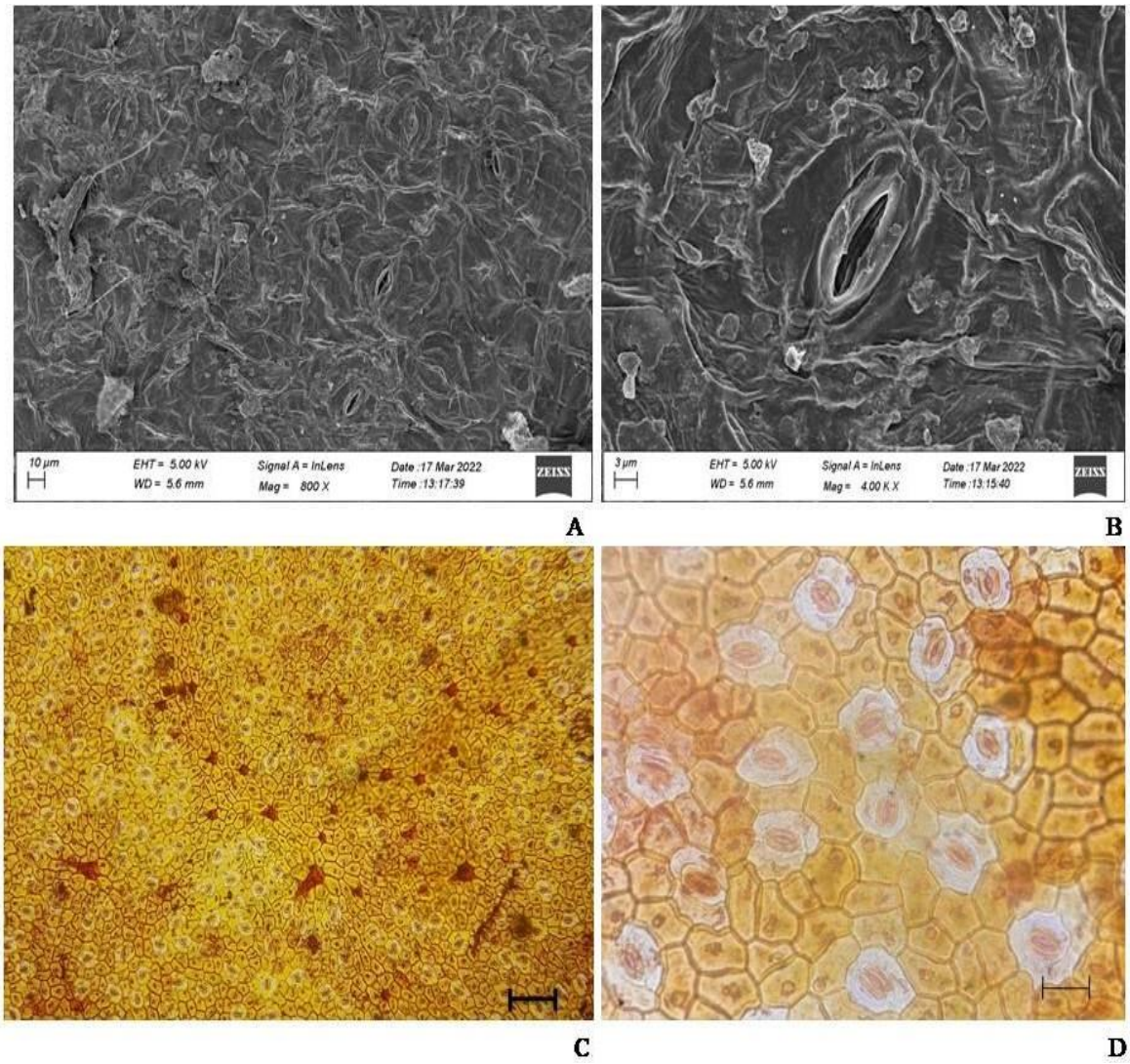

Plate 14 Foliar epidermal study of *O. succirubra.* A- Abaxial surface in SEM; B- Magnified stomata in abaxial surface; C & D- Adaxial surface with epidermal cell in LM. (Scale: C- 30µm; D- 10µm).

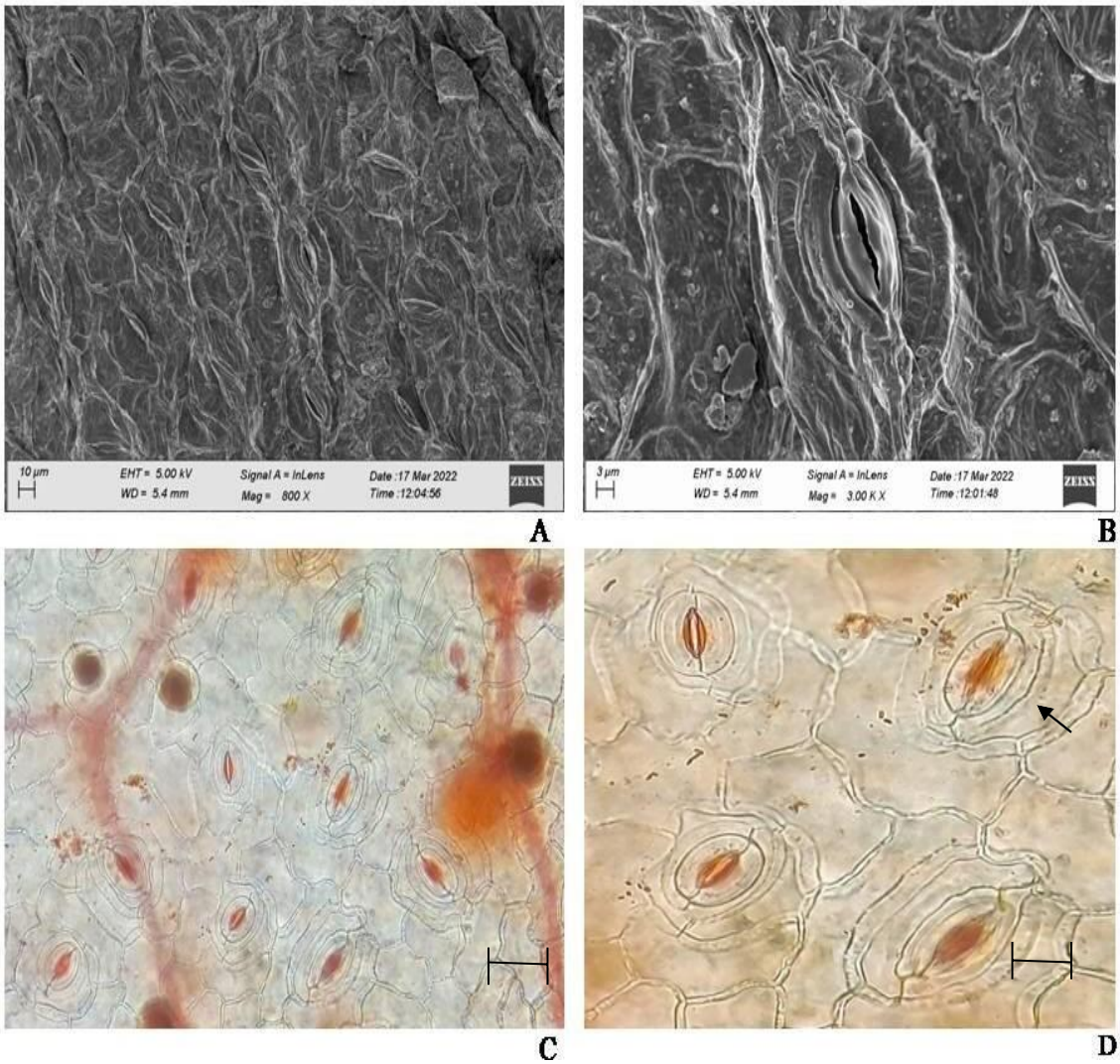

Plate 15 Foliar epidermal study of *O. fasciculata*. A- Abaxial surface in SEM; B- Magnified stomata in abaxial surface; C & D- Abaxial Stomata in LM. (Scale: C- 10µm; D- 5µm). (Paracytic stomata is marked in fig D).

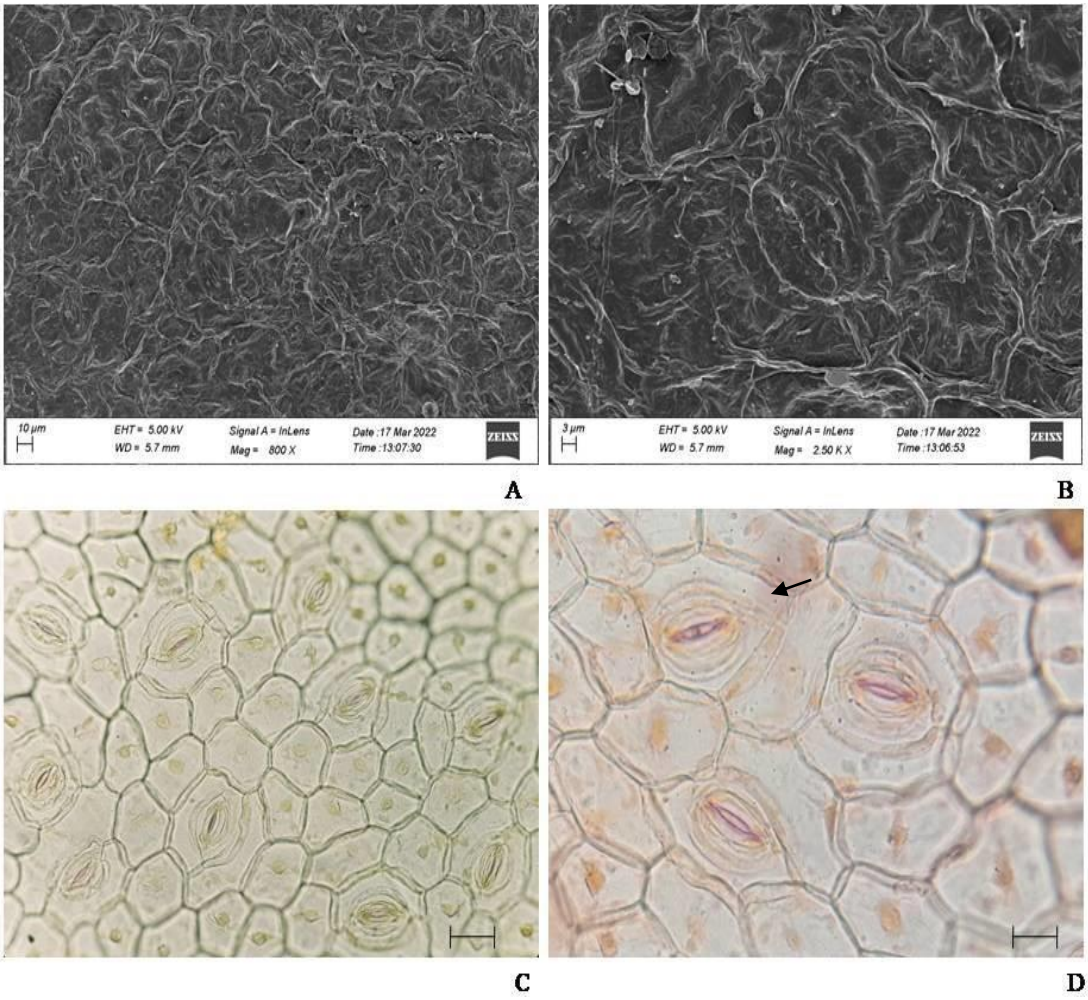

Plate 16 Foliar epidermal study of *O. oppositiflora.* A- Adaxial surface in SEM; B- Magnified stomata in abaxial surface; C & D- Abaxial Stomata with epidermal cell in LM. (Scale: C- 10µm; D- 5µm). (Anisocytic stomata is marked in fig D).

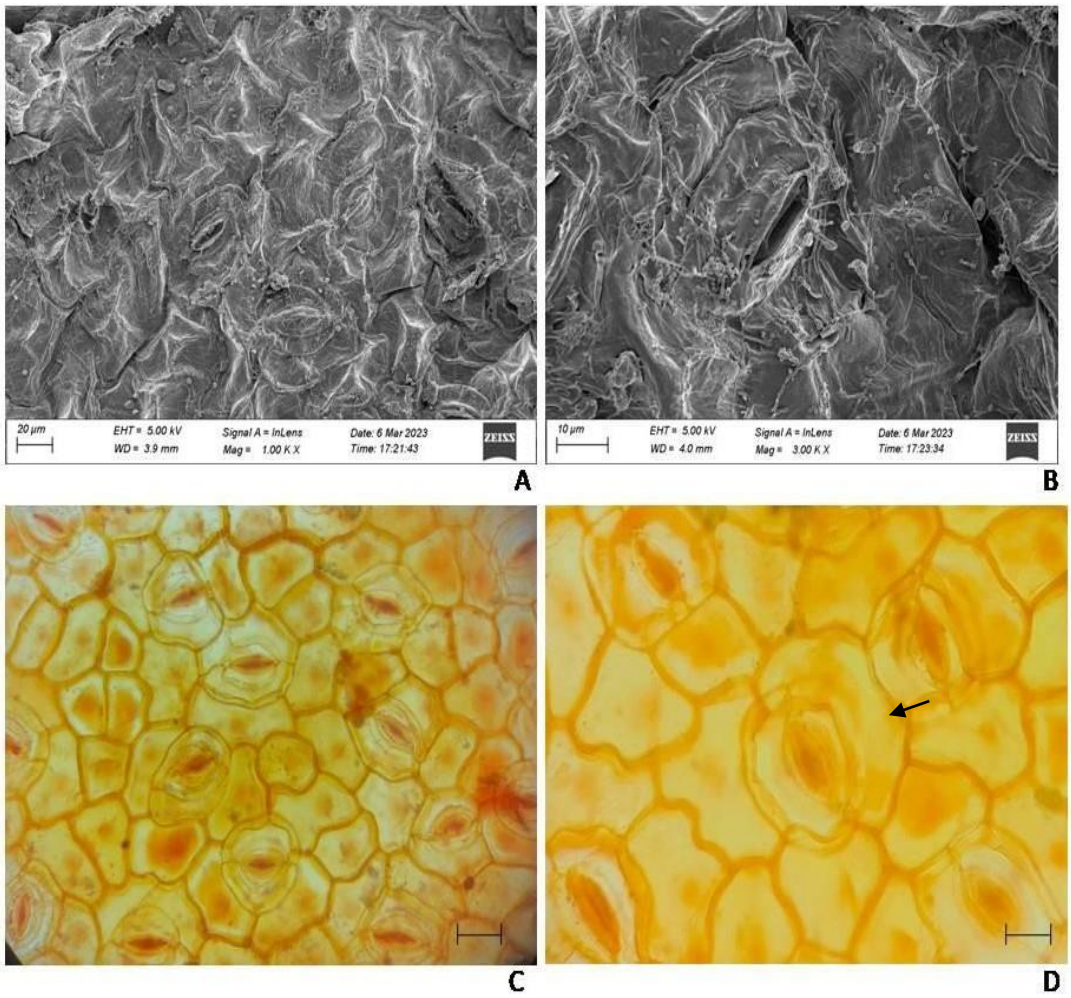

Plate 17 Foliar epidermal study of *O. rugosa.* A- Abaxial surface in SEM; B- Magnified stomata in abaxial surface; C- Abaxial surface showing stomata and epidermal cell in LM; D- Magnified stomata in abaxial surface. (Scale: C- 20µm; D- 10µm). (Paracytic stomata showing in fig C).

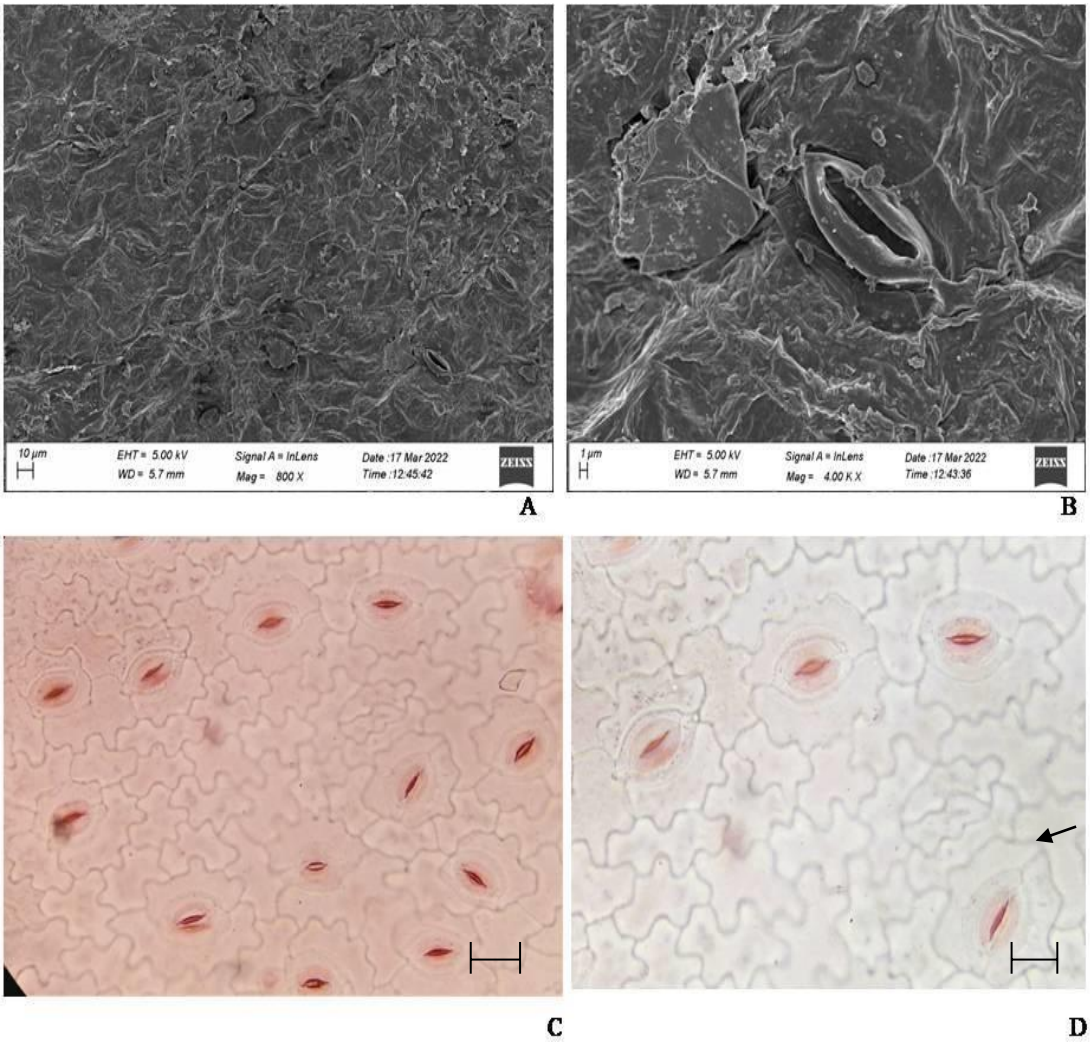

Plate 18 Foliar epidermal study of *O. rugosa* var. *argentea.* A- Abaxial surface in SEM; B- Magnified stomata in abaxial surface; C & D- Abaxial Stomata with epidermal cell in LM. (Scale: C- 10µm; D- 5µm). (Paracytic stomata is marked in fig D).

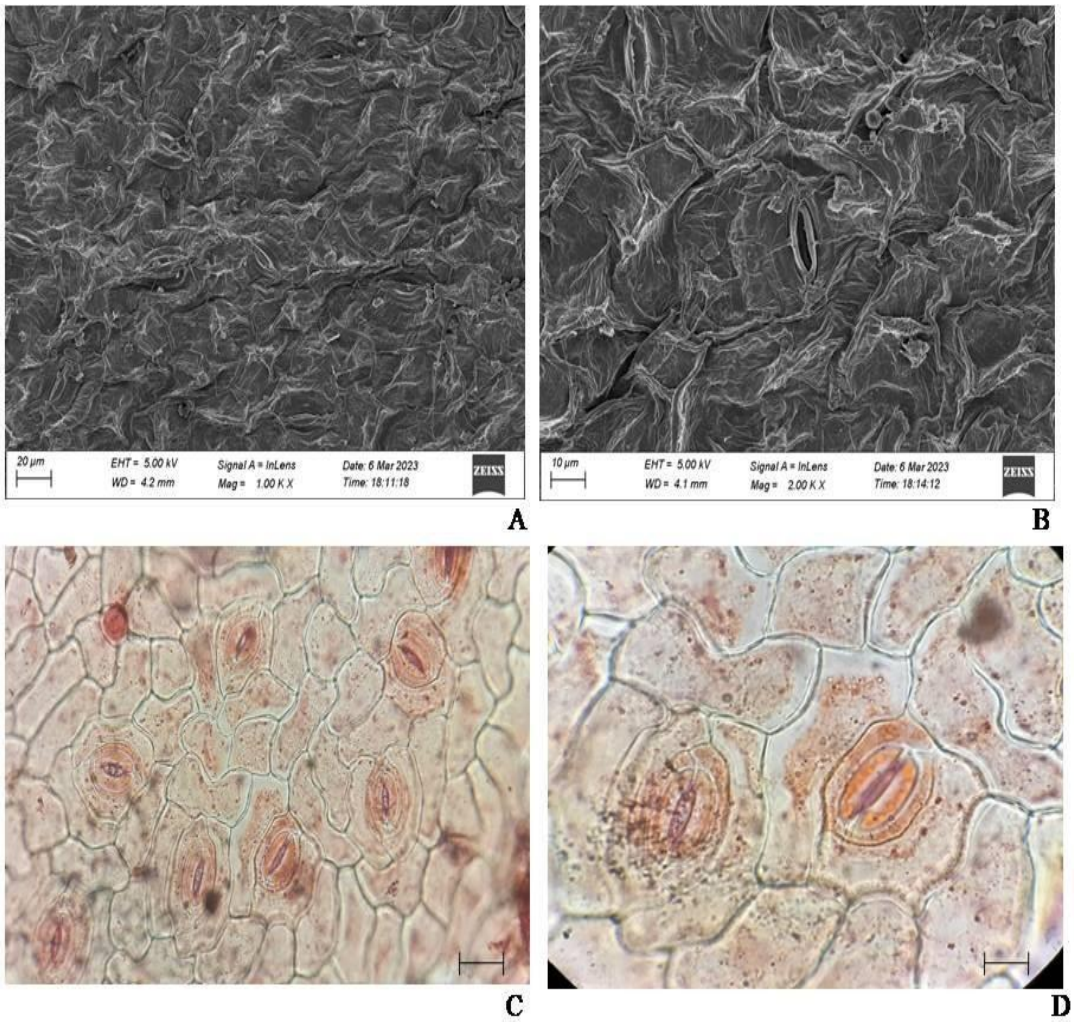

Plate 19 Foliar epidermal study of *O. rugosa* var. *prostata*. A- Abaxial surface in SEM; B- Magnified stomata in abaxial surface; C- Abaxial surface showing stomata and epidermal cell in LM; D- Magnified stomata in abaxial surface. (Scale: C- 20µm; D- 10µm).

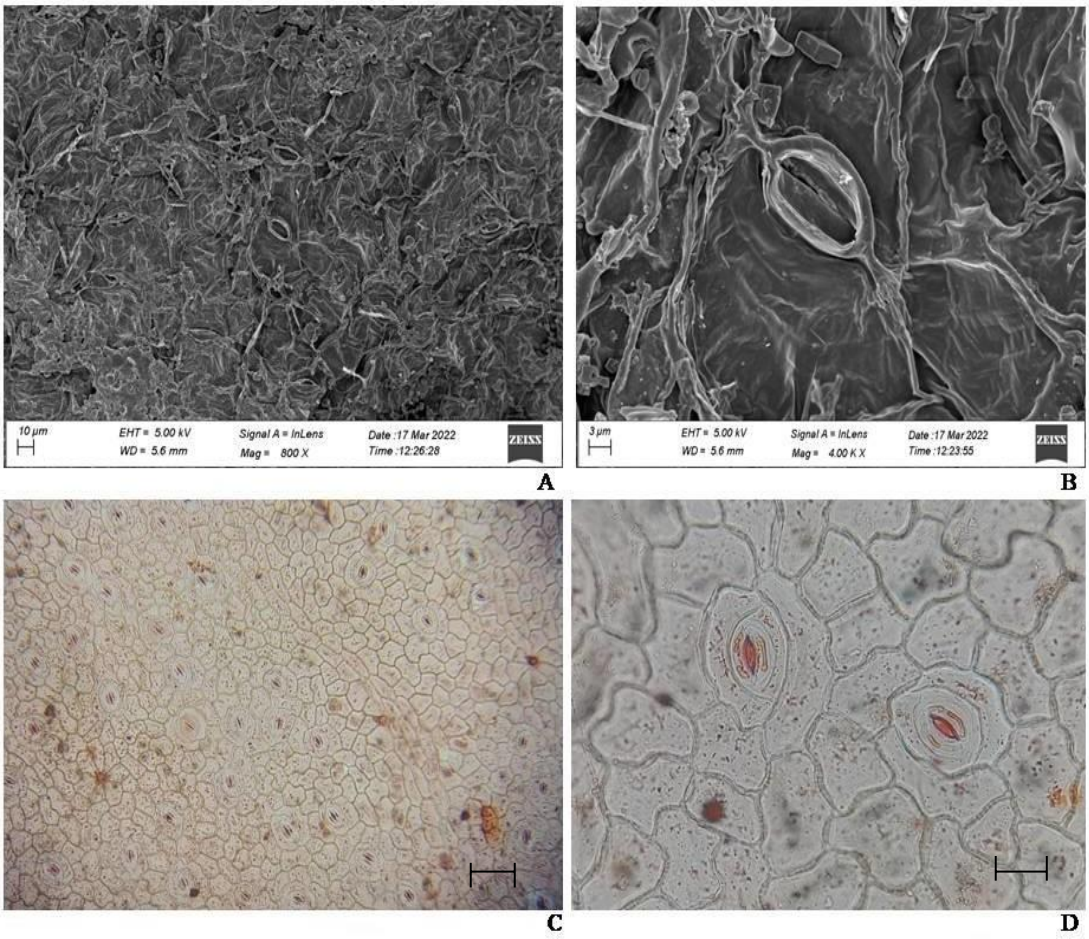

Plate 20 Foliar epidermal study of *O. tingens.* A- Abaxial surface in SEM; B- Magnified stomata in abaxial surface; C- Abaxial surface with epidermal cell in LM; D- Magnified stomata in LM (Scale: C- 30µm; D- 5µm).

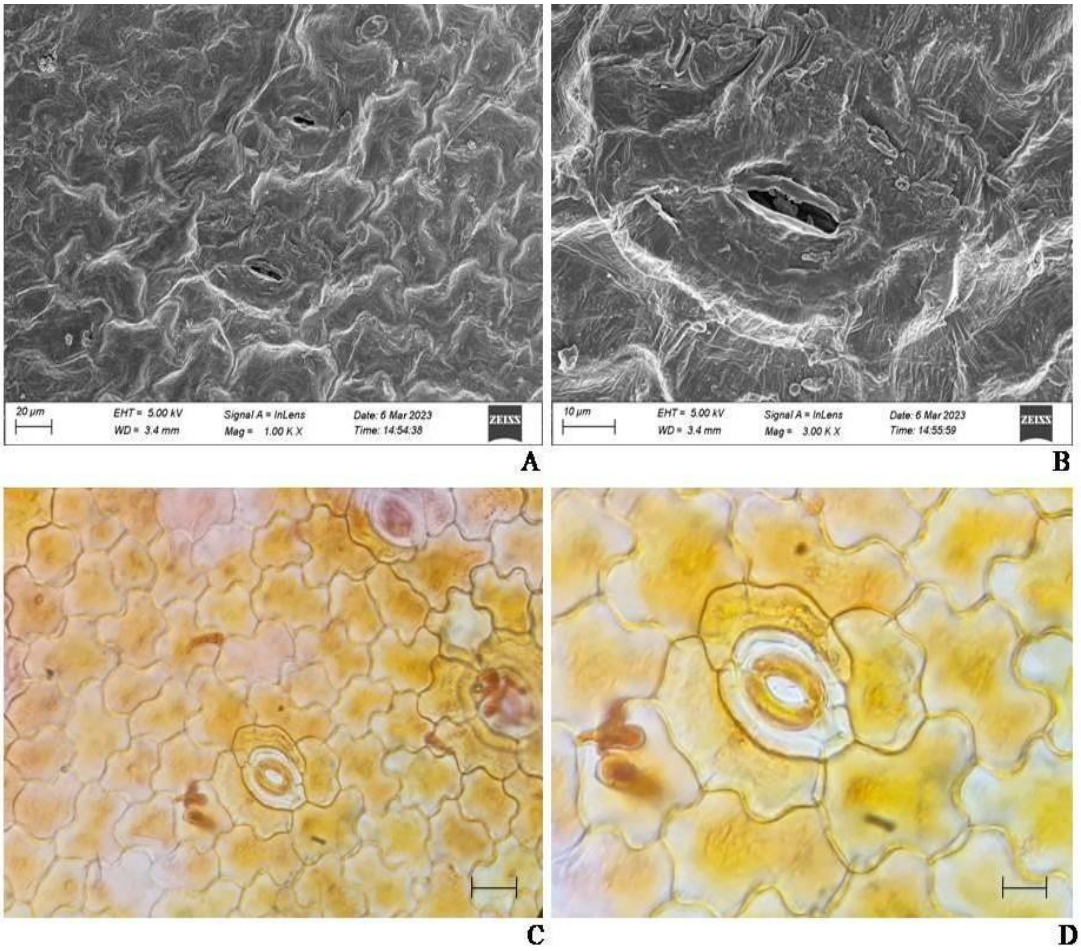

Plate 21 Foliar epidermal study of *O. hispida* (Adaxial). A- Adaxial surface in SEM; B- Magnified stomata in adaxial surface; C -Abaxial surface showing stomata in LM; D- Magnified anisocytic stomata in adaxial surface. (Scale: C- 30µm; D- 15µm).

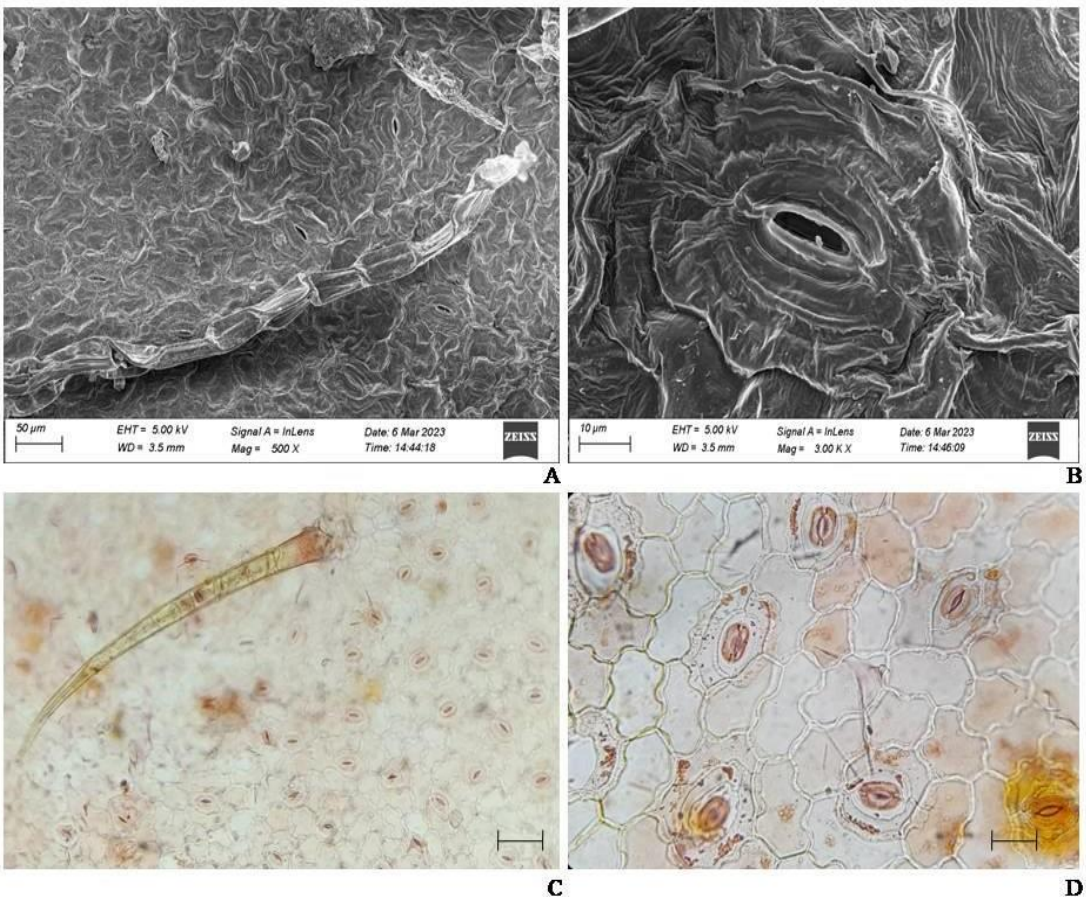

Plate 22 Foliar epidermal study of *O. hispida* (Abaxial). A- Abaxial surface in SEM; B- Magnified stomata in abaxial surface; C- Abaxial surface showing stomata and uniseriate hair in LM; D- Magnified stomata in abaxial surface. (Scale: C- 30µm; D- 15µm).

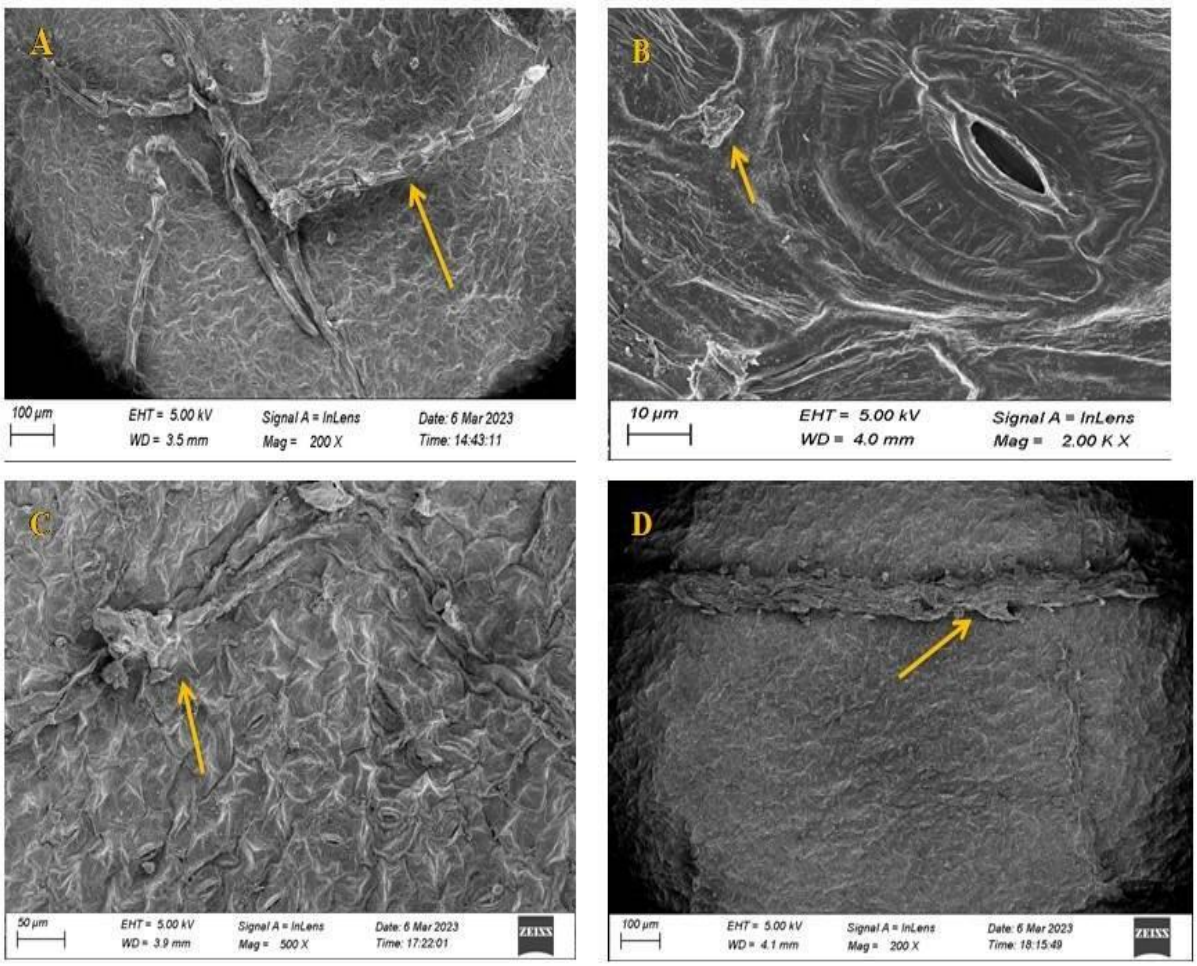

Plate 23 A-D: Showing trichomes under SEM. A- Multicellular trichome of *O. hispida*; B- Uniseriate trichome of *O. hispida*; C- Uniseriate trichome of *O. rugosa* var. *prostata*; D- Uniseriate trichome of *O. rugosa* var. *argentea*

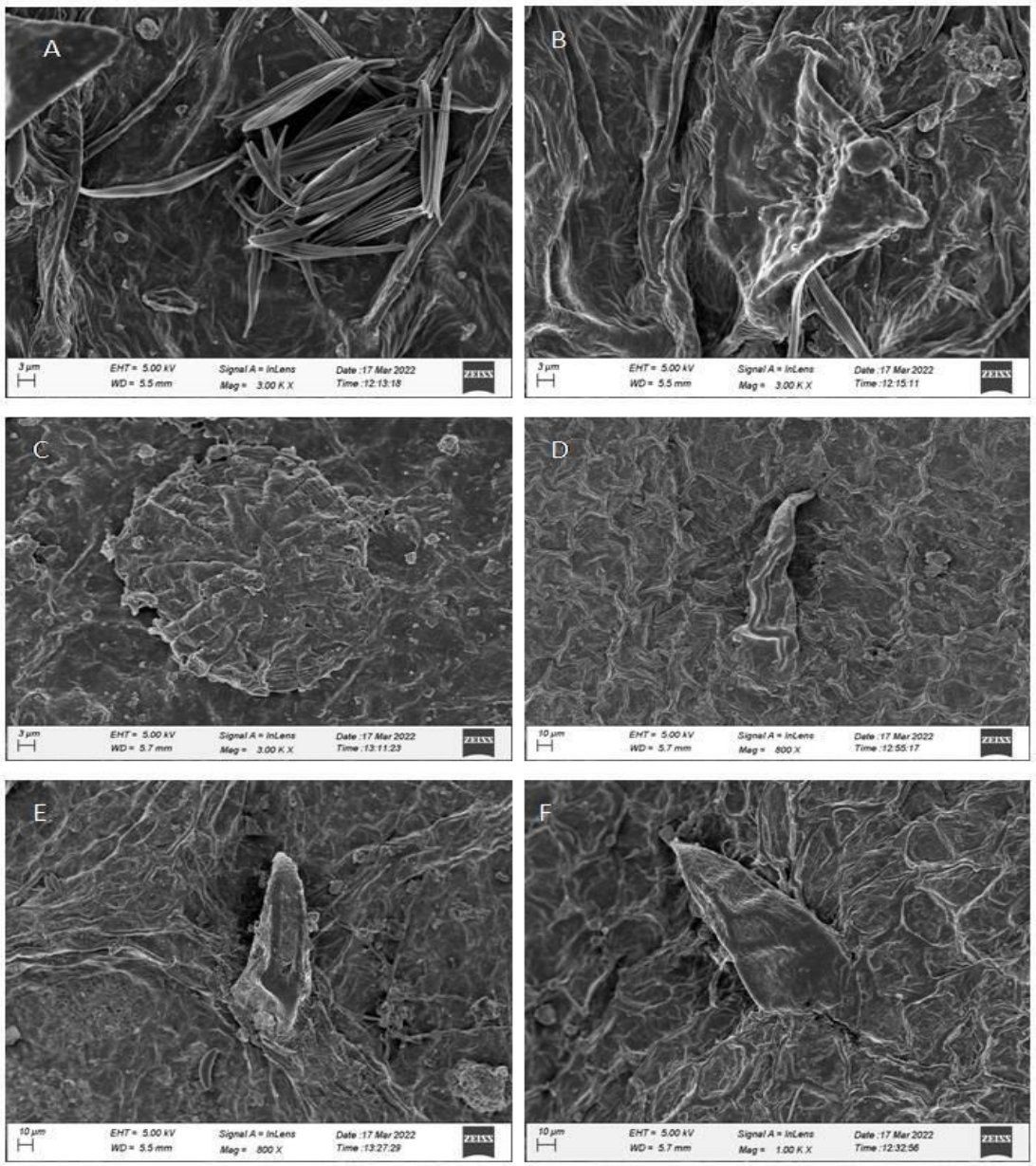

Plate 24 A-F: Trichomes and raphides under SEM. A- Needle like raphides in *O. fasciculata;* B- Uniseriate trichome of *O. fasciculata;* C- Peltate glandular trichome of *O. oppositifolia;* D- Uncinate trichome of *O. rugosa;* E- Uniseriate trichome of *O. succirubra*; F- Uniseriate trichome of *O. tingens.*

4.3 Leaf architecture study

The aim of the study was to examine the leaf architectural features of the collected species which would help in provides information in the proper taxonomic assessment of the members of the genus. The various taxonomic attributes of primary, secondaries, tertiaries, higher order veins, nature of areoles, free vein endings are found to be significant in some members of the genus.

Both qualitative and quantitative characteristic features of the foliar architecture of all the 10 taxa of *Ophiorrhiza* in Assam have been worked out and also presented in Tabulated form (Table 4.4 & 4.5). The results observed under light microscope have been presented in Plate no. 25 to Plate no. 34 Taxonomic keys were prepared based on leaf architecture features.

4.3.1 Key to the species based on leaf architecture characters

1a. Phyllotaxy opposite and decussate 2

1b. Phyllotaxy opposite ..... ***O. oppositiflora***

2a. 2° vein is uniform.....3

2b. 2° vein is irregular ..... ***O. tingens***

3a. Intersecondary vein weak…..... 4

3b. Intersecondary vein strong… ..... ***O. succirubra.***

4a. 3° vein category random reticulate.....5

4b. 3° vein category is alternate percurrent ..... ***O. fasciculata.***

5a. Intersecondary vein absent..... 6

5b. Intersecondary vein present 7

6a. Free vein ending are linear and dichotomously branched…..... ….***O. rugosa.***

6b. Free vein endings are dichotomously branched… .....***O. rugosa* var. *prostata*.**

7a. 4° vein category are dichotomizing… ..... ***O. ochroleuca.***

7b. 4° vein category are alternate percurrent… ..... ***O. rugosa* var. *argentea*.**

8a. Free vein endings encircled with bundle sheath..... ***O. hispida.***

8b. Bundle sheath is absent……..***O. mungos.***

4.3.2 Leaf architectures characters of the studied species

1. *Ophiorrhiza mungos* L. Sp. Pl.: 150 (1753)

Venation of leaves is pinnate with single primary vein (1°). Secondary veins (2°) are weak brochidodromous, joined together in a series of arches (U shaped). Secondary vein spacing is uniform in nature. Secondary vein angle smoothly decreasing towards the base. Interscecondary veins are absent. 3° veins are random reticulate, rejoin with other 3° veins or 2° veins at random angles. 3° veins angle is inconsistent, angle of the tertiary vein extend randomly over the lamina. 4° veins are regular polygonal reticulate - rejoins with other veins to form polygons of similar size and shape. Areoles are formed by union of 2nd and 3rd order of veins; areoles are 3 or 5 sided, moderately developed with irregularly shape, more or less variations in size. Free vein endings are linear, 1 and 2 or more branched and some are dichotomously branched in Y shaped. Free vein endings are encircled with specialised bundle sheath cells **(Plate 25).**

2. *Ophiorrhiza ochroleuca* Hook.f. Fl. Brit. India 3: 78 (1880)Venation of leaves is pinnate with single primary vein (1°). Secondary veins (2°) are weak brochidodromous, joined together in a series of arches (U shaped). Secondary vein spacing is uniform in nature. Secondary vein angle is uniform in nature. Interscecondary veins are weak. Tertiary veins are random reticulate, tertiaries rejoin with other 3° veins or 2° veins at random angles. 3° veins angle is inconsistent, angle of the tertiary vein extend randomly over the lamina. 4° vein are dichotomizing, branch freely. Areoles are formed by union of 2nd and 3rd order of veins; areoles are 4 and 5 sided, moderately developed with irregularly shape, more or less variations in size. Free vein endings are linear, curved and some are dichotomously 1- branched in Y shaped **(Plate 26).**

3. *Ophiorrhiza succirubra* King ex Hook.f. Fl. Brit. India [J. D. Hooker] 3(7): 82 (1880)

Venation of leaves is pinnate with single primary vein (1°). Secondary veins (2°) are weak brochidodromous, joined together in a series of arches (U shaped). Secondary vein spacing is decreasing towards the base. Secondary vein angle is smoothly increasing towards base. Intersceondary veins are strong, reaches the margin. Tertiary veins are alternate percurrent, tertiary veins crosses between secondaries with abrupt angular discontinuity. 3° veins angle is inconsistent - angle of the tertiary vein extend randomly

over the lamina. 4° veins are regular polygonal reticulate, 4° veins comes together with other veins to form polygons. Areoles are formed by union of 2nd and 3rd order of veins, areoles are 3, 4 or 5 sided, well developed with consistent shape and size. Free vein endings are unbranched, linear and some are dichotomously branched. Free vein endings are encircled with specialised bundle sheath cells **(Plate 27).**

4. *Ophiorrhiza fasciculata* D.Don Prodr. Fl. Nepal.: 136 (1825)

Venation of leaves is pinnate with single primary vein (1°). Secondary veins (2°) are weak brochidodromous, joined together in a series of arches (U shaped). Secondary vein spacing is decreasing towards the base of the leaf. Secondary vein angle is smoothly decreasing towards the base of the leaf. Intersceondary veins are weak, did not reaches the margin. Tertiary veins are alternate percurrent, tertiary veins crosses between secondary veins with abrupt angular discontinuity. 4° veins are alternate percurrent crosses between tertiary veins with abrupt angular discontinuity. Areoles are formed by union of 2nd and 3rd order of veins, areoles are 4-5 sided, well developed with consistent size and shape. Free vein endings are unbranched, linear and some are curved in nature. Free vein endings are encircled with specialised bundle sheath cells **(Plate 28).**

5. *Ophiorrhiza oppositiflora* Hook.f. Fl. Brit. India 3: 80 (1880)

Venation of leaves is pinnate with single primary vein (1°). Secondary veins (2°) are weak brochidodromous, joined together in a series of arches (U shaped). Secondary vein spacing is uniform in nature. Secondary vein angle smoothly decreasing towards the base. Interscecondary veins are absent. 3° veins are random reticulate, rejoin with other 3° veins or 2° veins at random angles. 3° veins angle is inconsistent, angle of the tertiary vein extend randomly over the lamina. 4° veins are regular polygonal reticulate - rejoins with other veins to form polygons of similar size and shape. Areoles are formed by union of 2nd and 3rd order of veins; areoles are 3 or 5 sided, moderately developed with irregularly shape, more or less variations in size. Free vein endings are linear, 1 and 2 or more branched and some are dichotomously branched in Y shaped. Free vein endings are encircled with specialised bundle sheath cells **(Plate 29).**

6. *Ophiorrhiza rugosa* Wall., Fl. Ind. (Carey & Wallich ed.) 2: 547 (1824)

Venation of leaves is pinnate with single primary vein (1°). Secondary veins (2°) are weak brochidodromous, joined together in a series of arches (U shaped). Secondary vein spacing is uniform in nature. Secondary vein angle smoothly decreasing towards the base. Interscecondary veins are absent. 3° veins are random reticulate, rejoin with other 3° veins or 2° veins at random angles. 3° veins angle is inconsistent, angle of the tertiary vein extend randomly over the lamina. 4° veins are regular polygonal reticulate - rejoins with other veins to form polygons of similar size and shape. Areoles are formed by union of 2nd and 3rd order of veins; areoles are 3 or 5 sided, moderately developed with irregularly shape, more or less variations in size. Free vein endings are linear, 1 and 2 or more branched and some are dichotomously branched in Y shaped. Free vein endings are encircled with specialised bundle sheath cells **(Plate 30).**

7. *Ophiorrhiza rugosa var. argentea* (Wall. ex G.Don) Deb & Mondal Bull. Bot. Surv. India 24: 228 (1982 publ. 1983)

Venation of leaves is pinnate with single primary vein (1°). Secondary veins (2°) are weak brochidodromous, joined together in a series of arches (U shaped). Secondary vein spacing is uniform in nature. Secondary vein angle is uniform in nature. Intersceondary veins are weak, did not reaches the margin. Tertiary veins are random reticulate, tertiary veins rejoin with other 3° veins or 2° veins at random angles. 3° veins angle is inconsistent - angle of the tertiary vein extend randomly over the lamina. 4° veins are alternate percurrent crosses between tertiary veins with rough angular discontinuity. 4° vein are dichotomizing. Areoles are formed by union of 2nd and 3rd order of veins,areoles are 3, 4 or 5 sided, moderately developed with irregularly shape, more or less variation in size. Free vein endings are unbranched, linear and some are 1 dichotomously branched. Free vein endings are encircled with specialised bundle sheath cells **(Plate 31).**

8. *Ophiorrhiza rugosa* var. *prostrata* (D.Don) Deb & Mondal Bull. Bot. Surv. India 24 228 (1982 publ. 1983)

Venation of leaves is pinnate with single primary vein (1°). Secondary veins (2°) are weak brochidodromous, joined together in a series of arches (U shaped). Secondary vein spacing is uniform in nature. Secondary vein angle smoothly decreasing towards the

base. Interscecondary veins are absent. 3° veins are random reticulate, rejoin with other 3° veins or 2° veins at random angles. 3° veins angle is inconsistent, angle of the tertiary vein extend randomly over the lamina. 4° veins are regular polygonal reticulate – rejoins with other veins to form polygons of similar size and shape. Areoles are formed by union of 2nd and 3rd order of veins; areoles are 3 or 5 sided, moderately developed with irregularly shape, more or less variations in size. Free vein endings are linear, 1 and 2 or more branched and some are dichotomously branched in Y shaped. Free vein endings are encircled with specialised bundle sheath cells **(Plate 32).**

9. *Ophiorrhiza tingens* C.B.Clarke ex C.E.C.Fisch., Bull. Misc. Inform. Kew 1940: 33 (1940)

Venation of leaves is pinnate with single primary vein (1°). Secondary veins (2°) are weak brochidodromous, joined together in a series of arches (U shaped). Secondary vein spacing is irregular in nature. Secondary vein angle is uniform in nature. Interscecondary veins are absent. Tertiary veins are dichotomizing, branch freely. 3° veins angle is inconsistent, angle of the tertiary vein extend randomly over the lamina. 4° veins are alternate percurrent crosses between tertiary veins with rough angular discontinuity. 5° vein are dichotomizing, branch freely. Areoles are formed by union of 2nd and 3rd order of veins; areoles are 4 sided, moderately developed with irregularly shape, more or less variations in size. Free vein endings are linear and some are dichotomously branched in Y shaped. Free vein endings are encircled with specialised bundle sheath cells **(Plate 33).**

10. *Ophiorrhiza hispida* Hook.f., Fl. Brit. India (J. D. Hooker) 3(7): 83 (1880)

Venation of leaves is pinnate with single primary vein (1°). Secondary veins (2°) are weak brochidodromous, joined together in a series of arches (U shaped). Secondary vein spacing is uniform in nature. Secondary vein angle smoothly decreasing towards the base. Interscecondary veins are absent. 3° veins are random reticulate, rejoin with other 3° veins or 2° veins at random angles. 3° veins angle is inconsistent, angle of the tertiary vein extend randomly over the lamina. 4° veins are regular polygonal reticulate rejoins with other veins to form polygons of similar size and shape. Areoles are formed by union of 2nd and 3rd order of veins; areoles are 3 or 5 sided, moderately developed with irregularly shape, more or less variations in size. Free vein endings are linear, 1

and 2 or more branched and some are dichotomously branched in Y shaped. Free vein endings are encircled with specialized bundle sheath cells **(Plate 34).**

Table 4.4 Morphological characters of leaves among the investigated taxa

Name of taxa	**Phyllotaxy**	**Leaf organisation**	**Laminar shape**	**Leaf apex shape**	**Leaf base shape**	**Leaf margin**	**No. of Lateral vein**
O. mungos	Opposite and decussate	Simple	Eliptical-lanceolate	Acuminate apex	Narrowed base	Entire	8–18
O.ochroleuca	Opposite and decussate	Simple	Eliptical-lanceolate	Acuminate apex	Attenuate base	Entire	8–12
O.succirubra	Opposite and decussate	Simple	Eliptical-lanceolate	Acuminate apex	Acute at base	Entire	8–12
O.fasciculata	Opposite and decussate	Simple	Ovate-lanceolate	Acute apex	Tapering at base	Entire	5–15
O. oppositiflora	Opposite	Simple	Lanceolate	Acuminate	Acute base	Entire	7–13
O. rugosa	Opposite and decussate	Simple	Ovate-lanceolate	Obtuse-acute apex	Tapering at base	Entire	5–12
O. rugosa var. *argentea*	Opposite and decussate	Simple	Narrowly lanceolate	Acuminate apex	Acute at base	Entire	6 –11
O. rugosa var. *prostata*	Opposite and decussate	Simple	Ovate	Subacute apex	Subcordate base	Entire	4–8
O. tingens	Opposite and decussate	Simple	Broadly ovate-lanceolate	Sub caudate apex	Tapering at base	Entire	7–15
O. hispida	Opposite and decussate	Simple	Ovate	Acute apex	Obtuse base	Entire	6–13

Table 4.5 Qualitative characters of leaf architectural studies

Name of taxa	**1° vein category**	**2°vein**		**Intersecondary vein**	**3° vein category**	**4° vein category**	**Areolation**	**Free vein ending**
		2° vein category	**Vein spacing**					
O. mungos	Pinnate	Weak brochidodromous	Uniform	Absent	Random reticulate	Regular polygonal reticulate	Moderately developed, 3 or 5 sided	2 + dichotomously branched in Y shaped
O. ochroleuca	Pinnate	Weak brochidodromous	Uniform	Weak	Random recticulate	Dichotomizing	Moderately developed, 4-5 sided	Linear, curved, 1-branched
O. succirubra	Pinnate	Weak brochidodromous	Decreasing towards the base	Strong	Alternate percurrent	Regular polygonal reticulate	Well developed, 3-5 sided	Linear, dichotomously branched.
O.fasciculata	Pinnate	Weak brochidodromous	Decreasing towards the base	Weak	Alternate percurrent	Alternate percurrent	Well developed, 4-5 sided	Unbranched, Iinear, curved
O. oppositiflora	Pinnate	Weak brochidodromous	Uniform	Weak	Random reticulate	Regular polygonal reticulate	Moderately developed, 3 & 5 sided	Linear, 2+ branched
O. rugosa	Pinnate	Weak brochidodromous	Uniform	Absent	Random reticulate	Regular polygonal reticulate	Moderately developed, 3 or 5 sided	Linear, dichotomously branched in Y shaped
O. rugosa var *prostata*	Pinnate	Weak brochidodromous	Uniform	Absent	Random reticulate	Regular polygonal reticulate	Moderately developed, 3 or 5 sided	2 + dichotomously branched in Y shaped
O. rugosa var.	Pinnate	Weak brochidodromous	Uniform	Weak	Random recticulate	Alternate percurrent	Moderately develope	Linear, curved, 1-branched

argentea							d, 3-5 sided	
O. tingens	Pinnate	Weak brochidodromous	Irregular	Absent	Dichotomizing	Alternate percurrent	Moderately developed, 4 sided	Linear, Y-shaped branched
O. hispida	Pinnate	Weak brochidodromous	Uniform	Absent	Random reticulate	Regular polygonal reticulate	Moderately developed, 3 sided	dichotomously branched in Y shaped

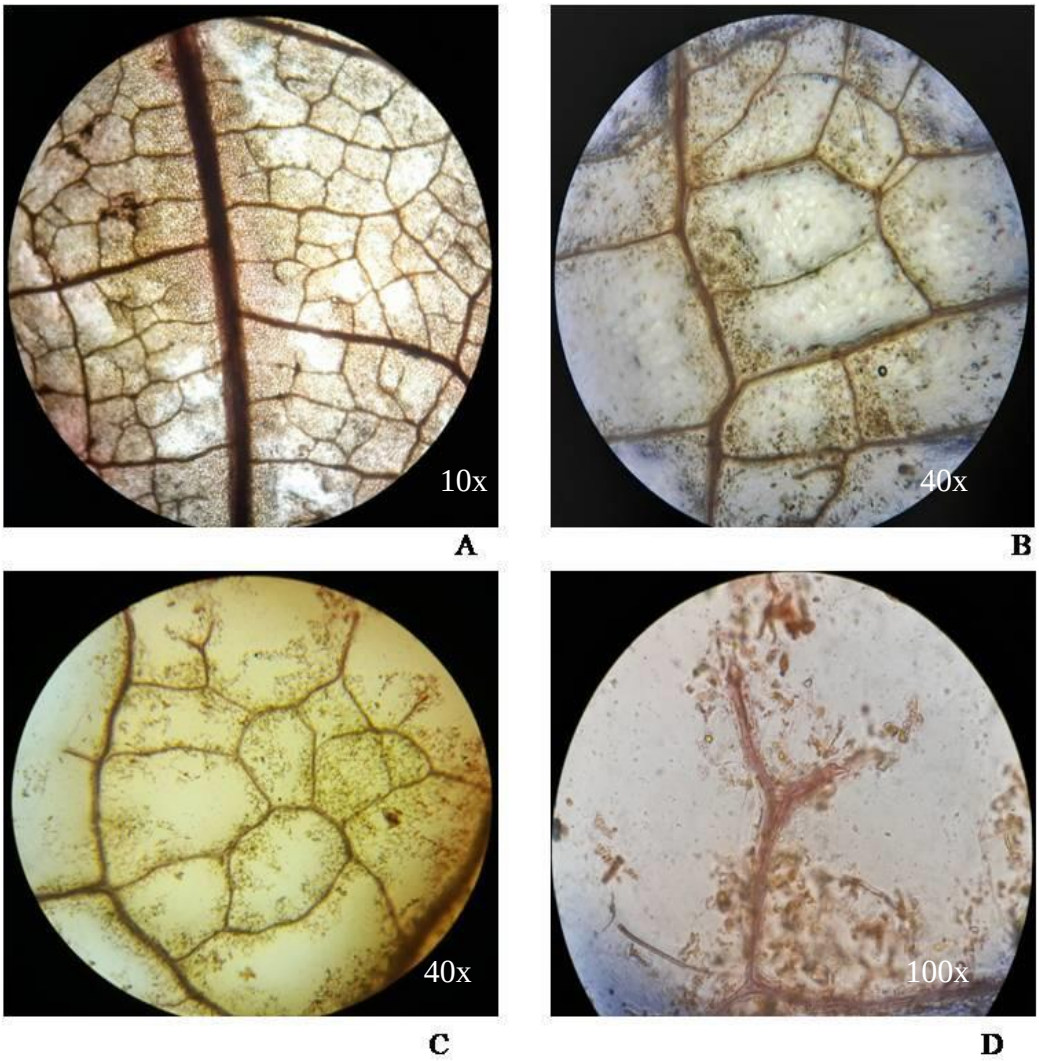

Plate 25 Leaf architecture study of *O. mungos*: A- Showing primary vein, secondary vein and tertiary vein; B & C- Well developed areoles; D- Y shaped free vein endings. (Scale: A- 30µm; B-20µm; C-15µm; D- 10µm)

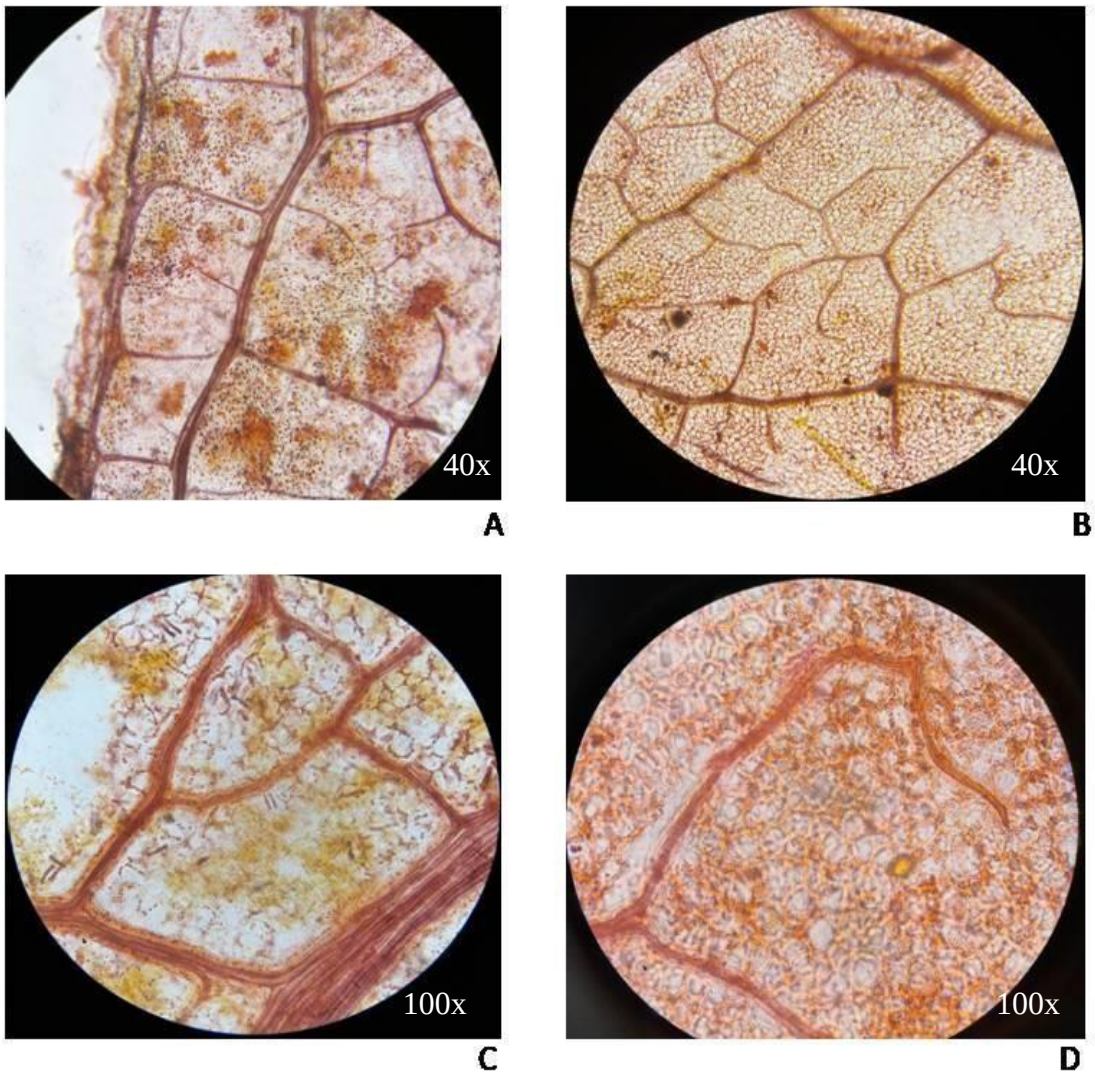

Plate 26 Leaf architecture study of *O. ochroleuca*: A-Margin showing inner intramarginal vein; B-Tertiary vein (3°) and free vein ending; C-3 sided areoles; D-Magnified showing free vein ending. (Scale: A- 20µm; B-20µm; C-10µm; D- 10µm)

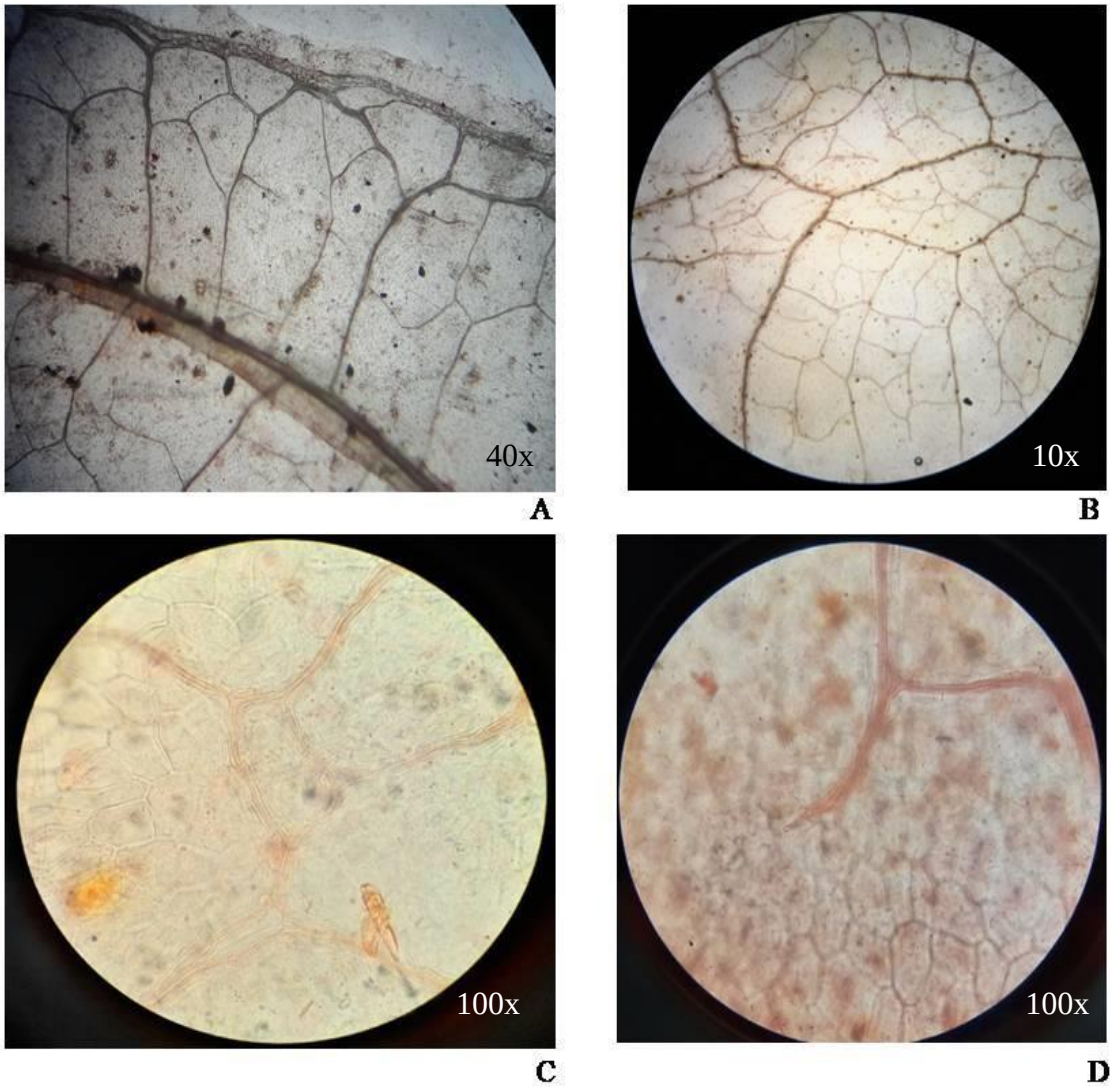

Plate 27 Leaf architecture study of *O. succirubra*: A-Margin showing inner intramarginal vein; B-Tertiary vein (3°); C- 4 sided areoles; D-Free vein endings. (Scale: A- 20µm; B-30µm; C-15µm; D- 15µm)

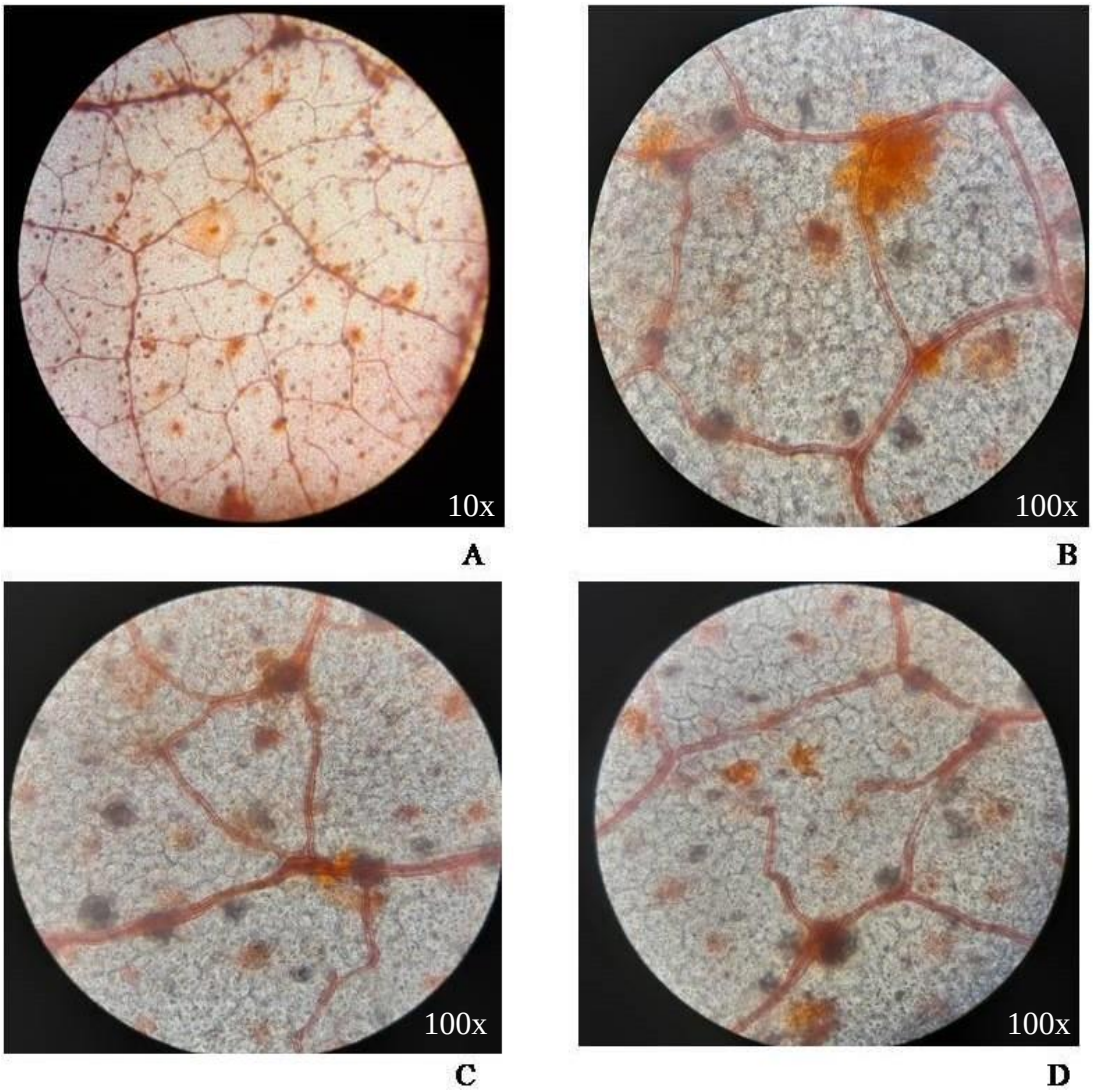

Plate 28 Leaf architecture study of *O. fasciculata*: A- Secondary vein (2°) and tertiary vein (3°); B & C: 3 and 4 sided aeroles; D- Free vein endings. (Scale: A- 30µm; B-15µm; C-15µm; D- 15µm)

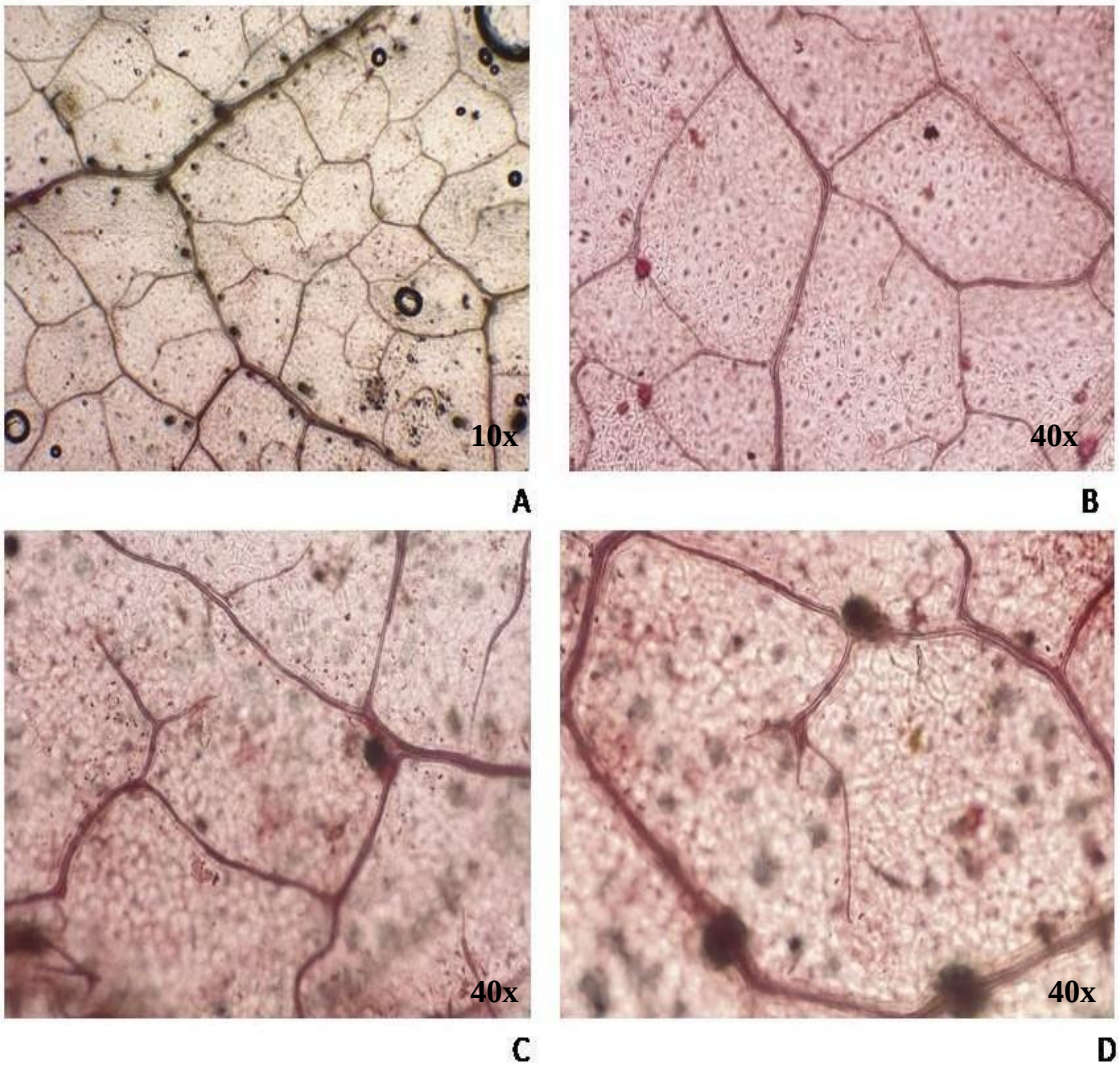

Plate 29 Leaf architecture study of *O. oppositiflora*: A-Secondary vein (2°) and tertiary vein (3°); B-Areoles; C-Y-shaped free vein ending; D- Branched free vein endings. (Scale: A- 30µm; B-30µm; C-15µm; D- 15µm

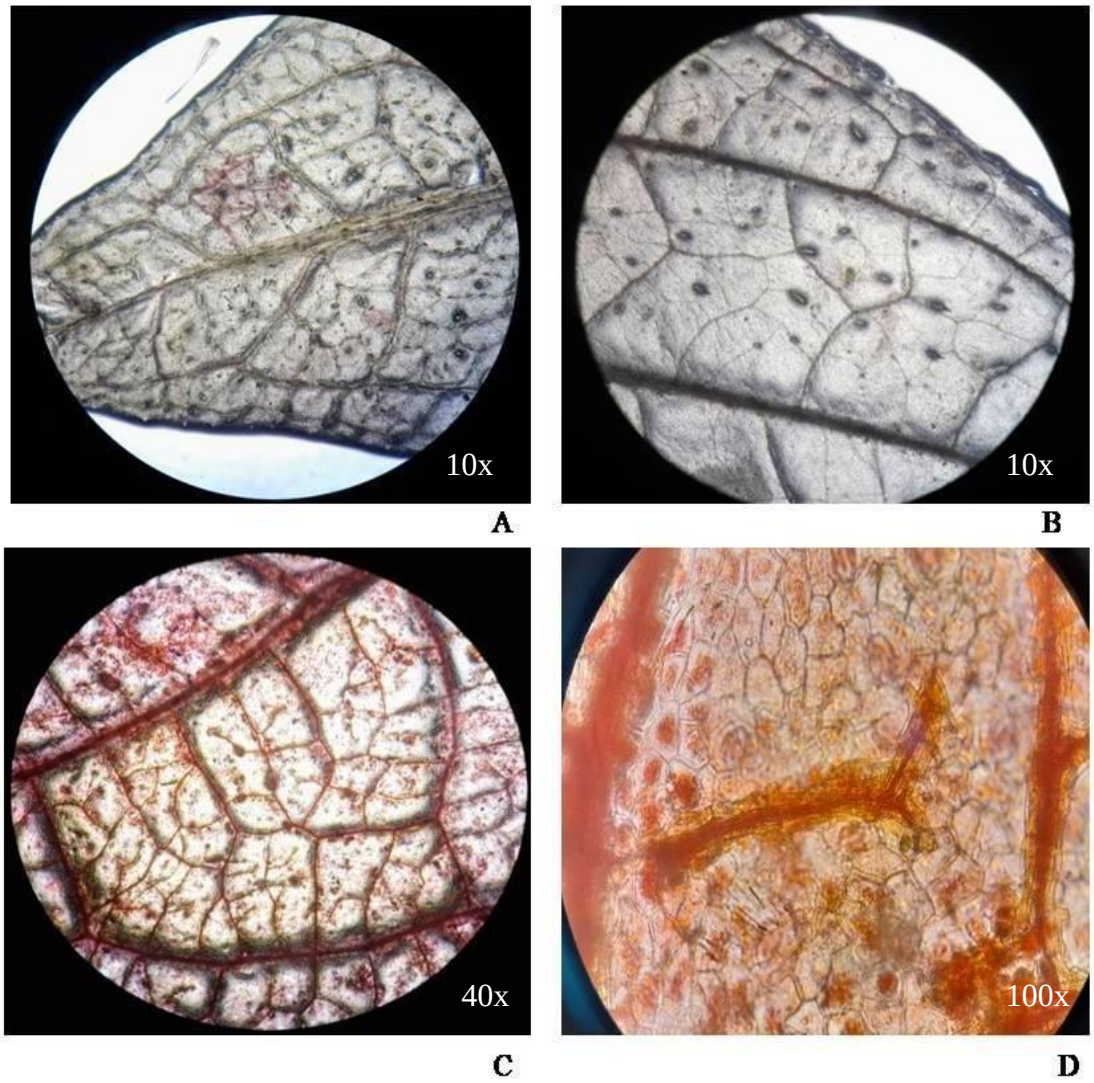

Plate 30 Leaf architecture study of *O. rugosa*: A & B- Margin showing intramarginal vein and primary vein; C: Tertiary vein (3°); D- Free vein ending. (Scale: A- 30µm; B- 20µm; C-15µm; D- 10µm)

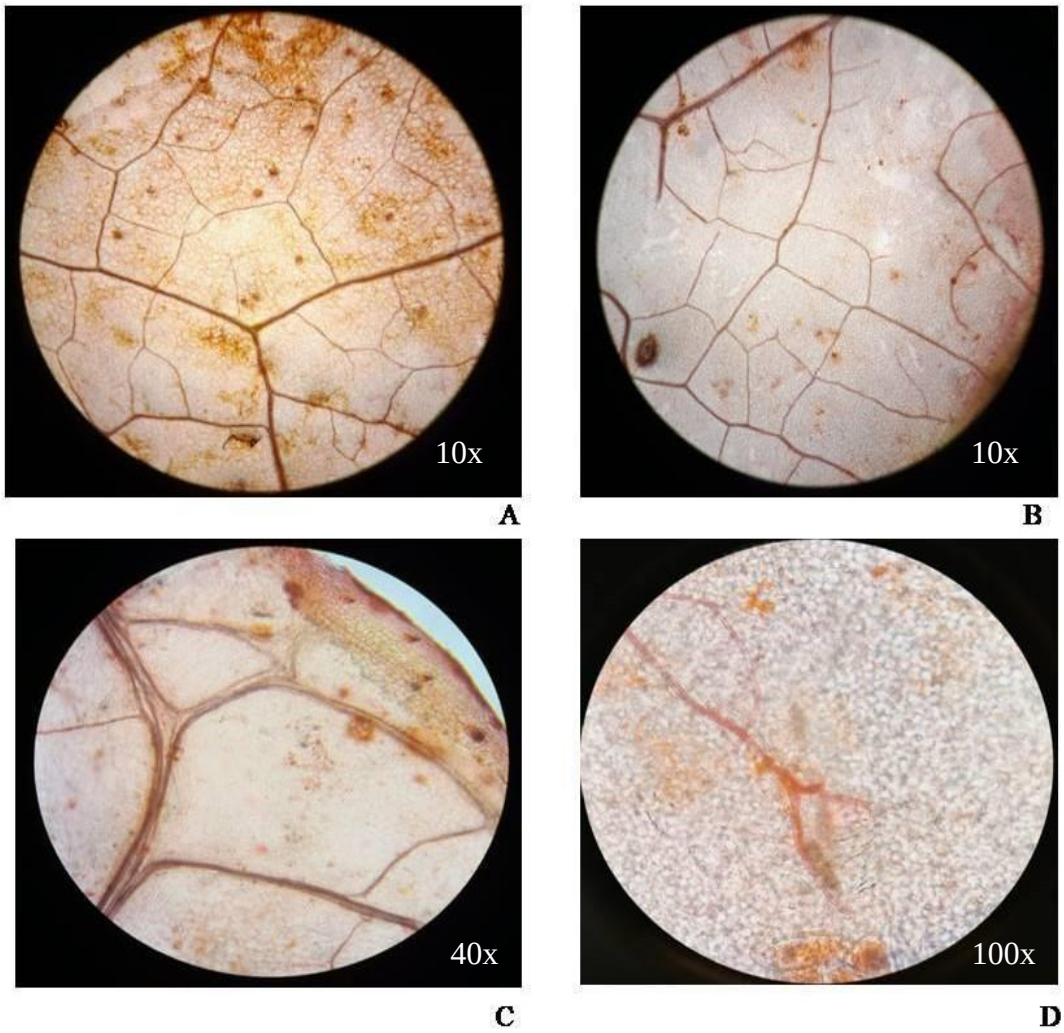

Plate 31 Leaf architecture study of *O. rugosa* var. *argentea*: A-Secondary vein (2°) and tertiary vein (3°); B-Tertiary vein; C-3 sided areole; D-Y-shaped free vein ending. (Scale: A- 30µm; B-30µm; C-15µm; D- 15µm

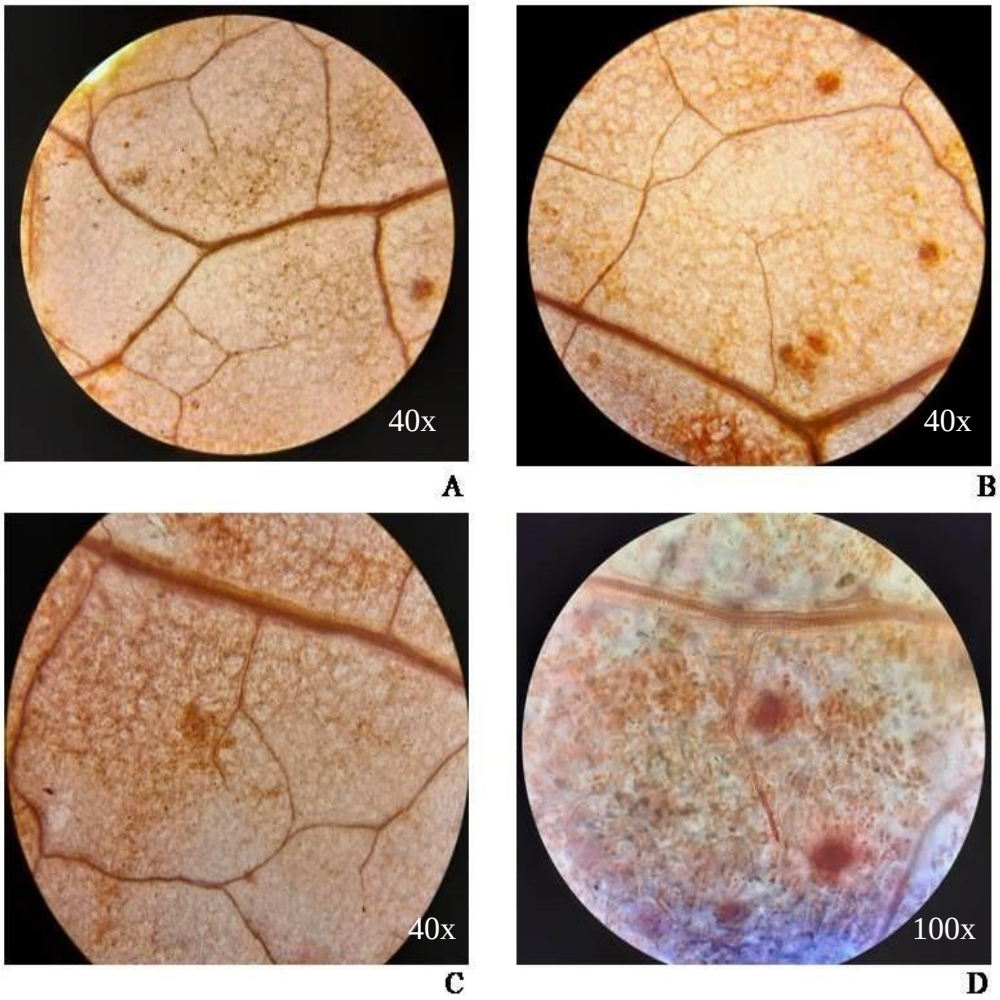

Plate 32 Leaf architecture study of *O. rugosa* var. *prostata.* A & B- Showing secondary vein (2°); and tertiary vein (3°); C & D- Free vein endings. (Scale: A-20µm; B-20µm; C-15µm; D- 15µm)

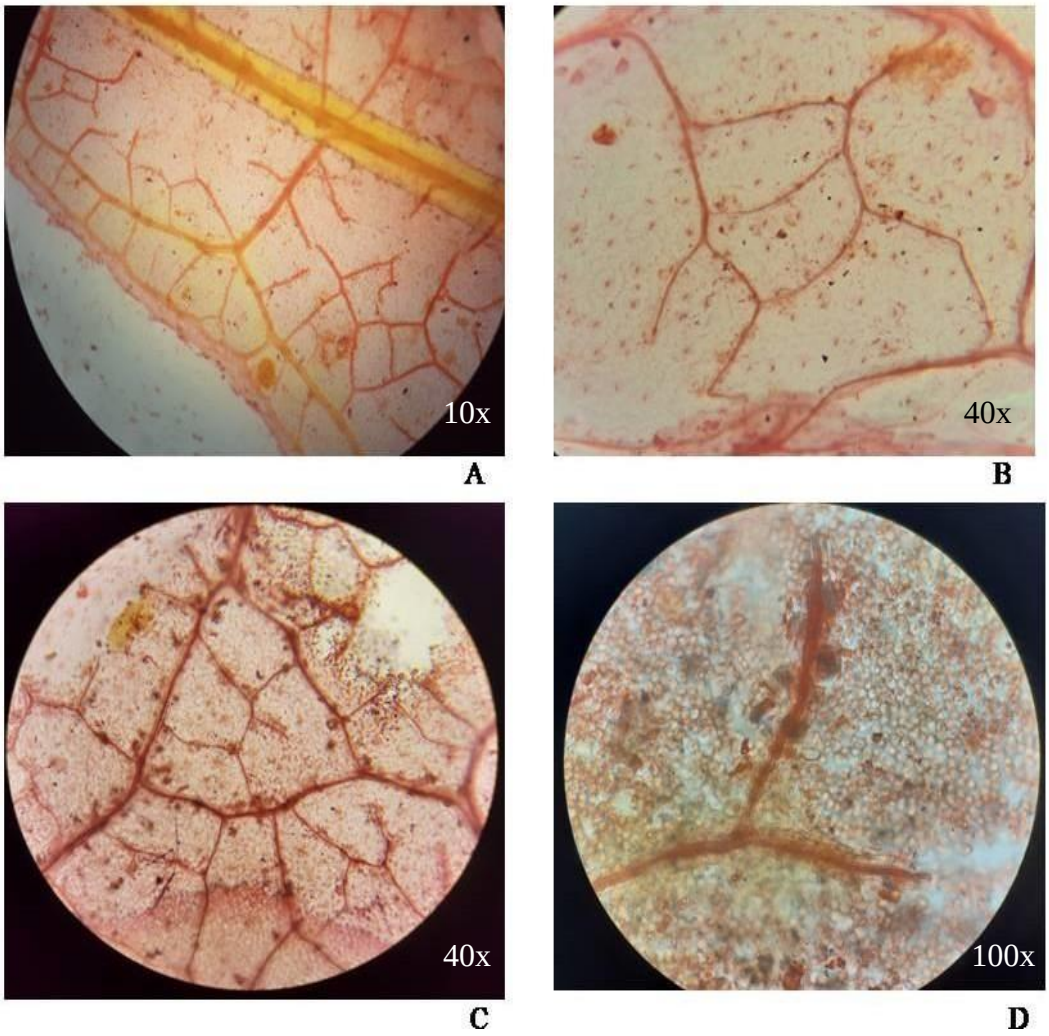

Plate 33 Leaf architecture study of *O. tingens*. A- Margin showing inner intramarginal vein and secondary vein (2°); B- 4 sided areoles; C: Magnified image of tertiary vein (3°); D-Y shaped free vein ending. (Scale: A- 30µm; B-20µm; C-15µm; D- 10µm)

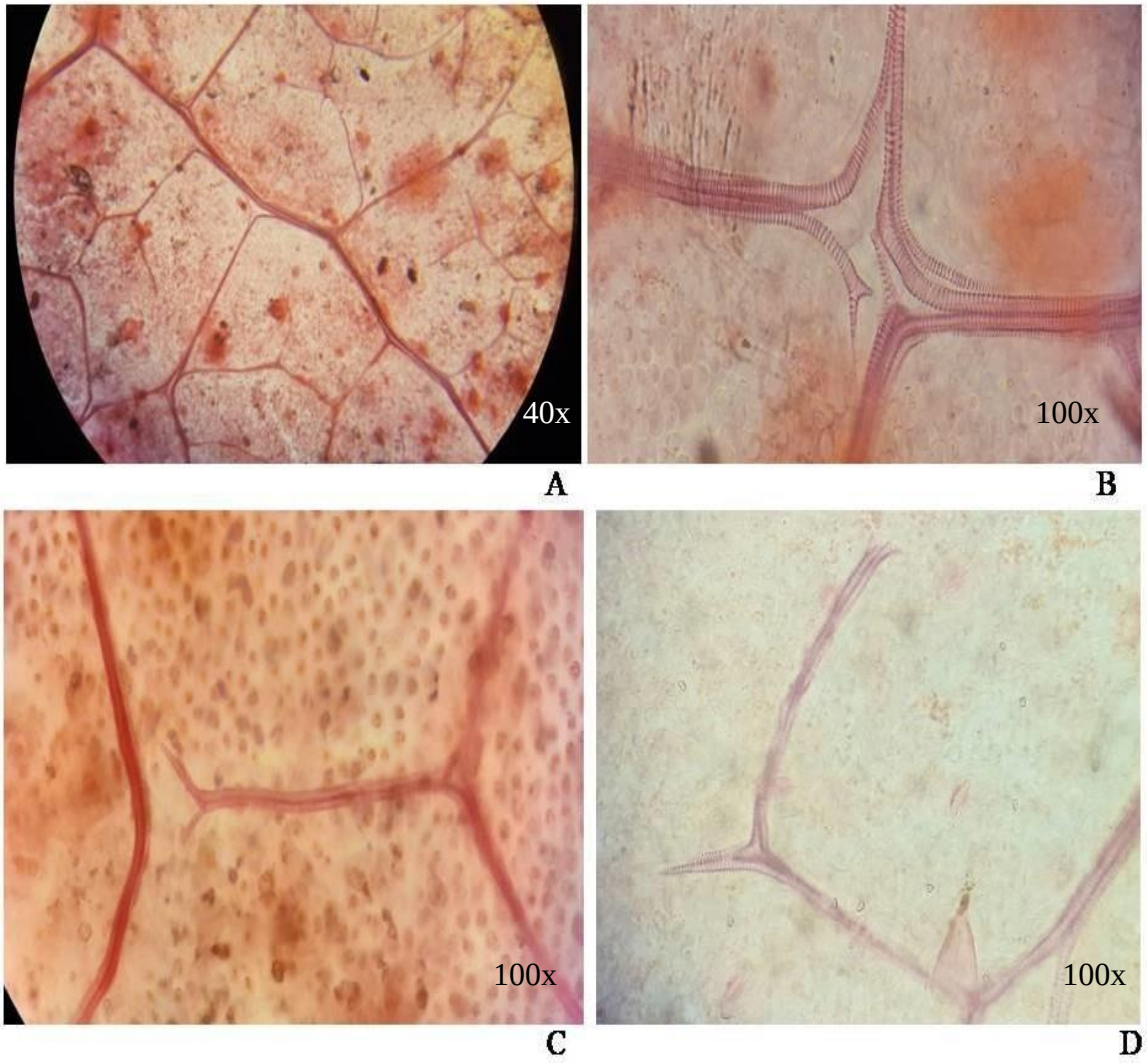

Plate 34 Leaf architecture study of *O.hispida*. A- Secondary vein (2°); B- Marginal vein; C & D- 1 branched free vein ending. (Scale: A- 30µm; B-20µm; C-15µm; D-10µm)

4.4 Anatomical study

The anatomical characteristics of the stem in *Ophiorrhiza* species have been thoroughly examined and presented. The results were observed in light microscope and presented along with photographic plates. The nature of the epidermis, endodermis, cortex, nature and types of vascular bundle, and presence and absence of hairs, raphides, druses and calcium oxalates were studied. The features of the anatomy of all 10 taxa of *Ophiorrhiza* in Assam have been worked out and also presented in tabulated form (Table 4.6). The results observed under a light microscope have been presented in Plate no. 35 to Plate no. 44.

4.4.1 Anatomical characters of the investigated species

1. *Ophiorrhiza mungos* L. Sp. Pl.: 150 (1753)

In the stem's transverse section, a circular shape was observed with epidermis with single layer of cell and presence of hairs. Under the single layered of epidermis, sub epidermal cell were composed of 5–6 layers of loosely packed parenchyma cells followed by continuous sheath of packed 6–7 layers of parenchymatous cortex. There are 1–2 layers of endodermis present, followed by three layers cells of pericycle, which encircle the vascular system. The vascular cylinder was found with xylem occurs around the pith, and a ring of phloem surrounds outside the xylem. The xylem and phloem was arranged in continuous rings with a distinct differentiation. The pith is composed of oval shaped parenchyma cells with raphides inside the cell. **(Plate 35)**

2. *Ophiorrhiza ochroleuca* Hook.f. Fl. Brit. India 3: 78 (1880)

The transverse section of the stem showed somewhat circular in shape with a single layer of epidermis with small hairs. Under the single layer of epidermis, sub epidermal cell were composed of 3–4 layers of parenchyma cells followed by continuous sheath of 5–6 layers of oval shaped parenchymatous cortex. Single layer of elongated endodermis is present followed by complete 3–4 layered of pericycle were observed which surround the vascular system. 5–6 layers of vascular cylinder were found with xylem occurs around the pith, and a ring of phloem surrounds outside the xylem. The xylem and phloem were arranged in continuous patches of rings. The pith is composed of oval shaped largely packed parenchyma cells. Bundle of needle like raphides were observed insides the parenchyma cells of pith. **(Plate 36)**

3. *Ophiorrhiza succirubra* King ex Hook.f., Fl. Brit. India (J. D. Hooker) 3(7): 82 (1880)

The transverse section of the stem showed circular shaped with a single layer of epidermis and trichomes. Under the single layered of epidermis, sub epidermal cell were composed of 5–6 layers of loosely packed collenchymatous cells followed by continuous sheath of 6–7 layers of parenchymatous cortex. 2 layered of endodermis were observed followed by 4 layered of pericycle which surrounds the vascular bundle. The vascular cylinder was found with xylem which occurs around the pith, and a ring of phloem surrounds outside the xylem. The xylem and phloem were arranged in a continuous ring with a distinct differentiation. The pith is composed of oval shaped large parenchyma cells which encircled by the vascular bundle. Calcium oxalates and bundle of needle like raphides were observed insides the parenchyma cells of pith. **(Plate 37)**

4. *Ophiorrhiza fasciculata* D.Don Prodr. Fl. Nepal.: 136 (1825)

The transverse sections of the stem of *O. fasciculata* showed an oval shape with a uniseriate epidermis. 3–4 layers of collenchymatous sub epidermal cells were observed, followed by packed of continuous sheath of 4–5 parenchymatous cortex. A complete cylinder of two layers of endodermis followed by a 2–3 layer of pericycle that surrounds the vascular system were observed. The vascular cylinder was found with xylem occurring around the pith, and a ring of phloem occurs outside the xylem. The xylem and phloem was arranged in continuous cylinders with distinct differentiation. Almost half of the volume of the stem was occupied by the pith which had round to oval shaped parenchymatous cells containing needle like raphides inside the cells **(Plate 38).**

5. *Ophiorrhiza oppositiflora* Hook.f. Fl. Brit. India 3: 80 (1880)

The transverse section of the stem showed somewhat circular in shape with a single layer of epidermis with small hairs. Under the single layered of epidermis, sub epidermal cell were composed of 4–5 layers of packed parenchyma cells. Cortex is large, composed of continuous patches of 8–9 layers of round shaped parenchyma cells. 3–4 layers of irregular shaped endodermis was present followed by a complete 2–3 layered of pericycle which surrounds the vascular system were observed followed by were present. Vascular Bundle was composed of xylem and phloem. Vascular cylinder were found with xylem occurs around the pith, and a ring of phloem surrounds outside

and around the xylem. The xylem and phloem was arranged in continuous patches of rings with distinct differentiation around the pith. The pith is large, composed of round and oval shaped large parenchyma cells. **(Plate 39)**

6. *Ophiorrhiza rugosa* Wall., Fl. Ind. (Carey & Wallich ed.) 2: 547 (1824)

The transverse section of the stem showed circular in shape with a single layer of epidermis. Under the single layered of epidermis, sub epidermal cell were composed of 3–4 layers of irregular shape parenchyma cells followed by continuous sheath of 6 layers of oval shaped parenchymatous cortex were present. 3–4 layers of endodermis small cells were present followed by 3–4 layer of pericycle were observed which surrounds the vascular system. Vascular Bundle was composed of xylem and phloem. Vascular cylinder were found with xylem occurs around the pith, and a ring of phloem surrounds outside the xylem. The xylem and phloem was arranged in continuous rings which surrounds the pith. The pith is composed of round shaped large parenchyma cells. Bundle of needle like raphides and calcium oxalates were observed insides parenchyma cells of pith. **(Plate 40)**

7. *Ophiorrhiza rugosa var. argentea* (Wall. ex G.Don) Deb & Mondal Bull. Bot. Surv. India 24: 228

The transverse section of the stem showed an oval shape with a single layer of epidermis and trichomes. Under the single layered of epidermis 5–6 layers of loosely packed collenchymatous sub epidermal cells were observed, followed by a continuous sheath of 6–7 layers of round shaped parenchymatous cortex. 2 layered irregular shaped endodermis were present followed by 2–3 layered of pericycle surroundings the vascular system was observed. The vascular cylinder was found with xylem occurs around the pith, and a ring of phloem occurs outside the xylem. The xylem and phloem were arranged in a continuous ring with a distinct differentiation. The pith is composed of oval shaped parenchyma cells which encircled by the vascular bundle. The cell of the pith composed of calcium oxalates and small needle like raphide **(Plate 41).**

8. *Ophiorrhiza rugosa* var. *prostrata* (D.Don) Deb & Mondal Bull. Bot. Surv. India 24 228 (1983)

The transverse section of the stem showed somewhat circular in shape with a single layer of epidermis with small hairs. Under the single layer of epidermis, sub epidermal cell were present which composed of 4 layers of packed parenchyma cells followed by continuous sheath of 6–7 layers of oval shaped parenchymatous cortex were present. 1–2 layers of elongated endodermis were present followed by 2–3 layered of pericycle were observed which surrounds the vascular system. Vascular Bundle was composed of xylem and phloem. Vascular cylinder were found with xylem occurs around the pith, and a ring of phloem surrounds outside the xylem. The xylem and phloem were arranged in continuous patches of rings which surrounds the pith. The pith is composed of round and oval shaped large parenchyma cells. Bundle of needle like raphides were observed insides the parenchyma cells of pith. **(Plate 42)**

9. *Ophiorrhiza tingens* C.B.Clarke ex C.E.C.Fisch., Bull. Misc. Inform. Kew 1940: 33 (1940)

The transverse section of the stem of *O. tingens* showed a round shaped with a single layer of epidermis and trichomes. Under the single layered of epidermis 5 layers of collenchyma sub epidermal cells were observed, followed by a continuous sheath of 5 layers of parenchymatous cortex. 1–2 layered of irregular shaped endodermis is present followed by complete 1–2 layered of pericycle that surrounds the vascular system was observed. The vascular cylinder was found with xylem occuring around the pith, and a ring of phloem occurs outside the xylem. The xylem and phloem was arranged in continuous ring like structure. The central portion of stem is known as pith which is composed of round to oval shaped large parenchyma cells. **(Plate 43)**

10. *Ophiorrhiza hispida* Hook.f., Fl. Brit. India (J. D. Hooker) 3(7): 83 (1880)

The transverse section of the stem of *O. hispida* showed a round shape with a single layered epidermis and multiseriate trichomes. Under the epidermis, 5–6 layers of collenchymatous sub epidermal cells were observed, followed by a continuous sheath of 5–6 layers of parenchymatous cortex.Single layered endodermis was present followed by 2–3 layered of pericycle surrounding the vascular system was observed. The vascular cylinder was found with xylem occurs around the pith, and a ring of phloem occurs outside the xylem. The xylem and phloem were arranged in a continuous ring. After the

vascular bundle, the TS of the stem was occupied by the pith, which had oval shaped large parenchymatous cells. No calcium crystals and raphides were observed. **(Plate 44)**

Table 4.6 Anatomical characteristic of the investigated taxa

Name of taxa	**Presence /absence of hair/trichome**	**Sub-epidermis**	**Cortex**	**Endodermis**	**Pith**	**Raphides**	**Calcium crystals**
O. mungos	Present	of 5–6 layers of loosely packed parenchyma cells	6–7 layers of parenchymatous cell	1–2 layered of endodermis	Oval shaped parenchyma cells	Present	Absent
O. ochroleuca	Present	3–4 layers of packed parenchyma cells	5-6 layers of oval shaped parenchymatous cell	Single layer of elongated endodermis	Oval shaped largely packed parenchyma cells	Present	Absent
O, succirubra	Present	5–6 layers of loosely packed collenchymatous cells	6–7 layers of parenchymatous cell	2 layered of endodermis	Oval shaped largely packed parenchyma cells	Present	Present
O. fasciculata	Absent	3–4 layers of collenchymatous cell	4–5 parenchymatous cortex	2 layered of endodermis	Round to oval shaped parenchymatous cells	Present	Absent
O. oppositiflora	Present	4–5 layers of packed parenchyma cells	8–9 layers of round shaped parenchyma cells	3–4 layers of irregular shaped endodermis	Round and oval shaped largely packed parenchyma cells	Absent	Absent

O. rugosa	Absent	3-4 layers of irregular shape parenchyma cells	6 layers of oval shaped parenchymat ouscell	3-4 layers of endoder mis	Round shaped largely packed parenchy ma cells	Present	Present
O. rugosa var. *argentea*	Present	5-6 layers of loosely packed collenchymatous cell	6-7 layers of round shaped parenchymat ous	2 layered irregular shaped endoder mis	Oval shaped parenchy ma cells	Present	Present
O. rugosa var. *prostata*	Present	4 layers of packed parenchyma cells	6-7 layers of oval shaped parenchymat ous	1-2 layers of elongate d endoder mis	Round and oval shaped largely packed parenchy ma cells	Present	Absent
O. tingens	Present	5 layers of collenchymas cells	5 layers of parenchymat ous cell	1-2 layered of irregular shaped endoder mis	Round to oval shaped large parenchy ma cells	Absent	Absent
O. hispida	Present	5-6 layers of collenchymatous sub epidermal cells	5-6 layers of parenchymat ous cell	Single layered endoder mis	Oval shaped large parenchy matous cells.	Absent	Absent

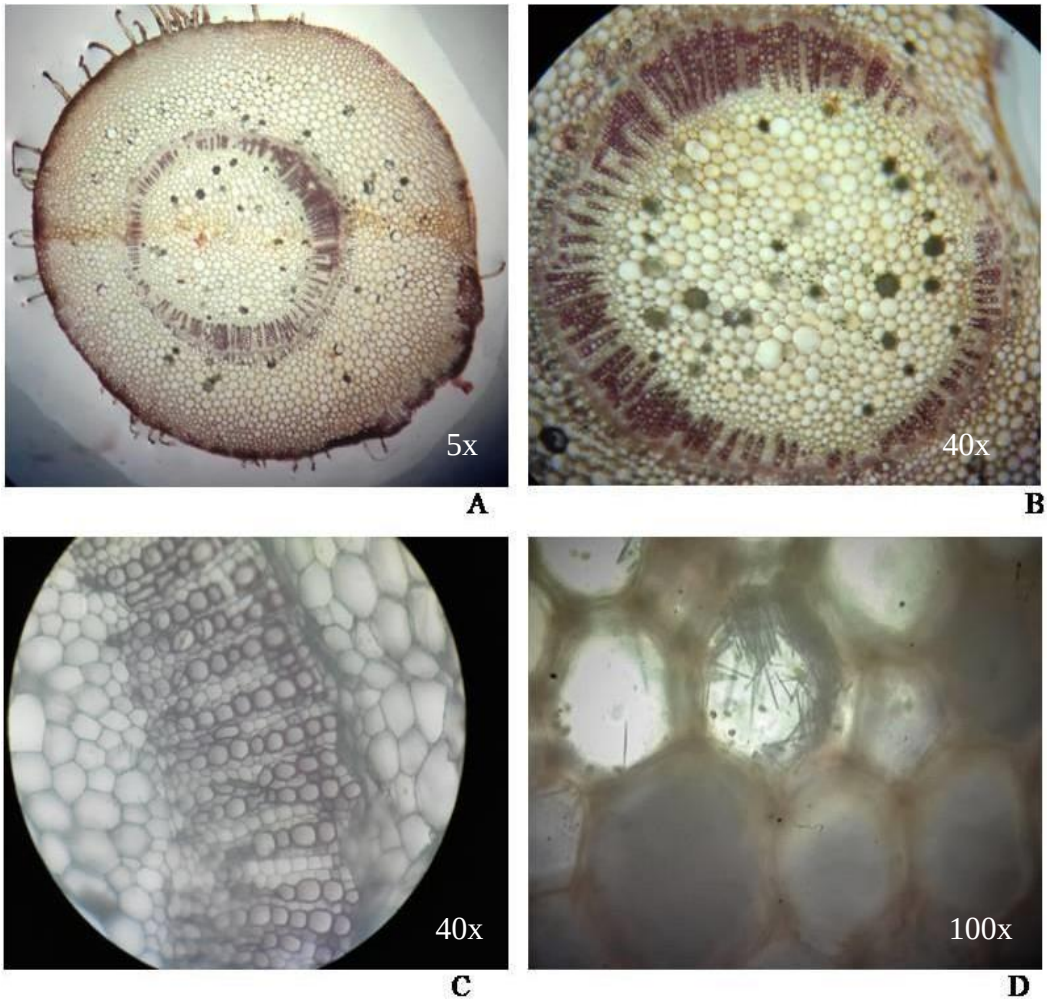

Plate 35 Stem anatomy of *O. mungos*. A- Transverse section of stem with epidermal hairs; B- Vascular bundle with parenchymatous pith; C- Vascular bundle showing xylem and phloem; D- Cell with raphides.

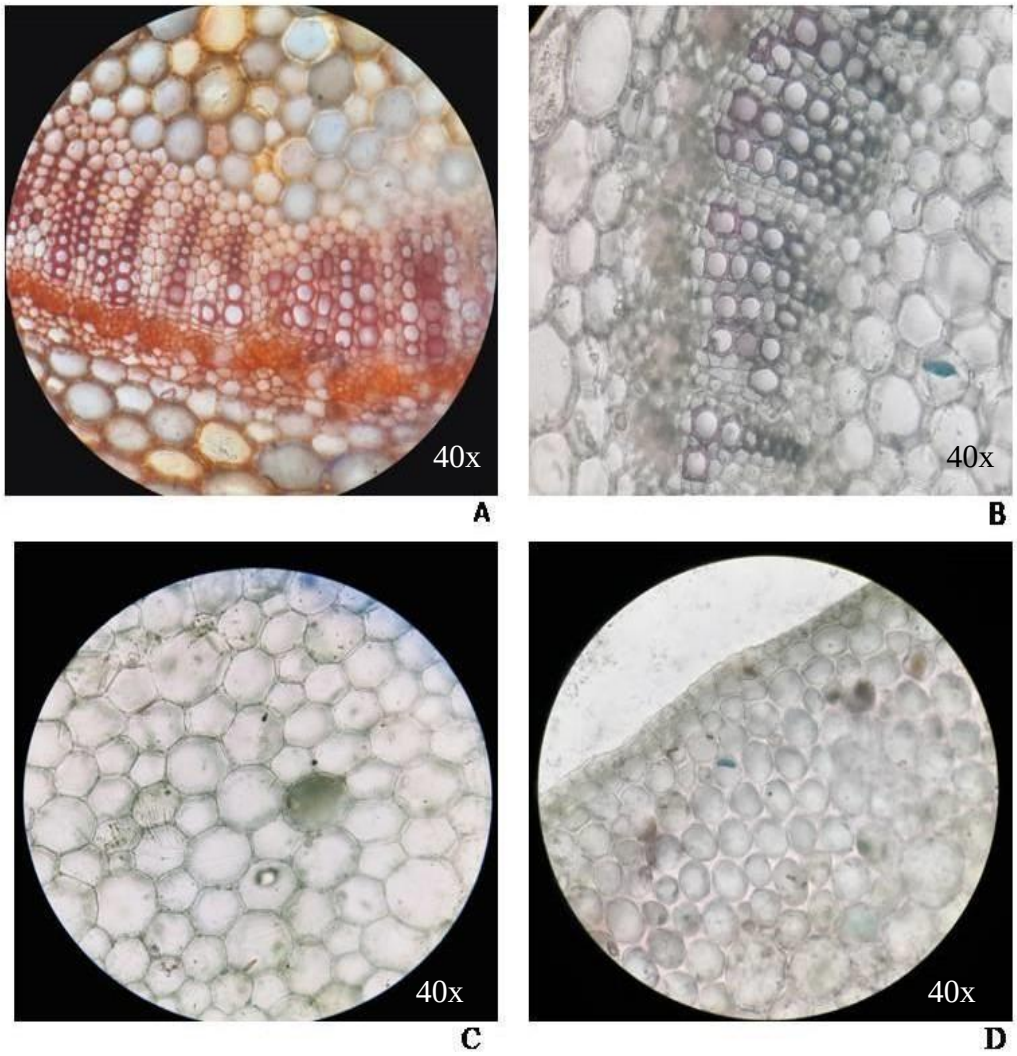

Plate 36 Stem anatomy of *O. ochroleuca.* A & B-Vascular bundle showing xylem and phloem; C-Parenchyma ground tissues; D- Single layer epidermis with loosely packed parenchyma cells.

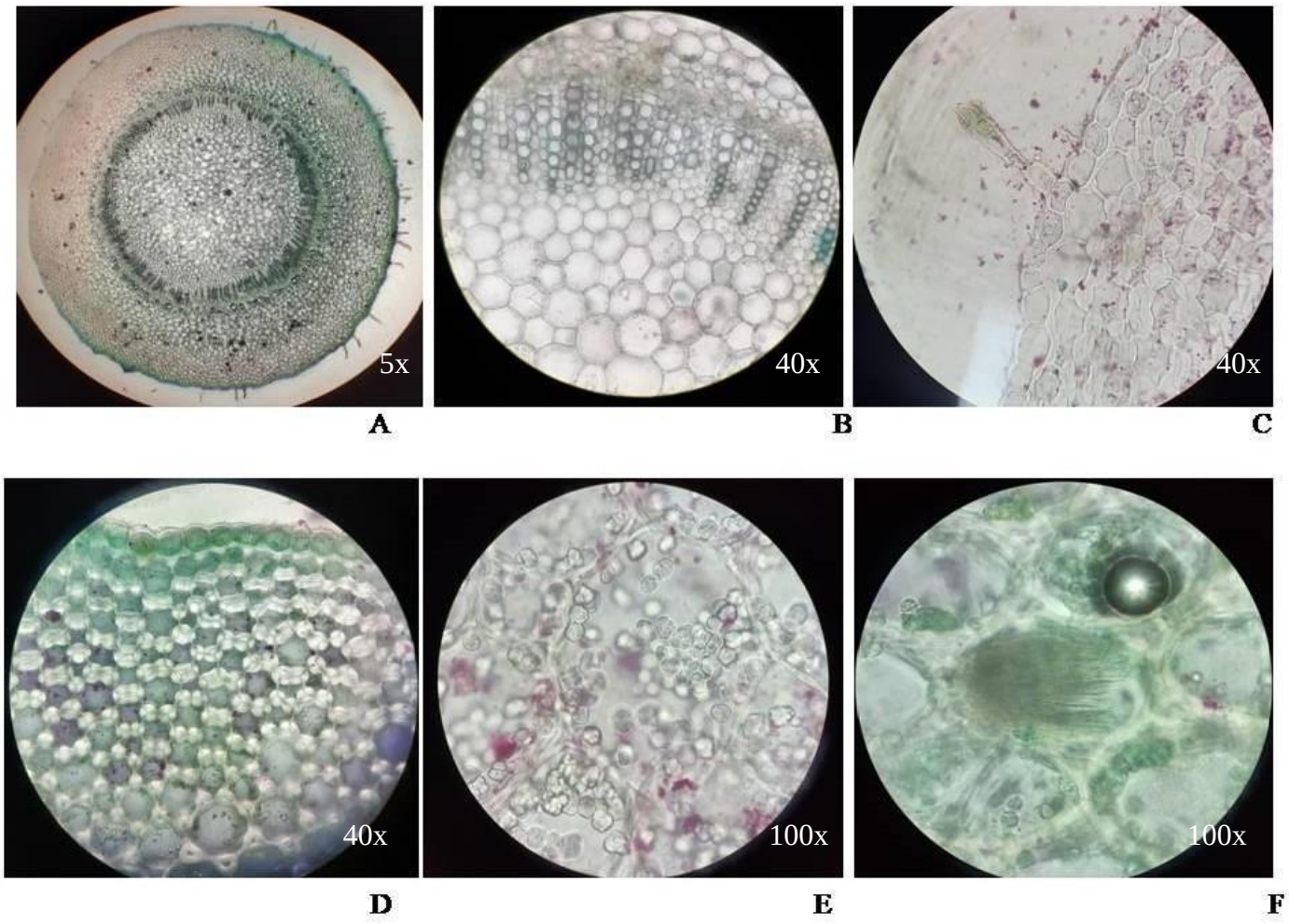

Plate 37 Stem anatomy of *O. succirubra*. A- Transverse section of stem. B- Vascular bundle C- Multicellular hair in epidermis. D- Collenchyma cells. E- Calcium Crystals inside cells. F- Bundle of Raphides inside the cell.

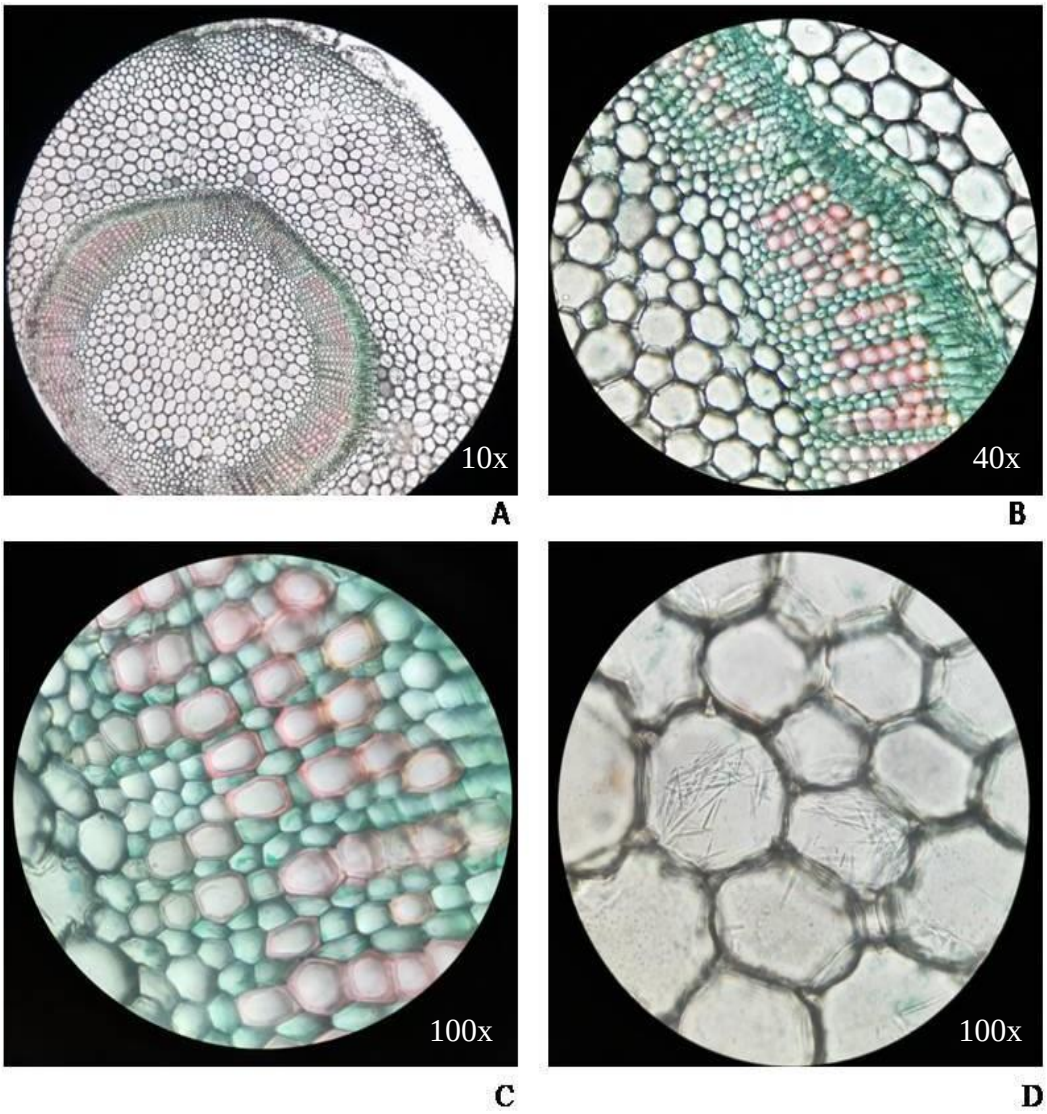

Plate 38 Stem anatomy of *O. fasciculata.* A- Transverse section of stem showing arrangement of vascular bundle and epidermis; B & C- Vascular bundle showing xylem and phloem; D- Parenchymatous ground tissues with raphides inside the cell.

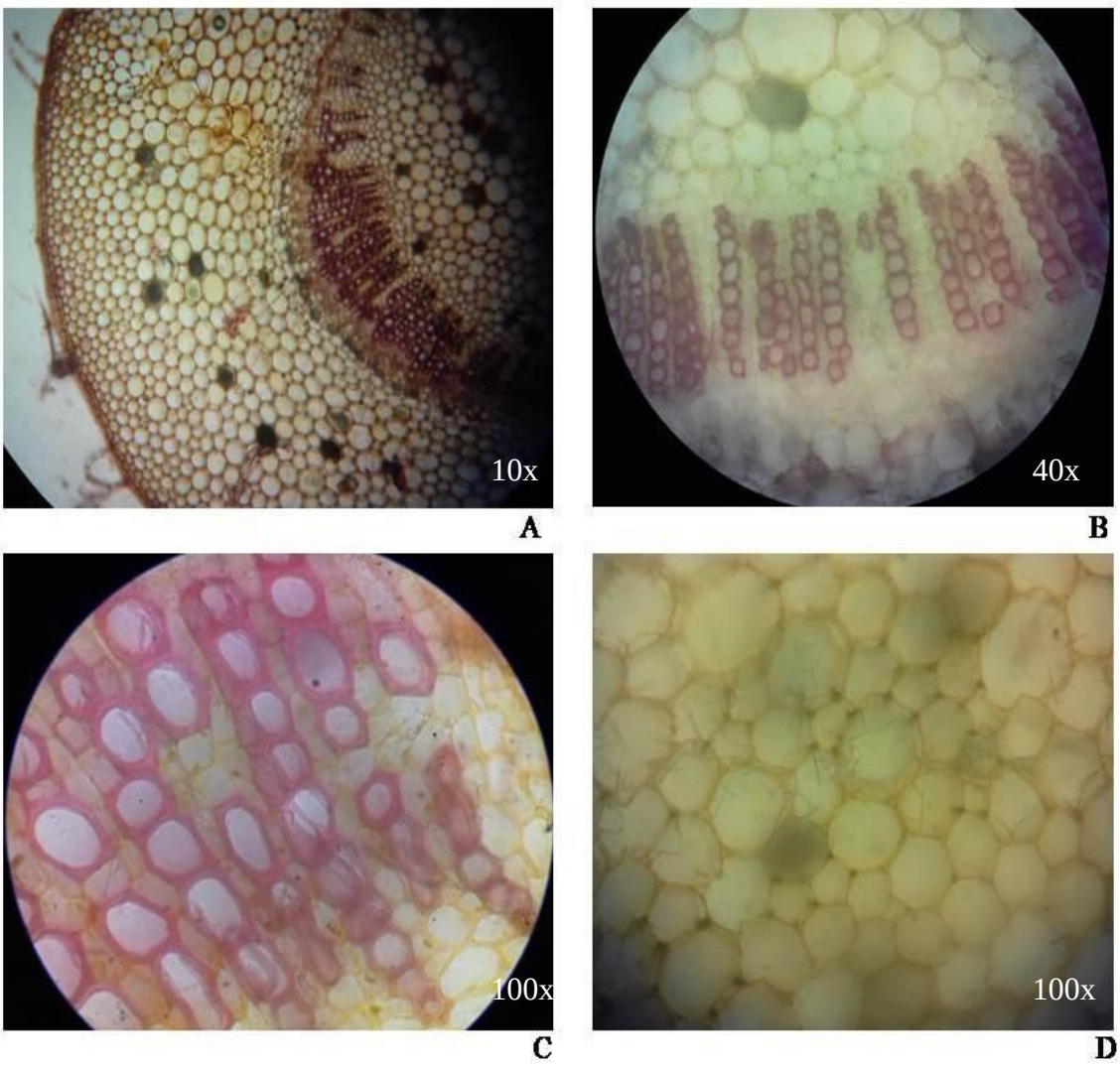

Plate 39 Stem anatomy of *O. oppositiflora.* A- Single layer epidermis and endodermis; B & C- Vascular Bundle; D- Cell with needle like raphides.

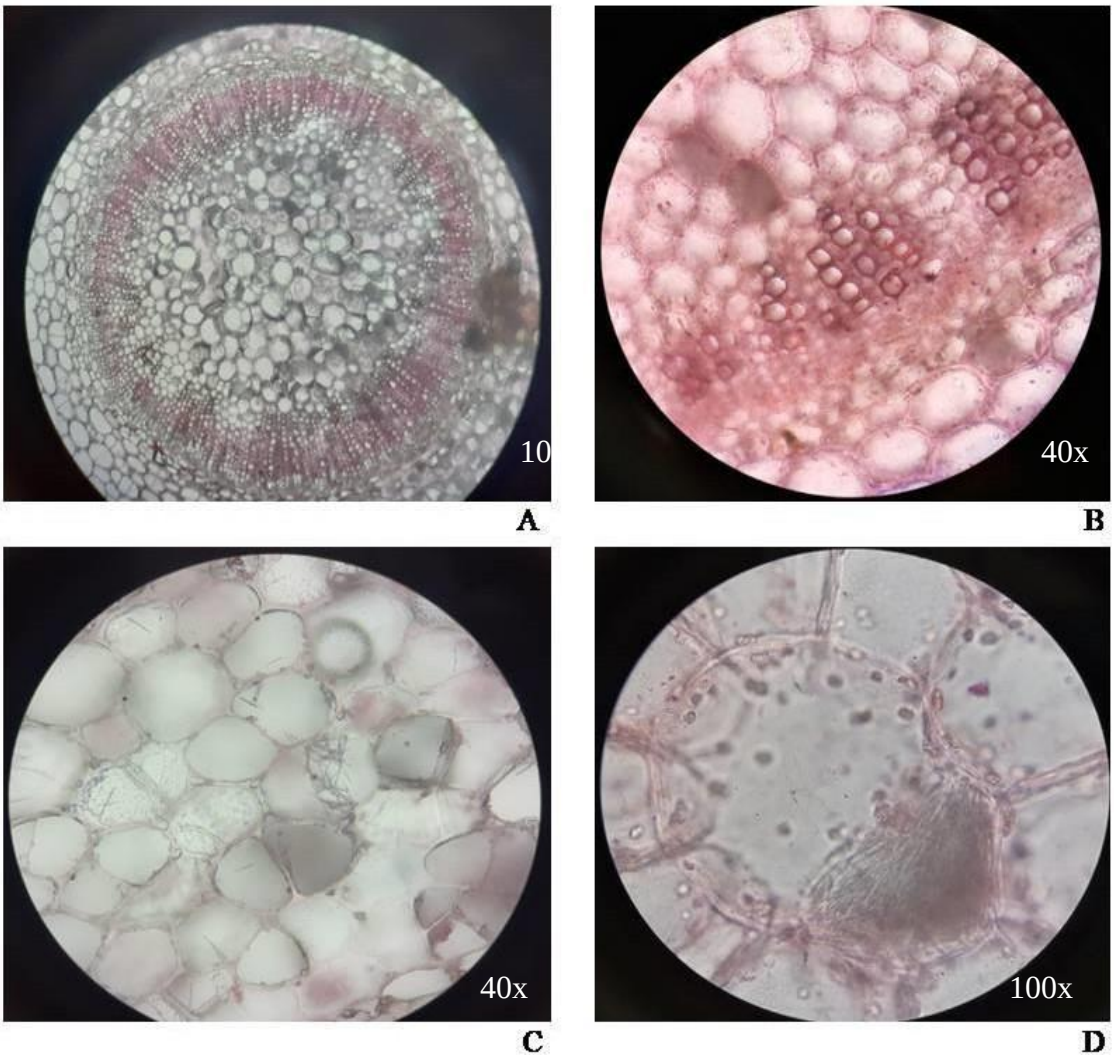

Plate 40 Stem anatomy of *O. rugosa*. A- Transverse section of stem with arranged vascular bundle; B- Vascular bundle with xylem and phloem; C- Parenchyma cell with needle like raphides; D- Bundle of raphides.

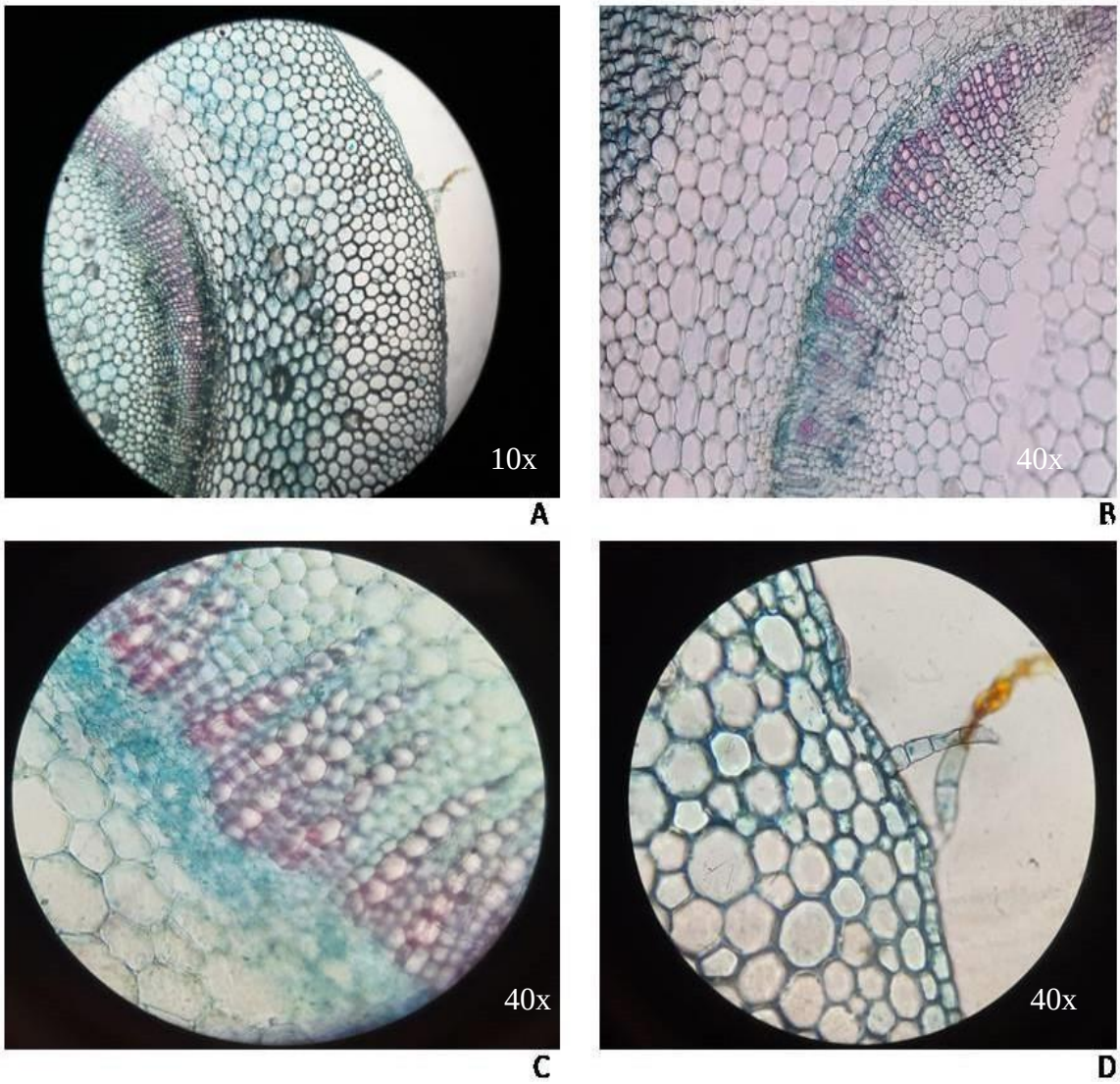

Plate 41 Stem anatomy of *O. rugosa* var. *argentea.* A & B- Single layer epidermis with hairs and endodermis; C- Vascular bundle; D- Single layer epidermis with epidermal hair.

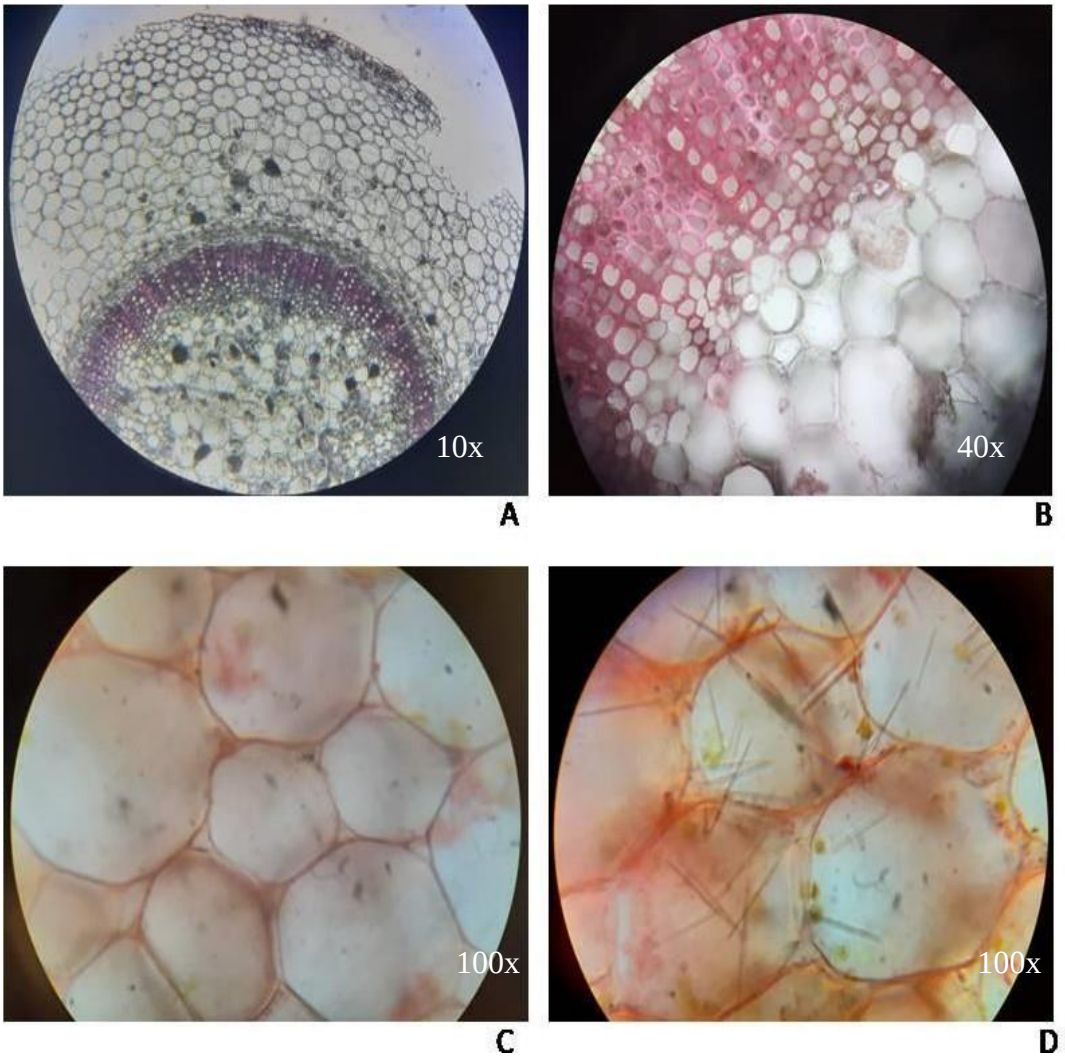

Plate 42 Stem anatomy of *O. rugosa* var. *prostata*. A- Single layer epidermis with parenchymatous cell; B- Vascular bundle showing xylem and phloem; C- Parenchymatous ground tissues; D- Needle like raphides inside the cell.

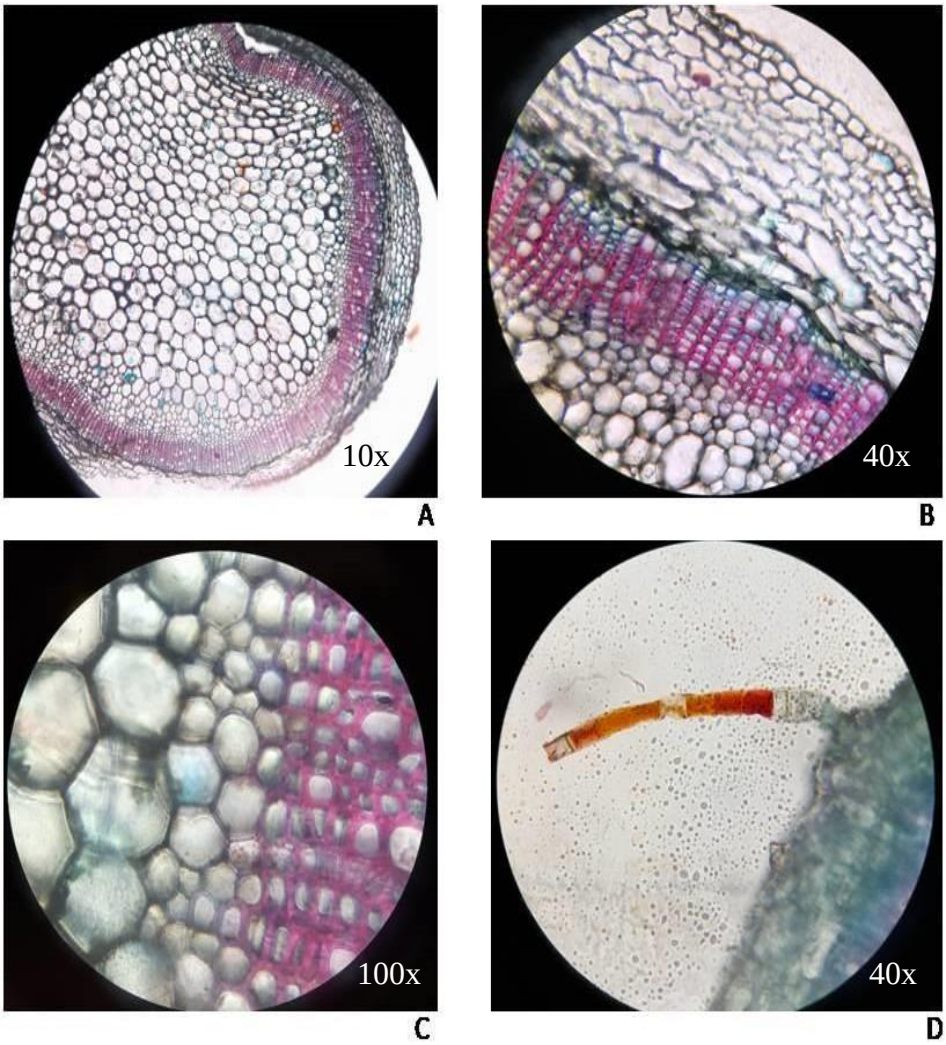

Plate 43 Stem anatomy of *O tingens*. A- Transverse section of stem with parenchyma cell; B- Single layer epidermis with long elongated hypodermis; C- Vascular bundle with xylem and phloem; D: Epidermal hair.

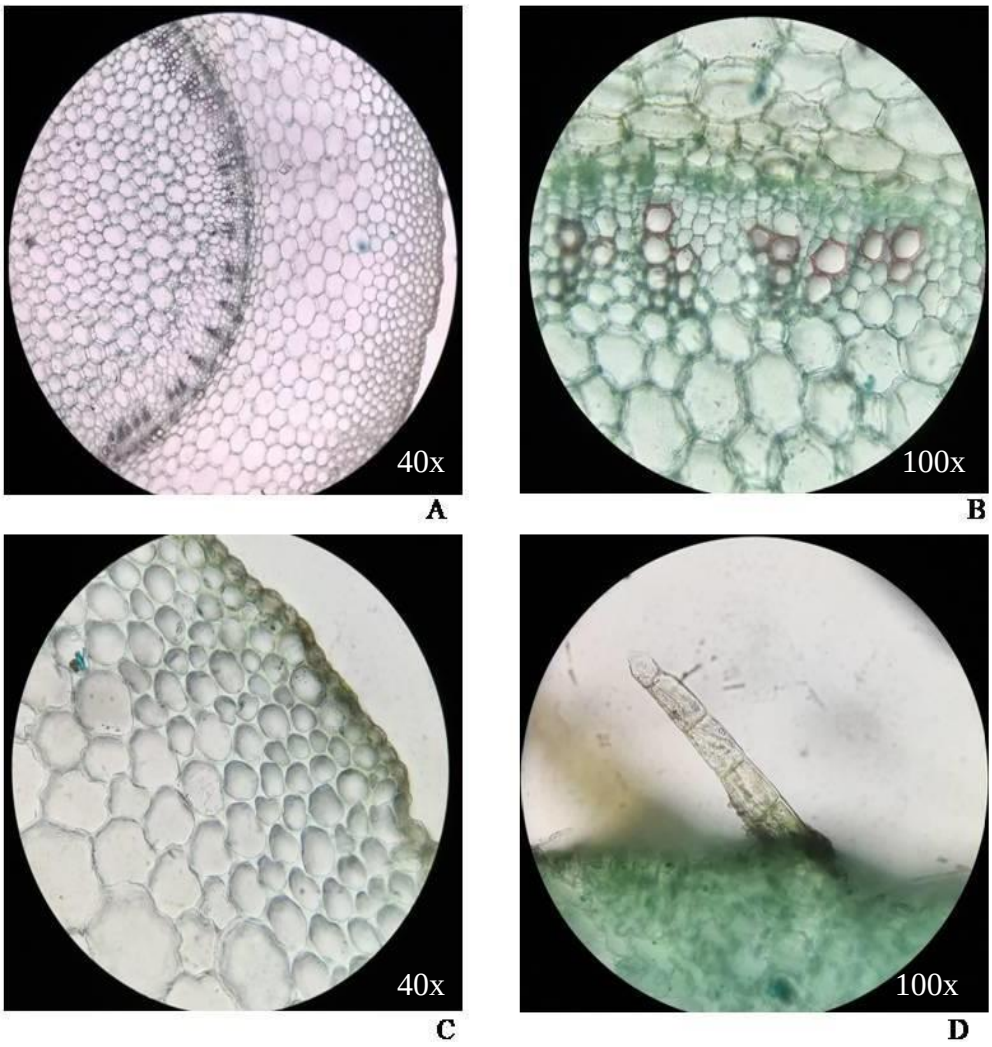

Plate 44 Stem anatomy of *O. hispida.* A- Transverse section of stem showing parenchyma cell; B- Vascular bundle showing xylem and phloem; C- Single layer of epidermis and loosely packed endodermis; D- Multicellular hair in epidermis.

4.5 ENM study

According to Nazeri *et al.* (2010), Polak & Saltz (2011), Adhikari *et al*. (2012), Environmental Niche Modelling or Habitat Distribution Modelling provide a new insight in the factors governing the distribution of species. Species reintroduction is one of the techniques for restoration of depleted species population and their degraded habitat. Environmental Niche Modelling can provide and helpful in introducing and identifying the areas for species reintroduction, restoration and can developed effective conservation measures for the rare and threatened species.

In the present study the model was worked on two rare and threatened members of the genus. For improving conservation status of the taxa, suitable habitat for reintroduction was predicted with the help of MaxEnt (Maximum Entropy distribution modelling algorithm). The results of the model were presented in a tabulated form (Table 4.7 & 4.8) and distribution maps were prepared for both species which shows the probable habitat or suitable areas for the reintroduction of the species (Fig 4 & 6).

4.5.1 Results

1. *Ophiorrhiza hispida* Hook.f., Fl. Brit. India [J. D. Hooker] 3(7): 83 (1880)

Calibration of models

The model calibration test for *O. hispida* results satisfactory. The training AUC results 0.98 and test AUC results 0.96. Among all the considered environmental variable, eu2_1_eur (February) and eu9_1_eur (September) most influential and significant contribute 42.9% and 37.4% to the habitat model. Environmental variable eu4_1_eur (April) with 13.2%, eu11_1_eur (November) with 4.5% also play important contribution to the Maxent model (Table 4.7). Considering the permutation importance eu9_1_eur (September) had the highest influence with 50.4% on the habitat model followed by eu2_1_eur, eu11_1_eur, eu4_1_eur collectively contribute with 35.2% to model.

The Jacknife analysis showed that eu9_1_eur, is the environmental variable with the highest gain when used in isolation and also has important information by itself. The variable that decreases the highest gain, when omitted is eu2_1_eur (Feb), so it appears to have the most informative and useful variable among all other variable.

1.2 Potential habitat distribution areas for reintroduction

In the primary field survey, the species was collected from forest foothill areas of Lakhimpur district of Assam. Suitable habitat for reintroduction of *O. hispida* in the highly predicted potential areas revealed the places in forest areas of Karbi Anglong, Dima Hasao, forest foothill of North Lakhimpur in Assam and foothills of Arunachal Pradesh and Bhutan shows much better places for reintroduction of the species. When overlaying the predicted potential habitat distributional map and species data onto Google Earth Pro, satellite imagery revealed areas characterized by optimal habitat suitability for the species' reintroduction, primarily within Tropical Wet Evergreen and Subtropical forests. The areas with moderate habitat suitability were tropical moist and dry deciduous forests.

Table 4.7 List of variable and their contribution used in the model for *O. hispida*

Variables	Description of the variable: (NDVI)	Percent contribution	Permutation importance
eu2_1_eur	NDVI February	42.9	18.9
eu9_1_eur	September	37.4	50.4
eu4_1_eur	April	13.2	7.9
eu11_1_eur	November	4.5	8.4
eu1_1_eur	January	0.7	0.8
eu12_1_eur	December	0.5	8
eu7_1_eur	July	0.3	0
eu10_1_eur	October	0.3	3.7
eu5_1_eur	May	0.2	1.8
eu6_1_eur	June	0	0
eu3_1_eur	March	0	0
eu8_1_eur	August	0	0

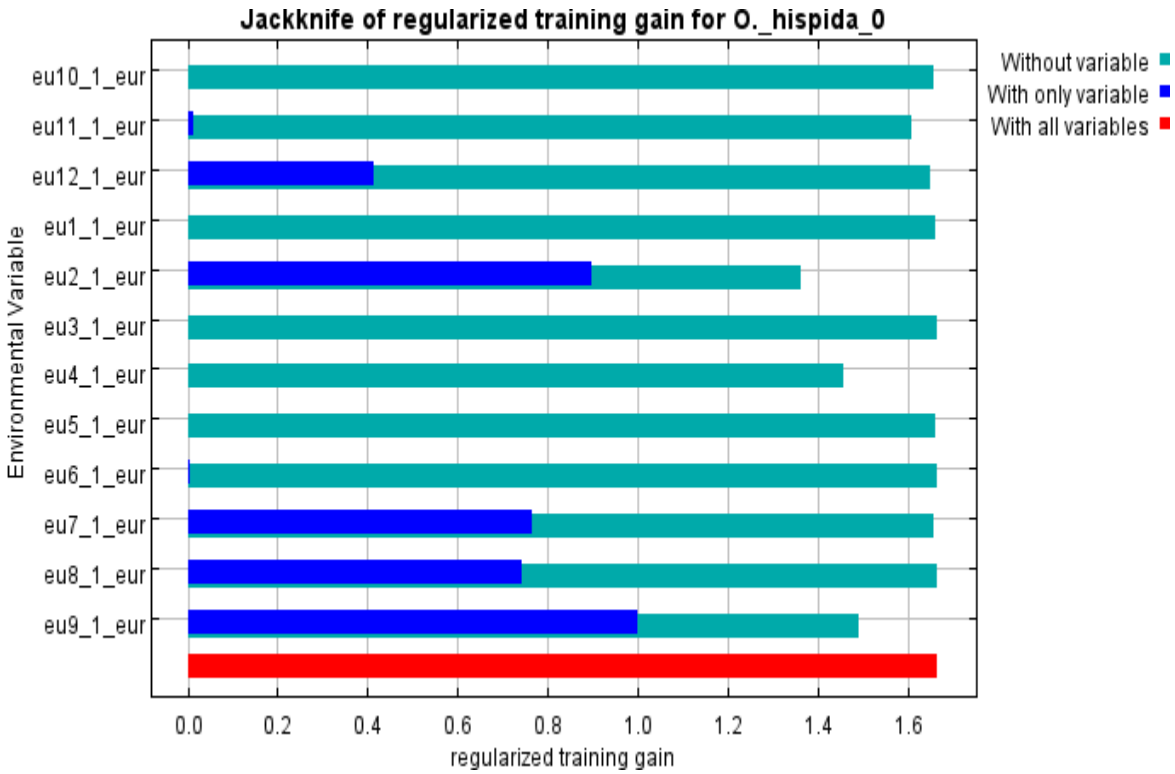

Fig 13 Result of Jackknife for *O. hispida*.

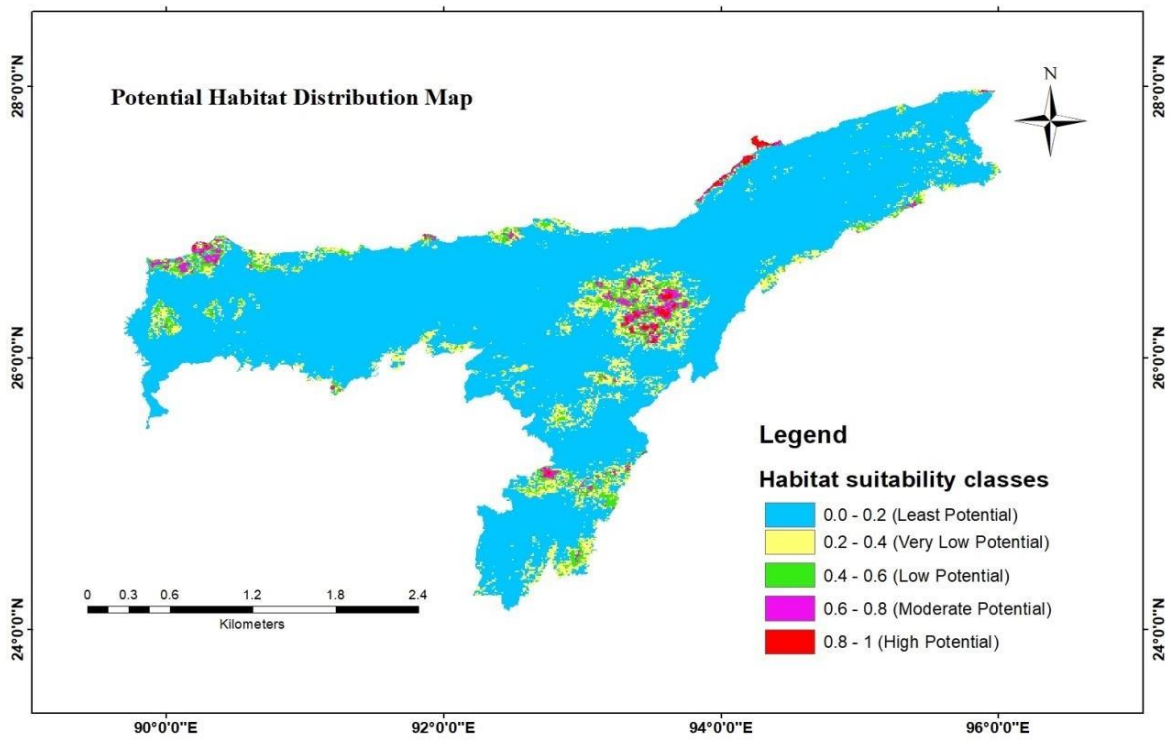

Fig 14 Potential habitat distribution map of *O. hispida*

2. *Ophiorrhiza tingens* C.B.Clarke ex C.E.C.Fisch., Bull. Misc. Inform. Kew 1940: 33 (1940)

Calibration of models

The model calibration test for *O. tingens* results satisfactory. The training AUC results 0.84 and test AUC results 0.63. Among all the considered environmental variable, eu11_1_eur (September) and eu5_1_eur (May) most influential and significant contribute 45.7% and 42.3% to the habitat model. Environmental variable eu8_1_eur with 7.9%, eu7_1_eur with 4.1% also play important contribution to the Maxent model. (Table 4.8). Considering the permutation importance eu11_1_eur had the highest influence with 94.2% on the habitat model followed by eu5_1_eur, eu8_1_eur, eu7_1_eur collectively contribute with 5.8% to model.

The Jacknife analysis showed that eu5_1_eur, is the environmental variable with the highest gain when used in isolation and also has important information by itself. The variable that decreases the highest gain, when omitted is eu2_1_eur, so it appears to have the most informative and useful variable among all other variable.

2.2 Potential habitat distribution areas for reintroduction

In the primary field survey, the species was collected from forest foothill areas of West Karbi Anglong of Assam. Suitable habitat for reintroduction of *O. tingens* in the highly predicted potential areas revealed the places in forest areas of Nagaon, Karbi Anglong, Dima Hasao, forest foothill of Meghalaya in Assam shows a much better places for reintroduction of the species.When the predicted potential habitat distributional map and data of the species superimposed on Google Earth Pro, satellite imageries showed that the areas exhibiting optimal habitat conditions for the reintroduction of the species were mostly in Tropical Wet evergreen and Subtropical forests. The areas with moderate habitat suitability were tropical moist and dry deciduous forests.

Table 4.8 List of variable and their contribution used in the model for *O. tingens*

Variables	Description of the variable (NDVI)	Percent contributon	Permutation importance
eu11_1_eur	November	45.7	94.2
eu5_1_eur	May	42.3	0.7
eu8_1_eur	August	7.9	2.8
eu7_1_eur	July	4.1	2.3
eu2_1_eur	February	0	0
eu1_1_eur	January	0	0
eu12_1_eur	December	0	0
eu9_1_eur	September	0	0
eu6_1_eur	June	0	0
eu4_1_eur	April	0	0
eu3_1_eur	March	0	0
eu10_1_eur	October	0	0

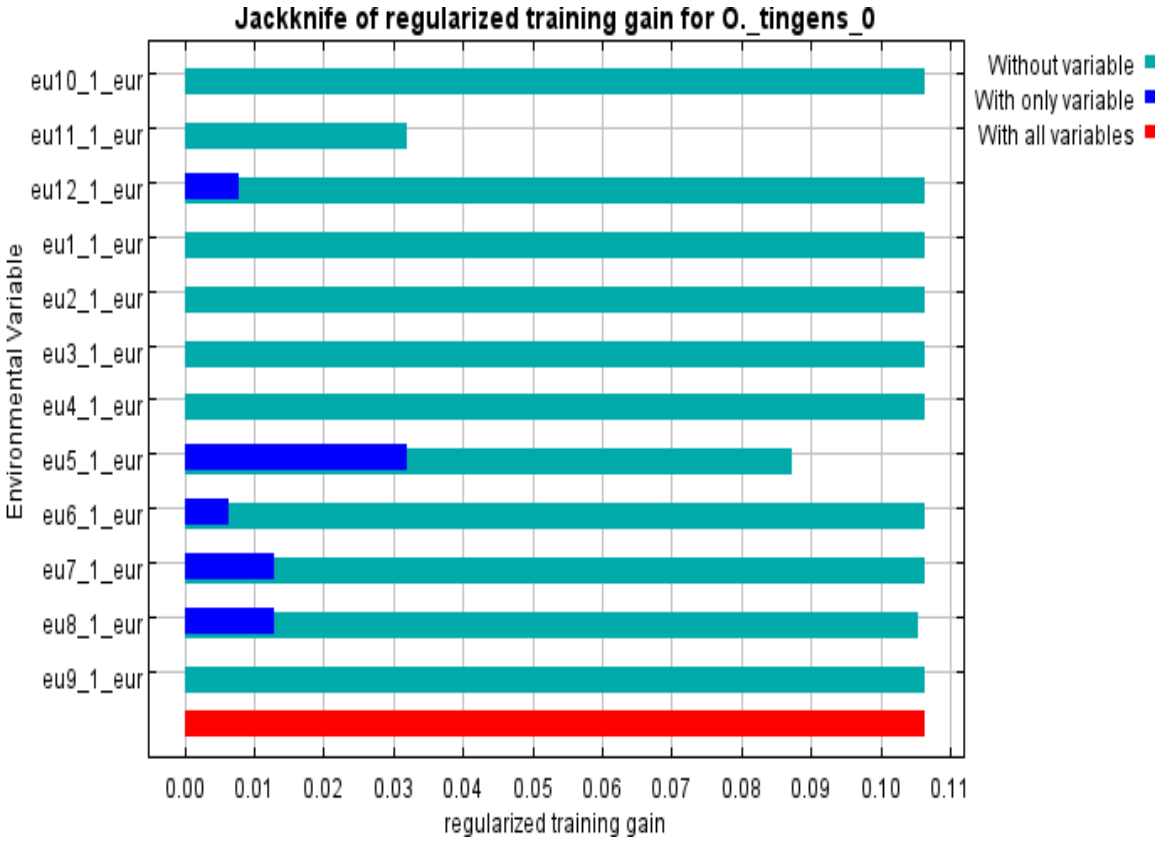

Fig 15 Result of Jackknife for *O. tingens*

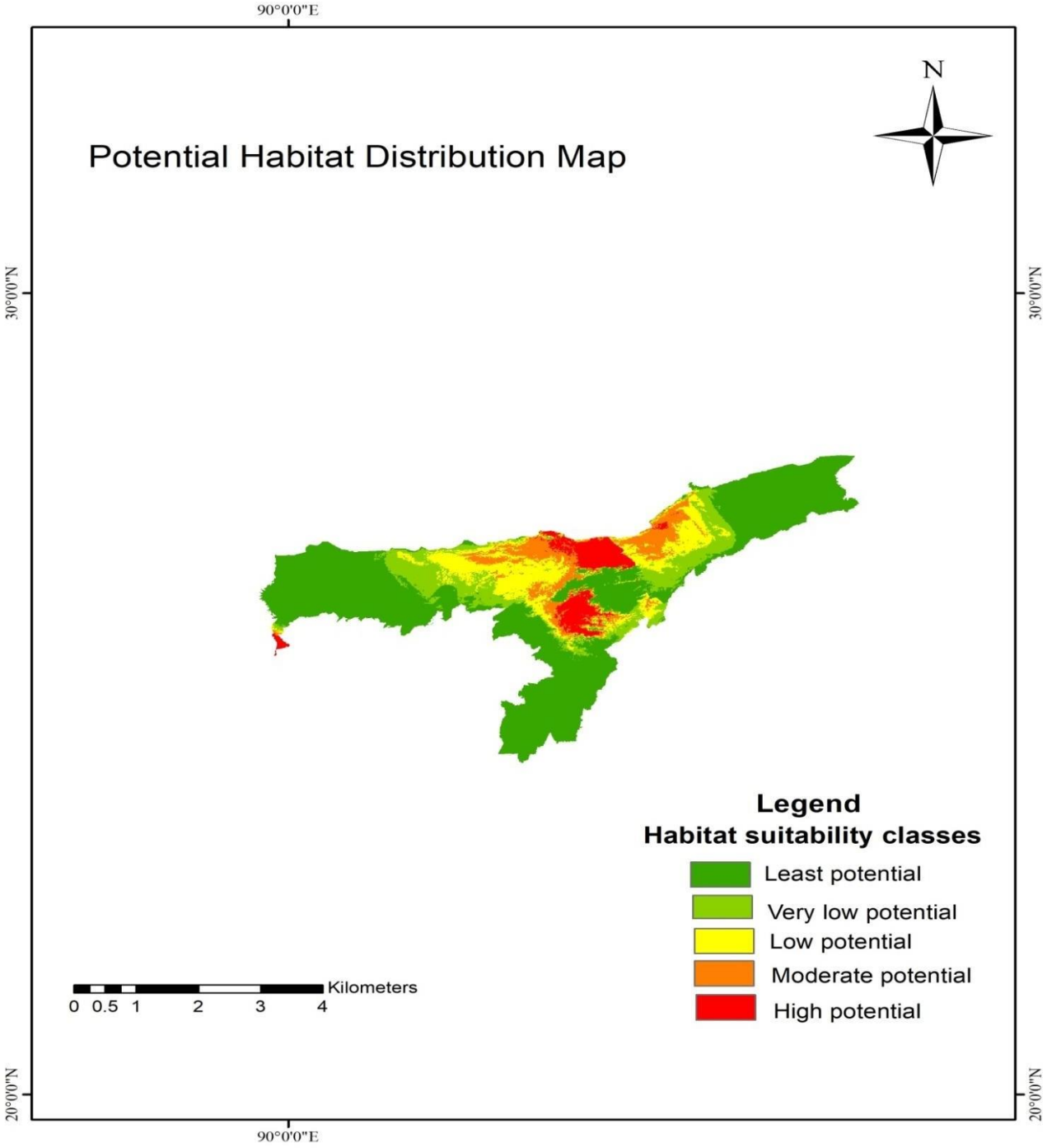

Fig 16 Potential habitat distribution map of *O.tingens*