



Gaultheria stapfiana (Ericaceae), a species to be recognized: insights from morphology, leaf anatomy and pollen morphology

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Abstract

This study, based on an investigation of morphology (as assessed through field and herbarium studies), leaf anatomy (stomata and vein islets), and pollen morphology (LM and SEM) reveals that *Gaultheria stapfiana* Airy Shaw is a distinct species and not a variant within of the *G. hookeri* C.B. Clarke as proposed by Ruizheng & P.F. Stevens (2005). Line drawings, photographs of living plants and specimens, photographs of leaf anatomical characters, and pollen of *G. stapfiana* and its allies, show that this species is clearly delimited from both *G. hookeri* and *G. fragrantissima* Wall.

Key words: *Gaultheria stapfiana*, *G. hookeri*, Ericaceae, exomorphology, leaf anatomy, pollen morphology

Introduction

Gaultheria stapfiana Airy Shaw (Fig. 1 & 4A–B) was described by Airy Shaw (1952) based on a specimen from Yunnan (China) collected by George Forrest in 1919 (*No.* 18021, K!). This species is similar to *G. fragrantissima* Wall. var. *racemosa* Hook.f. ex C.B. Clarke, which was treated as a heterotypic synonym of *G. stapfiana* by Airy Shaw (1952). *Gaultheria fragrantissima* var. *racemosa* was collected by J. D. Hooker (1849) from Darjeeling and described by C. B. Clarke (1882). Clarke rightly distinguished Hooker's specimen (K!) from var. *racemosa* mainly due to the presence of long racemes (10–12.7 cm long), narrow lanceolate leaves (110 × 12 mm), and median bracteoles. Hooker's specimen was also distinguished from *G. hookeri* C.B. Clarke by the presence of smaller bracts, sparsely pubescent branches, and a tall habit (not dwarf like *G. hookeri*).

Airy Shaw (1952) accepted *Gaultheria stapfiana* as a new species and distinguished it from its two close allies, *G. fragrantissima* (Fig. 3 & Fig. 4E–F) and *G. hookeri* (Fig. 2 & Fig. 4 C–D), on the basis of its sparsely pubescent branches, oblanceolate, obovate to oblong-elliptic lamina, bract that are longer than those of *G. fragrantissima* but shorter than those of *G. hookeri*, bracteoles median on the pedicel (as in *G. hookeri*) and arborescent habit (like *G. fragrantissima*, but not shrubby as in *G. hookeri*). Airy Shaw (1952) described several overlapping characters between *G. stapfiana* and *G. hookeri*, such as lamina size (4–14 × 1–4.5 cm), raceme length (2–5 cm), bract length (3–5 mm), bracteole position (median), corolla length (3–4 mm), nature of the stamens (1–2 mm long), ovary (globose, tomentose) and fruits (capsule enclosed in a fleshy bluish-purple calyx, ovoid). Based on the above overlapping characters, Ruizheng & P.F. Stevens (2005) treated *G. stapfiana* as a synonym of *G. hookeri* var. *hookeri* in *Flora of China*.

After Airy Shaw (1952), workers like Sealy (1973), Middleton (1991a; 1991b), Ruizheng & Stevens (2005), Panda (2008) and Panda et al. (2009) worked on *Gaultheria stapfiana*. As a result of revisionary work on Indian Ericaceae conducted as part of the Flora of India Project (1999–2004; which involved morphological investigations, see Table 1) as well as laboratory-based studies of leaf anatomy (i.e., leaf-stomata, Fig. 5, leaf areolar pattern, Fig. 6) and pollen morphology (Fig. 7) conducted from 2008–2010, evidence shows that *G. stapfiana* Airy Shaw is a good species and not a synonym of *G. hookeri*.

Materials and Methods

Exomorphology.—For this detailed study, flowers from living material and herbarium specimens (ASSAM, BSIS, CAL, DD, MH) were dissected and examined. The floral parts were pasted on white paper cards (8" × 5") using synthetic gum and measured. After considering the annotations of earlier workers and comparing them with the type specimens, protologues and with live materials, complete and detailed amplified descriptions of each of the three species discussed above were made (Table 1).

TABLE 1. Comparison of morphological characters among *G. stapfiana* Airy Shaw and the similar species *G. hookeri* C.B. Clarke and *G. fragrantissima* Wall. (Figs. 1–4)

Vegetative and reproductive morphological characters	<i>G. stapfiana</i>	<i>G. hookeri</i>	<i>G. fragrantissima</i>
1. Habit	0.3–2 m high.	0.3–1 m high.	0.5–2 (-3.5) m high.
2. Stem and branch texture Indumentum	Stem terete, blackish-brown, glabrous. Branches terete, light green, sparsely hispid-setose.	Stem terete, blackish-brown, sparsely setose. Branches terete, light green to pink, densely hispid-setose.	Stem terete, grey-brown to light green, glabrous. Branches winged, blood red, deep pink to rarely light green, glabrous, glaucous.
3. Abaxial leaf indumentum	Punctate.	Setulose and punctate.	Punctate.
4. Raceme length No. of flowers	2.5–11 cm long. 10–24 (-40)-flowered.	1.5–5 cm long. 10–15-flowered.	2.5–11 cm long. 10–20 (-40)-flowered.
5. length of flower	5–11 mm long.	7–15 mm long.	8–15 mm long.
6. Bract	3–5 × 1.5–2.5 mm.	5–7 × 3–4.5 mm.	2–4 × 1.5–2.5 mm.
6. Position of bracteoles on pedicel	Median.	Subbasal to median.	Apical to subapical.
7. Stamen length Anther awns	1–2 mm long. Filaments grey-white. Each lobe of anther with 2 unequal awns to rarely equal. Awn minute.	2–3 mm long. Filaments pinkish. Each lobe of anther with 2 equal awns. Awn up to 1 mm long.	3 mm long. Filaments grey-white. Each lobe of anther with 2 equal awns Awn 0.5–1 mm long.

Stomatal slide preparation.—Small square pieces of leaf blades (ca. 1 sq cm) were excised from the base, middle and apex (10 leaf samples from different natural habitats were taken). Slides were prepared using 10% HNO₃-boiling for 10 minutes and a 5% KOH overnight (12–24 hours) treatment with and without boiling. Pieces were rinsed in sterilized water until clear. After clearing, the pieces were dehydrated in an ethanol series followed by staining with 10% safranin and mounted onto a microscope slide in DPX (with pieces from the basal, middle and apical regions on one slide). The slide was examined under an Olympus (Tokyo, Japan) light microscope using 10× and 40× objectives and Camera Lucida drawings were made. The slides were deposited in the laboratory of Taxonomy & Biosystematics, PG., Department of Botany, Barasat Govt. College (Calcutta University). The descriptive terminology follows Metcalfe and Chalk (1950), Dilcher (1974), Stace (1965, 1989), Fahn (1997), Carpenter (2005), and Judd et al. (2008).

Methodology of leaf clearing for venation study (areoles).—Entire mature leaves (10 leaf samples from different natural habitats were taken) were immersed in 2.5% NaOH solution until clear (closed condition). In the present study, most of the leaves were cleared after 11–14 days of NaOH treatment. After 14 days, these NaOH-treated leaf samples were again immersed in 2.5% NaOH solution for 2–3 days followed by 1 drop

chloral hydrate treatment overnight. Leaf samples were then washed in distilled water. After clearing, an entire leaf was dehydrated in an ethanol series followed by staining with 1% safranin and mounted onto microscope slide in DPX (with entire leaf on a single slide). The slides were deposited in the laboratory of Taxonomy & Biosystematics, PG. Department of Botany, Barasat Govt. College (Calcutta University). The descriptive terminology follows Hickey (1973) and Dilcher (1974).

Preparation of pollen slides.—The method used in this study followed Erdtman (1952, 1969, 1986) and Sarwar et al. (2006). The slides were deposited in the laboratory of Taxonomy & Biosystematics, PG Department of Botany, Barasat Govt. College (Calcutta University). Pollen morphological data were based on 15 flower buds from a single population of each species. In the present study, three different populations (Sikkim, Darjeeling and Arunachal Himalayas) were studied.

Slide preparation for SEM.—Acetolysed pollen grains were mounted on the metallic stub using double stick tape (flower buds from single voucher specimen). Observations were made with Hitachi S530 (SEM, Tokyo, Japan) in the high vacuum mode at an applied voltage of 15 KV (digital images).

Results

Gaultheria stapfiana is morphologically distinct from *G. hookeri* and *G. fragrantissima* in its sparsely hispid-setose branches and glabrous stems, *G. hookeri* having densely hispid-setose branches and setose stems. The branches of *G. fragrantissima* are glabrous, reddish, and winged. Additional differences are found in the morphology (Table 1), leaf-anatomy (Table 2), and pollen morphology (Table 3) of the three species. Stems,

TABLE 2. Comparison of Leaf anatomical characters among *G. stapfiana* Airy Shaw and its two close allies i.e. *G. hookeri* C.B. Clarke and *G. fragrantissima* Wall. (Figs. 5–6).

Leaf anatomical characters	<i>G. stapfiana</i>	<i>G. hookeri</i>	<i>G. fragrantissima</i>
Leaf-stomata	Types: Para and amphiparacytic. Average dimension: 22.7(–32) × 21.3(–28) µm.	Types: Para and pericytic. Average dimension: 30 × 26 µm.	Type: only Paracytic. Average dimension: 25.5(18–33) × 22(16–28) µm.
Epidermal cells	Epidermal cells: polygonal. Epidermal walls in surface view: arched	Epidermal cells: polygonal. Epidermal walls in surface view: straight	Epidermal cells: Hexa- to polygonal. Epidermal walls in surface view: straight and sinuous.
Stomatal Index (SI)	15.05. average number of stomata is 28 per 158 epidermal cells per microscopic field.	26.2 average number of stomata is 32 per 90 epidermal cells per microscopic field.	15.0. average number of stomata is 36 per 204 epidermal cells per microscopic field.
Leaf venation Shape of areole: Average numbers of vein islets (areoles) per sq. mm: Vein endings: Vein ends:	Quadrangular to pentagonal. Larger areole (average): 998 × 353 µm. Smaller areole (average): 294 × 176 µm. 6 per 1 sq. mm. 48 (average) per 1 sq. mm, tapered to bluntly acute, ends not divided.	Quadrangular. Larger areole (average): 823 × 306 µm. Smaller areole (average): 270 × 317 µm. 5 per 1 sq. mm. 45 (average) per 1 sq. mm, tapered, acute to rarely bulbous, ends not divided.	Tri-, Qua- to pentagonal. Larger areole (average): 1200 × 470 µm. Smaller areole (average): 411 × 188 µm. 8 per 1 sq. mm. 102 (average) per 1 sq. mm, tapered, acute to bulbous, ends lobed or divided.

TABLE 3. Comparison of pollen morphological characters among *G. stapfiana* Airy Shaw and its two close allies i.e. *G. hookeri* C.B. Clarke and *G. fragrantissima* Wall. (Fig. 7).

Pollen morphological characters	<i>G. stapfiana</i>	<i>G. hookeri</i>	<i>G. fragrantissima</i>
Tetrads	Tetrahedral	Tetrahedral	Tetrahedral
Tetrad size (D)	25–28 µm diameter	32–34 µm diameter	32–36 µm diameter
P/E × 100	85.7 (sub-oblate)	79.4 (sub-oblate)	87.4 (sub-oblate)
Individual grain (d)	19.2–21.5 µm diameter	22–24 µm diameter	12.6–20.8 µm diameter
‘d’ with/without furrows	‘d’ possesses distinct transverse furrows.	‘d’ possesses distinct transverse furrows.	‘d’ does not possess distinct furrows.
Exine	1.9–5.2 µm thick surface: rugulate-psilate	1.9–3.2 µm thick surface: faintly striate	2–2.8 µm thick surface: faintly striate
D/d	1.30	1.43	2.03
Colpi	10–14 µm long	5.8–8.8 µm long	8.9–10.2 µm long
2f/D (Ratio of colpus length (2f) to tetrad diameter (D))	0.37–0.52 µm	0.17–0.26 µm	0.26–0.3 µm
Septum thickness	1.6–3.8 µm	1.6–3.8 µm	1.2–2.8 µm

bracts and bracteoles, corolla and stamens basically appear to be similar in most herbarium specimens of *G. stapfiana* and *G. hookeri* due to the range of variation that exists in *G. stapfiana*, e.g., *G. hookeri* has densely hispid-setose branches, 10–15-flowered short and congested racemes up to 5 cm long, and comparatively large bracts (5–7 mm long) and stamens (2–3 mm long), while plants of *G. stapfiana* show sparsely hispid-setose branches, 10–40-flowered long racemes up to 11 cm long, and comparatively shorter bracts (3–5 mm long) and stamens (1–2 mm long). Pollen (tetrad and individual grain dimensions, colpi length and exine surface), and leaf anatomy (stomatal dimension) also show consistent differences between these two species.

Discussion

Gaultheria stapfiana Airy Shaw is recognized here as a distinct species due to presence of distinctive vegetative and reproductive morphological characters (i.e., the combination of sparsely hispid branches, racemes up to 11 cm long, bracts 3–5 mm long, and minute anther lobes with 2 unequal or equal awns), differences in leaf anatomy (smaller stomatal dimension, 22.7×21.3 µm, arched epidermal walls, 15.05 stomatal index, and bluntly acute vein ends), and the form of its pollen grains (smaller tetrads, 25–28 µm in diameter, rugulate-psilate exine surface and comparatively long colpi, 10–14 µm long) (Figs. 1–7).

Key to three species (for easy identification in the field and herbarium)

1. Twig always glabrous, often winged; bracteoles apical on pedicel; leaf vein ends lobed or divided 3. ***Gaultheria fragrantissima***
1. Twig always hispid-setose, never winged; bracteoles subbasal to median on the pedicel; leaf vein ends never divided..... 2
2. Twig sparsely hispid-setose; racemes up to 11 cm long; bract 3-5 mm long; anther lobes with minute awns; average dimension of leaf-stomata 22.7×21.3 µm, stomatal Index (SI) 15.05; exine surface of pollen tetrads rugulate-psilate 1. ***G. stapfiana***

2. Twigs densely hispid-setose; racemes up to 5 cm long; bract 5-7 mm long; anther lobes with ca. 1 mm long awns; average dimension of leaf-stomata $30 \times 26 \mu\text{m}$, stomatal Index (SI) 26.2; exine surface of pollen tetrads faintly striate 2. *G. hookeri*

1. *Gaultheria stapfiana* Airy Shaw (1952: 171). TYPE: CHINA. YUNNAN: Western flank of the Shweli-Salwin divide, $25^{\circ}40'N$, 9000 ft, June 1919, *G. Forrest 18021* (HOLOTYPE: K, photo!).

Gaultheria fragrantissima Wall. var. *racemosa* Hook.f. ex C.B. Clarke (1882: 458). TYPE: INDIA: Darjeeling, 1849, *J.D. Hooker s.n.* (HOLOTYPE: K, photo!). Figs. 1 & 4A–B.

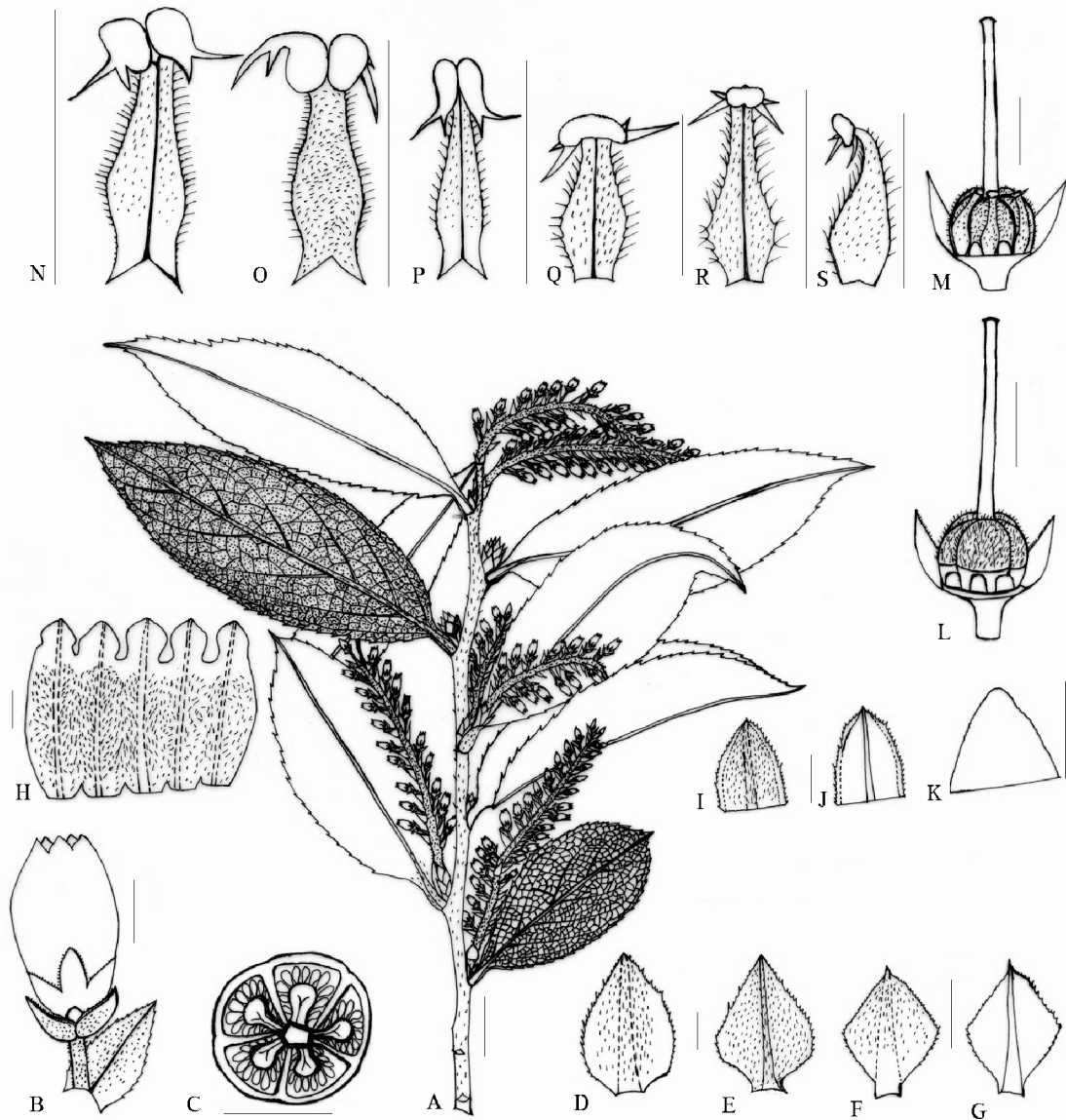


FIGURE 1. *Gaultheria stapfiana* Airy Shaw. A. habit; B. flower; C. ovary (t.s.); D–E. bracts; F–G. bracteoles; H. corolla (inside); I–J. calyx lobes; K. corolla lobe; L–M. pistils; N–S. stamens. — Scale bars: A = 1 cm; B = 2 mm; C, D, E, F, G, H, I, J, L, M = 1 mm; K = 0.5 mm; N–S = 1 mm (A–S: drawn from *S. Panda* 29906). Drawn by *S. Panda*.

Shrubs, stout, erect, dwarf, 0.3–2 m high, often hanging down from rock crevices. **Stem** terete, blackish-brown, profusely branched, glabrous; branchlets terete, light green, sparsely hispid-setose non-glandular multicellular hairs. Leaves alternate; petioles stout, 3–8 mm long, sparsely setulose non-glandular multicellular hairs up to 3 mm long; lamina oblong-obovate, oblanceolate, narrowly elliptic to obovate, 3–10 × 1–2.5 cm, serrulate at margin, narrowly cuneate at base, mucronate at apex, dark green, glabrous above, light green, punctate beneath; venation conspicuous brochidodromous with 4–5 pairs lateral veins. **Racemes** axillary, rarely pseudoterminal, perulate; rachis light green, 2.5–7(–11) cm long, 10–24-flowered, puberulous.

Flowers 6–11 mm long; pedicels 2.5–5 mm long, white puberulous to rarely glabrous; bract 1, basal, light green, ovate-elliptic to elliptic, 3–5 × 1.5–2.5 mm, ciliolate at margin, acute at apex, puberulous; bracteoles 2, opposite, light green with pinkish stripes, median on pedicel, ovate-elliptic to elliptic, 2–3 × 1–1.5 mm, ciliolate at margin, acute at apex, puberulous; calyx lobes light pink to white, ovate-triangular to elliptic, ca. 2 × 1.5 mm, ciliolate at margin, acute at apex, glabrous outside, puberulous inside; corolla globose to tubulourceolate, grayish-white, 4–5 × 2–3 mm, glabrous outside, pilose inside, minutely lobed; stamens 10, 1–2 mm long, loosely epipetalous with grayish-white filaments up to 1.5 mm long, slender, pilose or glabrous, dilated at base; anthers brown, oblong, up to 1 mm long, glabrous, each lobe with 2 unequal or equal warty apical awns; pistil 2.5–3.5 mm long; ovary globose, light green, ca. 1 mm long, ca. 1.5 mm diameter, sparsely to densely white tomentose, the placentation axile, the ovules numerous in each locule; nectar disc minutely 10-dentate; style light green, ca. 2.5 mm long, slender, glabrous; stigma truncate. **Capsule** loculicidally 5-valved, enclosed in a fleshy, bluish-purple accrescent calyx, ovoid, ca. 7 × 5 mm, with 2–4 mm long glabrous pedicel. **Seeds** numerous, minute, obconical, scariose.

Distribution.—India: Eastern Himalaya (Sikkim, West Bengal and Arunachal Pradesh); SC China and N Myanmar.

Habitat.—This is a rare species grown in discontinuous patches in moist humus-covered rocky slopes, rarely in loose humus-covered boulders, often hanging down from rock crevices in association with *Gaultheria hookeri*, *G. tetramera* and *G. semi-infera* at altitudes ranging from (1600–) 2200–3500 m.

Flowering.—May–June.

Fruiting.—July–September.

Vernacular name.—Sikkim: *Pochu* (Lepchas of Chhaten).

Specimens examined in India.—**Arunachal Pradesh**: Simbi Hotspring, Lohit district, 14 Sep 1994, Haridasan 7050 (APFH). **Sikkim**: East district: Zuluk, 28 Jul 1985, *D.C.S. Raju* 3999 (BSHC); North district: Zemu Valley, 9500 ft, 9 Jul 1909, *Smith & Cave* 1026 (CAL); Yumthang, 1901, *Dr. Prain's Collector* 365 (CAL); Lachen to Chhaten, 8000 ft, 8 May 2001, *S. Panda* 29911 (CAL); Yangdin, Lachen to Thangu, 10000 ft, 31 May 2002, *S. Panda* 29975 (CAL); between Chhaten & Lachen, 2550 m, 7 Jun 1999, *D. Maity* 21304 (BSHC); without precise locality, 7000 ft, *J.D. Hooker s.n.*, acc. no. 265849 (CAL). **West Bengal (Darjeeling)**: near Sonatek, 5000 ft, Jul 1906, *G.H. Cave s.n.*, acc. no. 6630 (Lloyd Bot. Garden Herbarium, Darjeeling); Tonglu, 9000 ft, 6 Dec 1924, *G.H. Cave s.n.* (CAL); Jalapahar, 7500 ft, 16 Dec 1910, *G.H. Cave* 4865 (CAL).

2. *Gaultheria hookeri* C.B. Clarke (1882: 458). TYPE: INDIA. SIKKIM: Lachen, 10000 ft, 3.6.1849, *J. D. Hooker s.n.* (top “in flowers”)(HOLOTYPE: K, photo!).

G. hookeri var. *angustifolia* C.B. Clarke (1882: 458). TYPE: INDIA. SIKKIM: YakLa, 9000 ft, 10.05.1876, *C. B. Clarke* 27837A (HOLOTYPE: K!; ISOTYPE: CAL!).

G. veitchiana Craib (1912: 188). TYPE: W CHINA. 6000–10000 ft, May, 1904, *E. H. Wilson* 3916 (HOLOTYPE: K, photo!). Figs. 2 & 4C–D.

Shrubs, stout, erect, bushy dwarf, 0.3–1 m high, often hanging down from rock crevices. **Stem** terete, blackish-brown, profusely branched, sparsely setose; branchlets terete, light green to pink, densely hispid-setose. Leaves alternate; petioles stout, 3–6 mm long, glabrous or punctuate; lamina oblong-elliptic, oblong to rarely oblanceolate or obovate, 2.5–5.5 (– 7.5) × 1.5–3 cm, serrulate-ciliate at margin, cilia deciduous and up to 2 mm long, broadly cuneate at base, mucronate at apex, dark green above, light green, setulose and punctate beneath, venation conspicuous brochidodromous with 4–5 pairs lateral veins. **Racemes** axillary to rarely pseudoterminal, perulate; rachis light green, (1.5 –) 2–5 cm long, 10–15-flowered, densely white puberulous. **Flowers** 7–14 mm long; pedicels greyish-white, (2 –) 4–7 mm long, white puberulous to rarely glabrous; bract 1, basal, light green with pinkish stripes, broadly ovate or ovate-elliptic to rarely lanceolate, 5–7 × 3–4.5 mm, ciliolate at margin, acute to rarely acuminate at apex, sparsely puberulous or glabrous; bracteoles 2, opposite, subbasal or median on pedicel, greyish-white with pinkish stripes, broadly ovate or elliptic to

ovate-triangular, 2–3.5 × 1–1.5 mm, ciliolate at margin, acuminate to acute at apex, glabrous; calyx lobes greyish-white to light pink, ovate-triangular or elliptic to rarely ovate-oblong, *c.* 2 × 1.5 mm, ciliolate at margin, acuminate at apex, glabrous to pilose inside; corolla ovoid-urceolate, globose-urceolate to tubular-urceolate, greyish-white to light pink, 5–7 × 2–4.5 mm, glabrous outside, pilose inside, lobes minute; stamens 10, 2–3 mm long, loosely epipetalous; filaments pinkish, 1–2 mm long, slender, papillose, pilose to glabrous, dilated at base; anthers orange brown, oblong, *c.* 1 mm long, glabrous, each lobe with 2 equal minute warty apical awns of 0.5–1 mm long; pistil 2.5–4.5 mm long; ovary globose to subglobose, light green, (0.5–) 1–2 × 1–2 mm, tomentose, ovules numerous on axile placenta in each locule; disc dark green, minutely 10-oblong-dentate; style pinkish, 2–3 mm long, slender, glabrous; stigma truncate-axillary, rarely pseudoterminal, perulate; rachis light green, 2.5–7(–11) cm long, 10–24-flowered, puberulous. **Capsule** loculicidally 5-valved, enclosed in a fleshy accrescent calyx, globose to subglobose, sky blue, 9–11 × 9 mm including *c.* 2 mm long persistent style with *c.* 5 mm long glabrous pedicel, tomentose. **Seeds** numerous, minute, obconical, scariose.

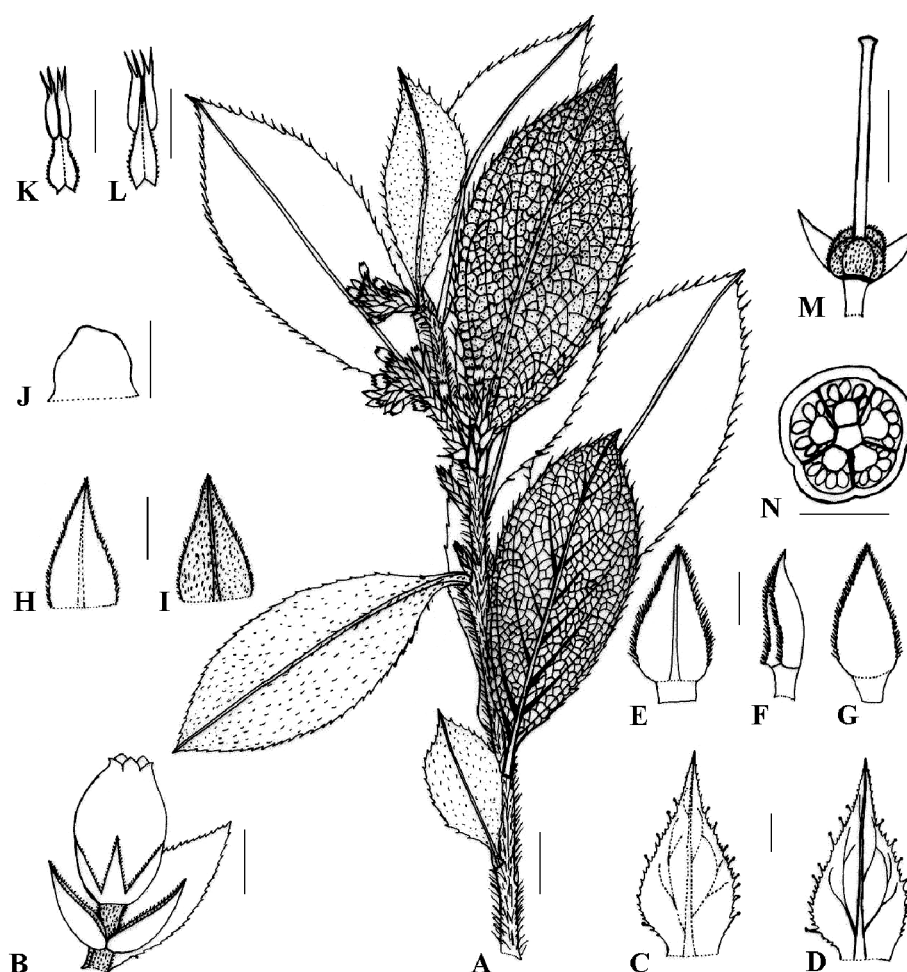


FIGURE 2. *Gaultheria hookeri* C.B. Clarke. A. habit; B. flower; C–D. bracts; E–G. bracteoles; H–I. calyx lobes; J. corolla lobe; K–L. stamens; M. pistil; N. ovary (t. s.). — Scale bars: A = 1 cm; B = 2 mm; C–I, K–N = 1 mm; J = 0.5 mm (A–N: drawn from *S. Panda* 30872, CAL). Drawn by S. Panda.

Distribution.—India: Eastern Himalaya (Sikkim, West Bengal and Arunachal Pradesh) and NE India (Nagaland), E Nepal, Bhutan, SW China and N Myanmar.

Habitat.—This is a rare species grown in discontinuous patches in moist humus-covered rocky slopes and in loose humus-covered boulders, often hanging down from rock crevices in association with other ericaceous species viz. *Gaultheria nummularioides*, *G. tetramera*, *G. stapfiana*, *G. semi-infera*, *Pieris formosa*, *Vaccinium nummularia*, *Rhododendron barbatum* and *R. cinnabarinum* at altitudes ranging from 2400–3600 m.

Flowering.—April–June.

Fruiting.—June–August.

Vernacular name.—Sikkim: *Kalum*, *Kalumba* (Bhutias of Lachen).

Specimens examined in India.—**Nagaland**: Saramati ridge, Tuensang district, 2800 m, 2.4.2003, *S. Panda* 30872 (CAL); Kohima district, Japhu Hill, 9900 ft, 25.10.1885, *C. B. Clarke* 41339 (ASSAM). **Sikkim**: East district, Yak La, 10000 ft, 10.05.1876, *C. B. Clarke* 27850 (CAL); North district, Lachen, 9000 ft, May, 1885, *Dr. King's Collector s.n.*, acc. no. 265793 (CAL); Tangkar Mt., 11500 ft, 01.08.1892, *G. A. Gammie* 480 (CAL); On the bank of Lachung Chhu River, 8000 ft, 01.05.2001, *S. Panda* 30057 (CAL); Lachung to Yumthang, 10000 ft, 02.05.2001, *S. Panda* 30061 (CAL); Yumthang to Lachung, 11000 ft, 02.05.2001, *S. Panda* 30063 (CAL); Lachen to Thangu, 9000 m, 07.05.2001, *S. Panda* 29903 (CAL); Yumthang to Lachung, 26.05.1986, *S. K. Rai & S. Pradhan* 5571 (BSHC); West district, Tsoka to Dzungri, 11000 ft, 14.05.2002, *S. Panda* 29941 (CAL). **West Bengal (Darjeeling)**: Above Dali, near Darjeeling town, 2150 m, 16.11.1980, *A. P. Das* 309 (North Bengal University Herbarium, Siliguri).

3. *Gaultheria fragrantissima* Wall. (1820: 397). TYPE: NEPAL. 1818, *Wallich s.n.* (HOLOTYPE: K, photo!).

Arbutus laurifolia Buch.-Ham. ex D. Don (1825: 151). TYPE: NEPAL. NARAINHETTY: March 10, 1803, *Buchanan-Hamilton s.n.* (HOLOTYPE: BM, *n.v.*).

Gaultheria ovalifolia Wall. (1829: 1523). TYPE: INDIA. TAMILNADU: Nilgiri hills (“Neilgherry”), October 14, 1825, *Noton* in Wall. list no. 1523 (HOLOTYPE: CAL!).

G. leschenaultii DC. (1839: 593). TYPE: INDIA. TAMILNADU: Nilgiri hills, *Leschenault s.n.* (HOLOTYPE: P, *n.v.*).

Leucothoe katagherensis DC. (1839: 606). *Andromeda katagherensis* (DC.) Hook. (1840: 246). TYPE: INDIA. TAMILNADU: Nilgiri hills, Kotagiri, *L. B. E. Schmid s.n.* (HOLOTYPE: W, *n.v.*).

Gaultheria forrestii Diels (1912: 210). TYPE: CHINA. SE XIZANG: Tali range, 25° 40' N, 10000–12000 ft, July, 1906, *G. Forrest* 4183 (HOLOTYPE: K, photo!). Figs. 3 & 4E–F.

Shrubs to treelets, stout, erect, 0.5–3.5 m high, often hanging down from rock crevices. **Stem** terete, grey-brown, light green to light brown, profusely branched, glabrous; branchlets winged to triangular, blood red to dark pink to rarely light green, glabrous, glaucous. Leaves alternate; petioles stout, 4–12 mm long, glabrous or punctate beneath; lamina ovate-elliptic, oblong-elliptic, ovate-lanceolate to rarely ovate or obovate, 4–10 (–14) × 1.8–4 (–8) cm, serrate to serrulate at margin, broadly cuneate at base, mucronate at apex, deep green, glabrous above, light green, punctate beneath; venation conspicuous brochidodromous with 3–5 pairs lateral veins. **Racemes** axillary, rachis 2.5–8 (–11) cm long, 10–20-flowered, puberulous. **Flowers** 8–14 mm long; pedicels greyish-white, 2–8 mm long, puberulous; bract 1, basal, light green, broadly ovate, 2–4 × 1.5–2.5 mm long, ciliate at margin, acute or subacute at apex, glabrous; bracteoles 2, opposite, apical or subapical on pedicel, pink with greenish stripes, broadly ovate, 1.5–2.5 × 1–2 mm, ciliolate at margin, acute at apex, puberulous; calyx lobes light pink, ovate-triangular, 2–2.5 × 1–1.5 mm, ciliolate at margin, acute at apex, puberulous inside; corolla ovoid-urceolate, greyish-white to light greenish-white, *c.* 5 mm long, 3–4 mm across, glabrous outside, pilose inside, lobes minute, *c.* 0.5 × 1 mm; stamens 10, *c.* 3 mm long, loosely epipetalous; filaments greyish-white, *c.* 1 mm long, papillose, pilose, basally dilated; anther lobes blackish-brown, oblong, *c.* 1 mm long, glabrous, each lobe with 2 apical awns of *c.* 1 mm long or minute. Pistil 2–3.5 mm long; ovary globose to subglobose, light green, 1–1.5 × 1.5–2 mm, tomentose, ovules numerous on axile placenta in each locule; disc minutely 10-dentate; style light green, 1–2 mm long, slender, glabrous; stigma truncate. **Capsule** loculicidally 5-valved, enclosed in a fleshy accrescent calyx, light green (immature) to deep blue or sky blue (mature), globose to subglobose, 5–8 × 3–6 mm including 2–4 mm long pedicel, pubescent. **Seeds** numerous, minute, obconical, scarious.

Distribution.—India: Eastern Himalaya (Sikkim, West Bengal and Arunachal Pradesh), NE States (Meghalaya, Nagaland and Manipur) and Hill-tops of SW Ghats (Tamil Nadu, Kerala and Karnataka); E Nepal, Bhutan, SC China, N Myanmar, Sri Lanka, N Vietnam and Malesia.

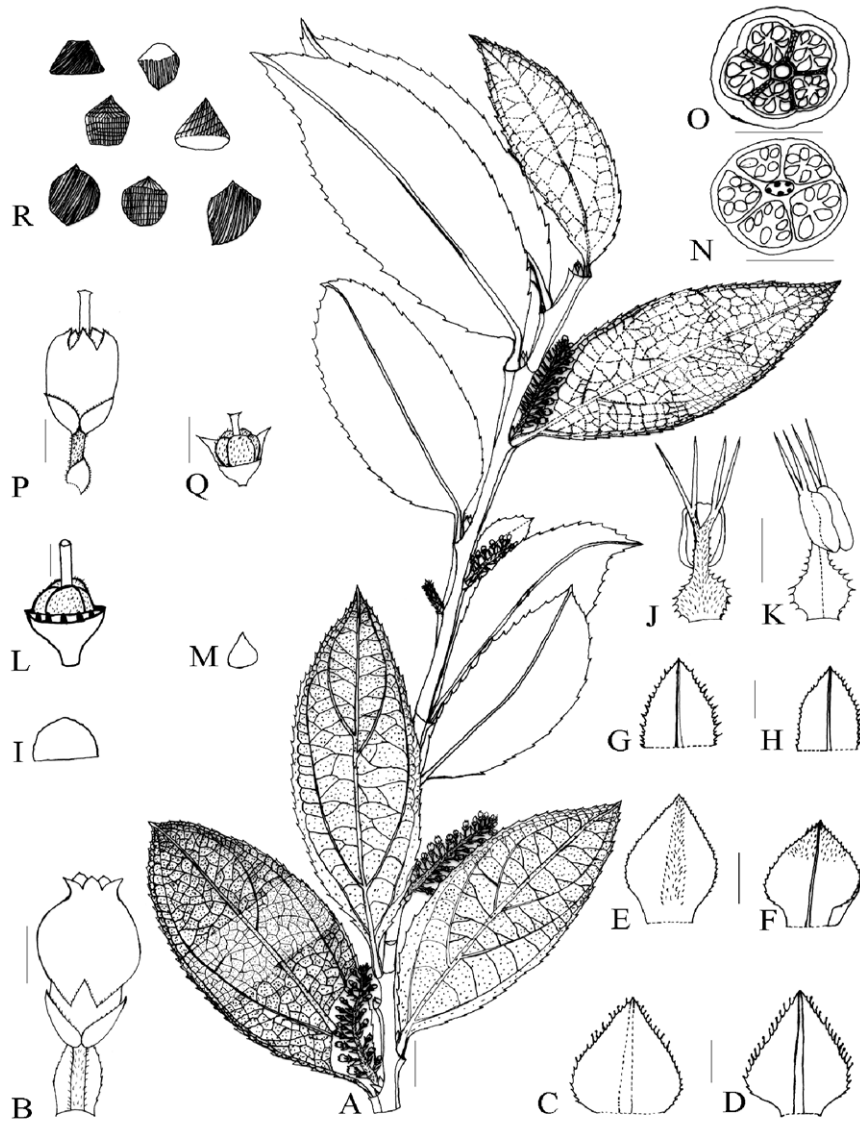


FIGURE 3. *Gaultheria fragrantissima* Wall. A. habit; B. flower; C–D. bracts; E–F. bracteoles; G–H. calyx lobes; I. corolla lobe; J–K. stamens; L. pistil; M. ovule; N–O. ovary (t. s.); P–Q. fruits; R. seeds. — Scale bars: A = 1 cm; B, P = 2 mm; C–H, J–L, N, O = 1 mm; Q = 5 mm (A–R: drawn from S. Panda 30701).

Habitat.—This species grows gregariously in moist rocky soil, often hanging down from rock crevices, rarely in loose humus-covered boulders or in landslide areas in association with other ericaceous species viz. *Gaultheria nummularioides*, *Lyonia ovalifolia*, *Leucothoe griffithiana*, *V. dunalianum*, *Rhododendron formosum* and *R. virgatum* at altitudes ranging from (1350–) 1600–2300 (2700) m.

Flowering.—March–May; December–January.

Fruiting.—May–October.

Vernacular name.—Sikkim: *Kaloma* (Tibetans of East district), *Jathyroid* (Sherpas), *Machino*, *Dhasingare* (Nepalese of Yuksum), *Goenhli* (Nepalese of Hilley), *Kalomba* (Lepchas of Lachung). West Bengal: *Chanchhewaa* (Tamang Nepalese of Darjeeling). Arunachal Pradesh: *Shep-Sheng* (Moplas of Tawang). Meghalaya: *Jirhapkynthai*, *Jirhap*, *Soh-lyngthrait*, *Dieng-la-sirhap*, *Jirhapiong* (Khasis of Shillong), *Lathynrait* (Khasis of Jongsha Village). Tamil Nadu: *Kolakkaai*, *Moolai* (Tamilise of Nilgiri hills).

Specimens examined in India.—**Arunachal Pradesh:** Dibang Valley district, Myodia to Tewarigaon, 17.11.2000, D. K. Singh & Party 97502 (BSD); Lohit district, Walong to Helmet top, 1450 m, 28.04.2003, S.

Panda 30886 (CAL); Lower Subansiri district, Pange to Talle Valley, 2500–2800 m, 31.12.2002, *S. Panda* 3084 (CAL); Tawang district, Moukto, 7000 ft, August, 2001, *B. Balodi* 10238 (ARUN); West Kameng district, Rupa to Jabrang, 23.05.1958, *G. Panigrahi* 16046 (ASSAM). **Kerala:** Sispara to Palghat, Palakkad district, 2000 m, 28.03.1983, *N. C. Nair* 77213 (CAL); Devicolam, Idduki district, 6000 ft, December, 1909, *A. Meebold* 13337 (CAL). **Meghalaya:** East Khasi Hill district, Shillong Peak, 5000 ft, 13.03.1970, *R. P. Patil* 21011 (ASSAM); Shillong Peak, 5500 ft, 08.03.1885, *C. B. Clarke* 37496 (CAL); Shillong Peak, 5000 ft, 17.03.2002, *S. Panda* 30703 (CAL). **Manipur:** Mao, Senapati district, 11.02.1958, *D. B. Deb* 1536 (CAL). **Nagaland:** Pegwima to Japhu Hill, 6000 ft, 19.05.1882, *G. Watt* 6873 (CAL). **Sikkim:** Yuksum to Bakhim, West district, 6000 ft, 12.05.2002, *S. Panda* 29928 (CAL); Phamtam, South district, 10.05.1991, *R. C. Srivastava* 13162 (BSHC). **Tamil Nadu:** Dindigul district, Bearshola, Kodaikanal, 2233 m, 10.03.1958, *K. Subramanyam* 5555 (CAL); Nilgiris district, Bison Camp, 7000 ft, 03.02.1911, *C. E. C. Fischer* 253 (CAL). **West Bengal (Darjeeling):** Sonada, 7000 ft, 19.05.1913, *G. H. Cave s.n.*, acc. no. 265787 (CAL).

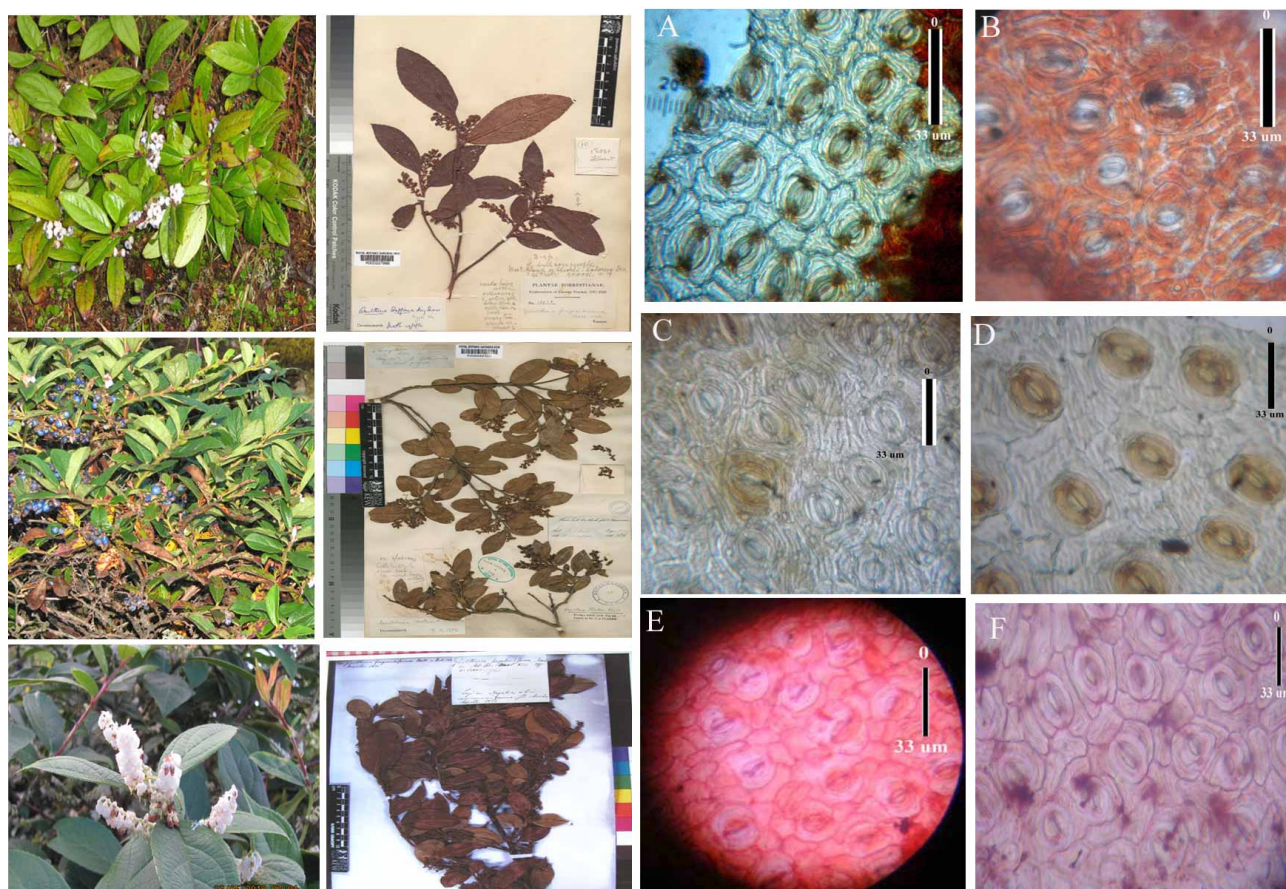


FIGURE 4. A–B. *Gaultheria stapfiana* Airy Shaw (A. live, B. cibachrome type photo); C–D. *G. hookeri* C.B. Clarke (live and cibachrome type photo); E–F. *G. fragrantissima* Wall (live and cibachrome type photo).

FIGURE 5. A–B. Stomatal complex of *Gaultheria stapfiana* (40X); C–D. Stomatal complex of *G. hookeri* (40X); E–F. Stomatal complex of *G. fragrantissima* (40X).

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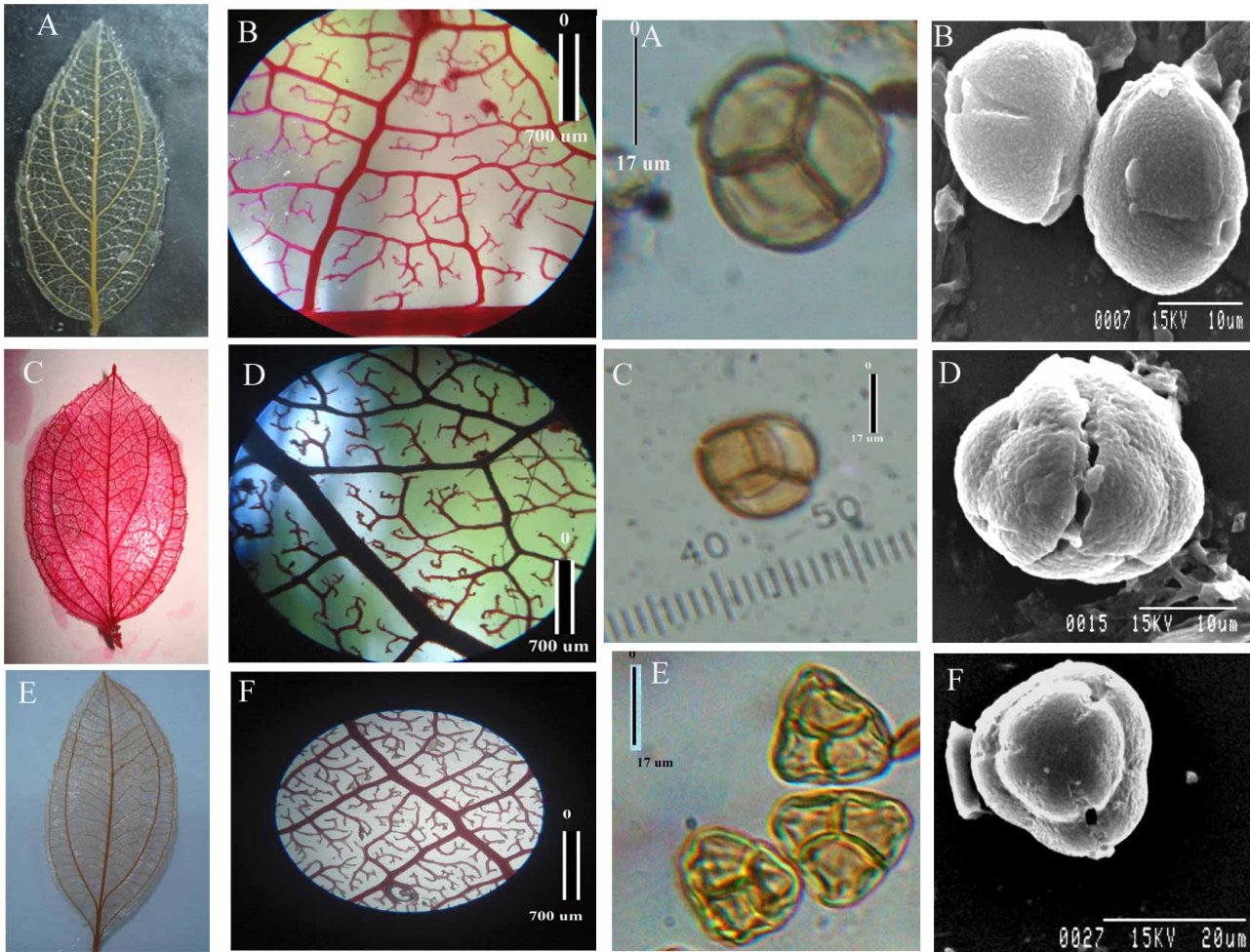


FIGURE 6. A–B. Leaf areolar pattern (vein-islets) of *Gaultheria stapfiana* (A. whole leaf, B. part in 10X); C–D. *G. hookeri* (A. whole leaf, B. part in 10X); E–F. *G. fragrantissima* (A. whole leaf, B. part in 10X).

FIGURE 7. A–B. Pollen morphology of *Gaultheria stapfiana* (A. LM in 40X, B. SEM); C–D. *G. hookeri* (A. LM in 40X, B. SEM); E–F. *G. fragrantissima* (A. LM in 40X, B. SEM).

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