

# *Udaria* – a new liverwort genus of Lophocoleaceae from Eastern Himalaya, India

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**A new genus and species of liverwort, *Udaria lamellicaulis* gen. & sp. nov., referable to the family Lophocoleaceae is described from Arunachal Pradesh and Sikkim in Eastern Himalaya, India. The new taxon can be easily differentiated from hitherto all the known genera of the family in the presence of longitudinal, 1–12 cells high seriatly arranged lamelliform strips on the surface of stem, leaves and female bracts, striolate–rugulose leaf cuticle, rhizoids arising from the lamina of underleaves, gynoecea with 1–2 subfloral innovations and gemmiparous female bracts and bracteoles.**

**Keywords:** Bryophytes, Eastern Himalaya, liverwort, Marchantiophyta, new genus and species, *Udaria lamellicaulis*.

THE East Himalayan bryogeographical region (EHBR) of India, as proposed by Pandé<sup>1</sup> and later partially modified by Singh<sup>2</sup> to include Sikkim (see also Singh *et al.*<sup>3</sup>), encompasses the ‘seven sister’ states of northeast (Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland and Tripura), Sikkim and the Himalayan West Bengal. Together, the region spreads across 265,328 sq. km covering about 8% of the total geographical area of the country. Physiographically, the region comprises the Eastern Himalaya, the Patkai hill ranges and the Brahmaputra and Barak valley plains, and is predominantly mountainous with altitudes ranging from less than 150 m to over 7000 m. Kanchenjunga (8586 m), situated at the border of Sikkim and Nepal, is the highest mountain peak in this region followed by several other peaks, like Jongson (7462 m), Kabru (7412 m), Kirat Chuli (7362 m), Talung (7348 m), Pauhunri (7128 m), Pathibhar (7123 m), Kangto (7060 m), Nyegi Kansang (7047 m), Shudu Tsenpa (7024 m), etc. in Sikkim and Arunachal Pradesh rising above 7000 m. EHBR falls under two global biodiversity ‘hotspots’, viz. the Himalaya and the Indo-Burma<sup>4</sup> and represents a gateway for the migration of Sino-Himalayan and Indo-Malayan floristic elements. The varied topography together with the characteristically high rainfall and humidity has resulted in an array of ecosystem diversity in this territory supporting almost all types of vegetation

and a rich and diverse flora. It is host to about half of the country’s angiosperms<sup>5</sup>, and is regarded as the ‘cradle of flowering plants’ because of incidence of a large number of primitive flowering plant species<sup>6</sup>. EHBR is exceptionally rich in liverwort and hornwort diversity, accounting for almost 75% of the taxa so far recorded from the country and about 9.3% that of the world, with five families (Balantiopsidaceae, Myliaceae, Pleuroziaceae, Ptilidiaceae and Treubiaceae), 21 genera (*Acrobolbus* Nees, *Anastrepta* (Lindb.) Schiffn., *Apotreubia* S. Hatt. & Mizut., *Dendrobazzania* R. M. Schust. & W. B. Schofield, *Diplocolea* Amakawa, *Hamatostrepta* Váňa & D. G. Long, *Horikawaella* S. Hatt. & Amakawa, *Isopaches* H. Buch., *Isotachis* Mitt., *Metahygrobiella* R. M. Schust., *Mylia* Gray, *Nardia* Gray, *Neolepidozia* Fulford & J. Taylor, *Nowellia* Mitt., *Odontoschisma* (Dumort.) Dumort., *Pleurozia* Dumort., *Prasanthus* Lindb., *Ptilidium* Nees, *Saccogynidium* Grolle, *Temnoma* Mitt. and *Xenochila* R. M. Schust.), and about 300 species confined to this region alone in Indian bryoflora<sup>3</sup>. Over 55% of endemic Indian liverworts and hornworts occur in this region<sup>3</sup>.

The family Lophocoleaceae currently includes 21 genera in the world, 10 of which are monotypic<sup>7,8</sup>. More than half the genera, currently included in the family, have been established during the last five decades. However, the taxonomic circumscriptions of the genera, are not yet fully resolved<sup>9</sup>. In India the family is represented by 30 species and infraspecific taxa, belonging to genera *Chiloscyphus* Corda (6 species), *Heteroscyphus* Schiffn. (14 species) and *Lophocolea* (Dumort.) Dumort. (9 species and 1 variety), distributed mostly in the Indian Himalayan region<sup>3</sup>. Nine species or 30% of the hitherto recorded taxa are endemic to the country<sup>3</sup>. The taxonomy of the family in India is well understood<sup>10</sup>. Eastern Himalaya shows maximum diversity with 26 known taxa, followed by Western Himalaya and Western Ghats with 16 taxa each, Central India (6 species), Eastern Ghats and the Deccan Plateau (3 species) and the Andaman and Nicobar Islands (2 species)<sup>3</sup>. While some taxa are restricted to their respective bryogeographical regions, the others are common to one or more of the above territories.

While studying the liverworts of the Eastern Himalayan region, we came across certain interesting plants from Arunachal Pradesh and Sikkim which were morphologically

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allied to Lophocoleaceae, but were remarkably distinct from all the other known genera of this family and liverworts as a whole. Hence, a new genus and species, *Udaria lamellicaulis* D. K. Singh, S. Majumdar and D. Singh, is proposed here to accommodate these plants.

### Taxonomic description

*Udaria* D.K. Singh, S. Majumdar & D. Singh, *gen. nov.*

Stem surface with seriatly arranged, longitudinally oriented, 1–12 cell high lamellae; leaves occasionally lamellate adaxially with striolate–rugulose cuticle ornamentation; rhizoids arising from the lamina of underleaves; gynoecia with 1–2 sub-floral innovations, and gemmiparous female bracts and bracteoles, with the former often abaxially lamellate.

Type: *Udaria lamellicaulis* D.K. Singh, S. Majumdar & D. Singh (The new genus is at present represented by a single species only).

*Udaria lamellicaulis* D.K. Singh, S. Majumdar & D. Singh, *sp. nov.* (Figures 1–3).

Type: India: Eastern Himalaya, Sikkim, North district, Zakthang, 27°46'55.8"N, 88°28'09.4"E, c. 3360 m, 24 March 2013, D. Singh 60533A (Holotype & Isotype: CAL).

Plants are prostrate, growing in loose patches, light green–pale green when fresh, greyish green–pale brown in herbarium; shoots filiform, 9–28 mm long, (0.40–) 0.65–0.85 mm wide including leaves, sparsely branched; branches ventral and lateral intercalary. Stems oval–elliptical, or sub-orbicular–orbicular in outline in transverse section, 161.6–262.6 × (160.0–) 202.0–434.3 µm (with lamellar projections), 7–11 cells across diameter, undifferentiated; outer cells 10.0–32.5 (–40.0) × 7.5–22.5 µm; inner cells (7.5–) 15.0–37.5 × (5.0–) 10–30 µm, thin-walled, light yellowish–hyaline, non-trigonus, surface covered with seriatly arranged, longitudinally oriented lamellae, up to 4 cells high in older portion of the stem with acute–sub-acute end cells and 1–12 cells high with more or less rounded-end cells towards apical portion. Rhizoids fasciculate from the lamina of underleaves, hyaline, stout, often branched at the tip. Leaves distant, contiguous towards apical portion, sub-transverse to succubous, widely spreading, broadly quadrate–rectangulate, 0.28–0.70 mm long, 0.26–0.40 (–0.53) mm wide; bilobed to 1/4–1/2 of their length, sinus acute–widely obtuse, margin entire–slightly wavy, edentate; lobes equal or unequal, parallel–divergent or connivent, broadly triangulate, 6–17 cells long, (5–) 9–18 cells wide at base, acute–sub-acute towards apex; dorsal leaf base decurrent, ventral slightly decurrent; apical leaf cells 7.0–21.2 × 7.0–17.2 µm, thin-walled with indistinct trigones; median leaf cells 12.0–24.2 × 7.0–20.2 µm, thin-walled with nodulose trigones; basal leaf cells 12.0–32.3 × 10.0–23.2 µm, thin-walled with nodulose trigones, interme-

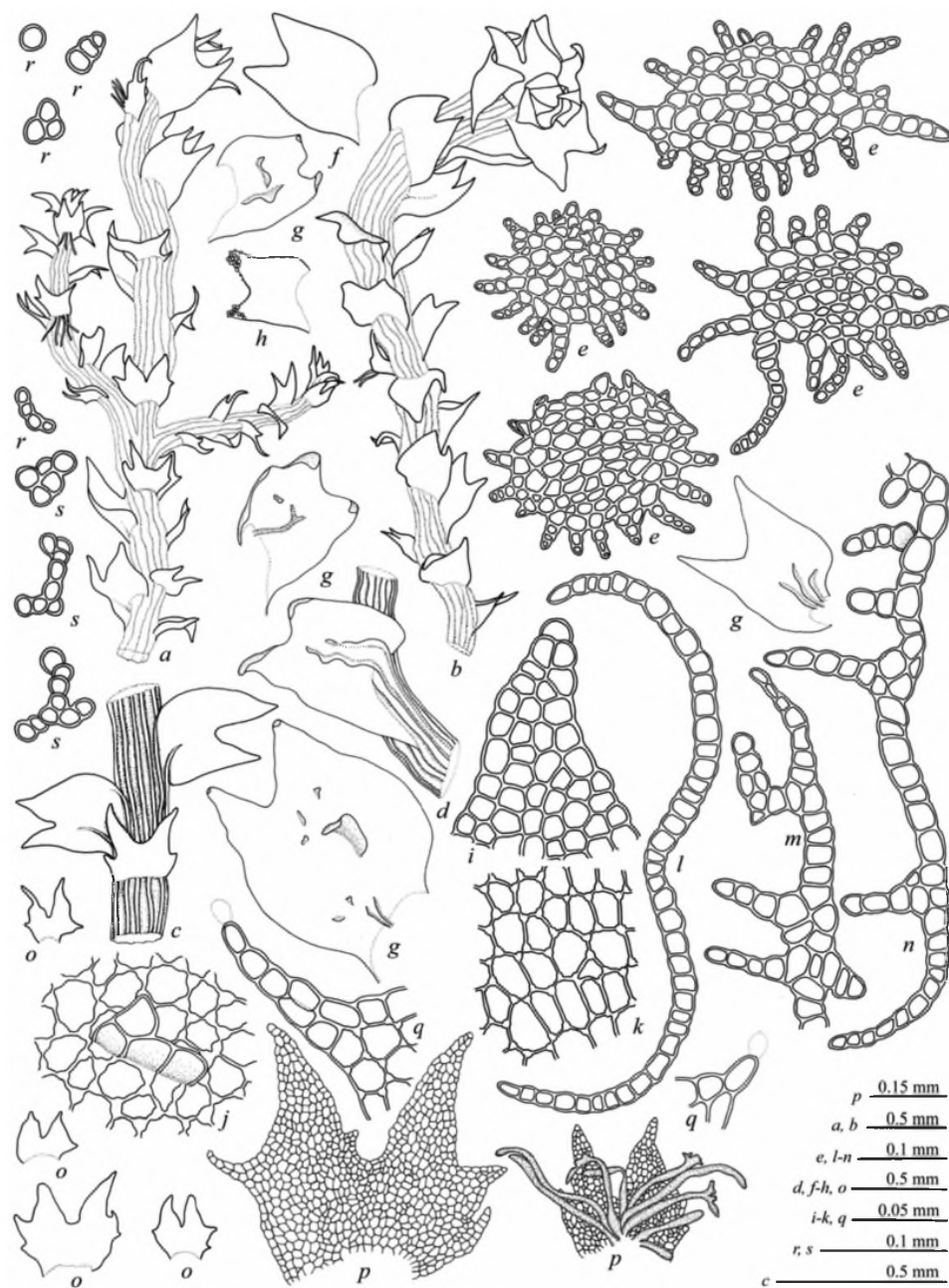
diolate thickenings absent; adaxial surface of leaves in distal portion of the shoot (rarely abaxial surface also) often lamellate with lamellae extending up to (1/9–) 1/8–3/4 of leaf length; cuticle striolate–rugulose; oil-bodies not seen. Underleaves distant, contiguous–imbricate towards apical portion, free, ovate–rectangulate, 0.19–0.35 (–0.52) mm long, 0.22–0.61 mm wide (with tooth), 2.2–3.8 times broader than stem at their widest, bilobed to 1/3–1/2 of their length, sinus broad, sub-acute–obtuse, lobes parallel–divergent or sometimes slightly connivent, triangulate, 10–24 cells long, 7–14 cells wide at base, 1–2 cells uniseriate at apex, margin toothed with 1–2 distinct, or sometimes blunt tooth present along both the lateral margins, occasionally with a single tooth on inner side of the lobe; tooth more or less triangulate, 1–7 cells long, 1–5 cells wide at base, 1–4 cells uniseriate towards apex, usually with a hyaline papilla at the tip. Gemmae in masses at the apex of leaf lobes in the apical region, smooth, pale green, 1-celled, globose, 15.0–17.5 µm in diameter, or 2–9-celled, linear-filamentous, (22.5–) 25.0–75.0 × 12.0–15.0 (–40.0) µm, thin-walled.

Plants dioicous (?). Androecial branches not seen. Gynoecia terminal on main shoot, with 1–2-sub-floral innovations; bracts and bracteoles more or less of the same size, larger than leaves and underleaves respectively, weakly connate at base, in 1–2 whorls grading gradually into leaves and underleaves respectively; bracts sub-rectangulate, 0.70–0.90 mm long, 0.50–0.65 mm wide, bilobed to 1/3–1/2 of its length, lobes acute–sub-acute, often ragged, gemmiparous, lamina often abaxially lamellate, margin irregularly toothed; bracteoles sub-rectangulate, 0.50–0.80 mm long, 0.40–0.60 mm wide, bilobed to 1/2–2/3 of its length, lobes acute–sub-acute or obtuse, often ragged, gemmiparous, margin toothed. Perianth long exserted, slender, more or less cylindrical, slightly narrowed towards apex, 1.2–1.8 mm long, 0.42–0.62 mm wide, trigonus; keel two lateral and one dorsal, reaching up to the base of perianth, mouth irregularly lobed; apical cells of perianth lobe 10.0–17.5 × 10.0–15.0 µm, thin-walled with minute–indistinct trigones; median cells of perianth lobe 10.0–25.0 × 10.0–17.5 µm, thin-walled with nodulose trigones; basal cells of perianth lobe 12.5–25.0 × 12.5–20.0 µm, thin-walled with minute–indistinct trigones. Mature sporophytes not seen.

Other specimens examined (Paratypes): India: Eastern Himalaya, Arunachal Pradesh, Anjaw district, 8 km from Hayuliang on way to Holiang, 28°05'13.16"N, 96°31'1.92"E, c. 820 m, 18 April 2010, S. Majumdar 47898 (CAL); Sikkim, north district, Yathang, 27°50'10.0"N, 88°32'58.0"E, c. 3590 m, 27 March 2013, D. Singh 60569A, 60571B (CAL).

### Etymology

The genus has been named after the renowned Indian bryologist late Prof. Ram Udar, F.N.A., Department of



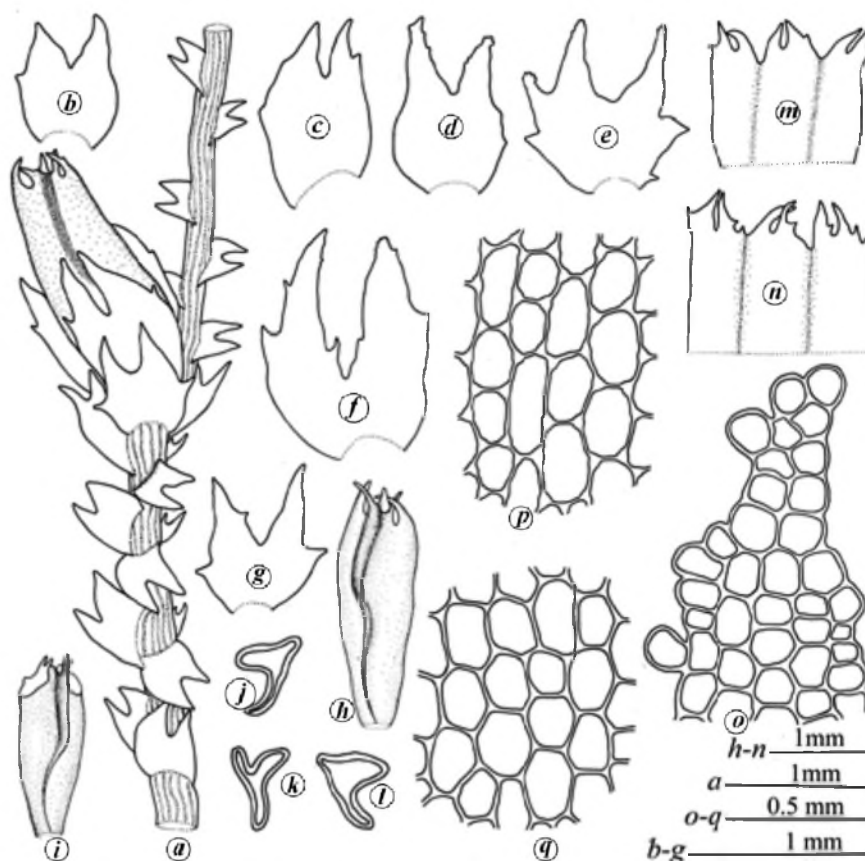
**Figure 1.** *Udaria lamellicaulis* D.K. Singh, S. Majumdar & D. Singh. *a*, A portion of the plant in ventral view; *b*, A portion of the plant in lateral view; *c*, *d*, Sectors of plant in ventral view showing lamellae on adaxial surface of leaves; *e*, Transverse sections of stem; *f*, A leaf; *g*, Leaves in adaxial view showing lamellar outgrowths; *h*, A leaf bearing gemmae at lobe apices; *i*, Apical leaf cells; *j*, Median leaf cells, note the lamellar outgrowth; *k*, Basal leaf cells; *l*, Transverse section of a leaf; *m*, Transverse section of a leaf showing lamellar outgrowths on both adaxial and abaxial surface; *n*, Transverse section of leaf with lamellar outgrowths on adaxial surface; *o*, Underleaves; *p*, Underleaves enlarged, note the rhizoids originating from the lamina cells in one of them; *q*, Marginal teeth of underleaves with apical hyaline papilla; *r*, *s*, Gemmae. (Figure *c* drawn from D. Singh 60533A by D. Singh; others from S. Majumdar 47898 by S. Majumdar).

Botany, University of Lucknow, for his invaluable contributions to Indian Hepaticology.

*Habitat and ecology*

The plants are terricolous and lignicolous, growing in very moist and shady places. The species was collected from Arunachal Pradesh at an altitude of about 820 m,

whereas in Sikkim the plants were found growing at altitudes ranging from 3360 to 3590 m. While the plants in Arunachal Pradesh (S. Majumdar 47898) were growing in degraded tropical forest close to human habitation, in association with *Metacalypogeia alternifolia* (Nees) Grolle, the type, D. Singh 60533A, from the mixed coniferous forests in Sikkim were found growing in association with *Blepharostoma trichophyllum* (L.) Dumort.



**Figure 2.** *Udaria lamellicaulis* D. K. Singh, S. Majumdar & D. Singh. **a**, A portion of female plant with a sub-floral innovation in lateral view (rhizoids not drawn); **b-d**, Female bracts; **e-g**, Female bracteoles; **h, i**, Perianths; **j-l**, Transverse sections of perianth; **m, n**, Perianths longitudinally cut-open to show mouth; **o**, Apical cells of perianth lobe; **p**, Median cells of perianth lobe; **q**, Basal cells of perianth lobe. (All figures from D. Singh 60533A by D. Singh).

subsp. *trichophyllum*, *Plagiochila corticola* Steph. and *Tritomaria exsecta* (Schmid. & Schrad.) Schiffn. ex Loeske. The plants from Yathang in Sikkim (D. Singh 60569A), growing in broad-leaved forest, formed association with *M. alternifolia*, *P. carringtonii* (Balf.) Grolle subsp. *lobuchensis* Grolle and *P. poeltii* Inoue & Grolle.

#### Distribution

India, Eastern Himalaya (Arunachal Pradesh (Anjaw district), Sikkim (North district)), probably endemic.

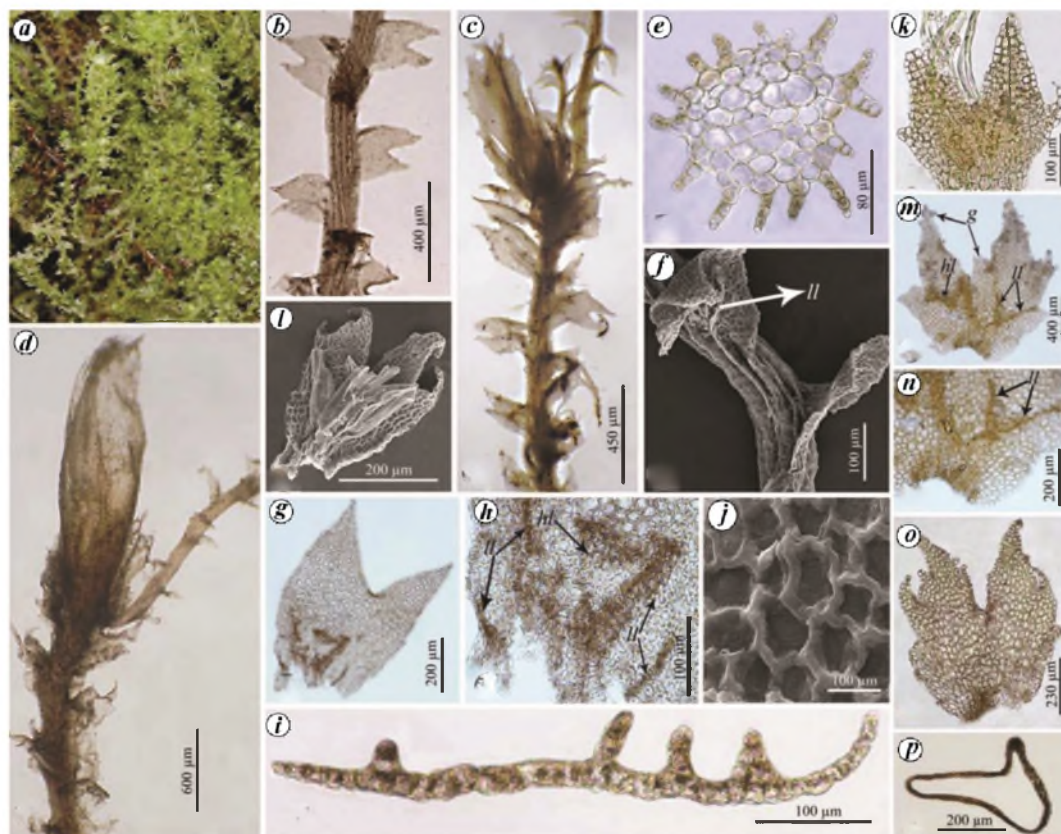
#### Systematics

Phylum: Marchantiophyta  
Class: Jungermanniopsida  
Subclass: Jungermanniidae  
Order: Jungermanniales  
Suborder: Lophocoleineae  
Family: Lophocoleaceae  
Genus: *Udaria* gen. nov.  
Species: *lamellicaulis* sp. nov.

#### Discussion

The genus *Udaria* is characterized by plants with 1–12 cells high, longitudinal lamelliform strips on the stem surface (Figures 1 *a-e*; 2 *a*; 3 *b, e, f*); usually 1/4–1/2 bilobed leaves often with 1–4 cells high lamellae on the adaxial surface, and the median and basal cells having nodulose trigones (Figures 1 *a-d, f-h, j, k, m, n*; 3 *f-i*); striolate–rugulose leaf surface (Figure 3 *j*); 1/3–1/2 bilobed underleaves with lateral margins 1–2-dentate with tooth which is 1–7 cells long, 1–5 cells wide at base and 1–4 cells uniseriate towards apex (Figures 1 *a, o-q*; 3 *k, l*); rhizoids are present on underleaf lamina (Figures 1 *p*; 3 *l*). There are either profuse, one-celled globose, or up to 9-celled linear-filamentous gemmae (Figure 1 *r, s*); gynoecia with 1–2 sub-floral innovations (Figures 2 *a*; 3 *c, d*); female bracts and bracteoles sub-equal and gemmiparous (Figures 2 *b-g*; 3 *m, o*) with bracts often with lamellae on the abaxial surface (Figure 3 *m* and *n*), and trigonous perianth with dorsal third keel (Figures 2 *j-l*; 3 *p*).

*U. lamellicaulis*, growing in tropical and alpine regions, shows a wide altitudinal preference and habitat



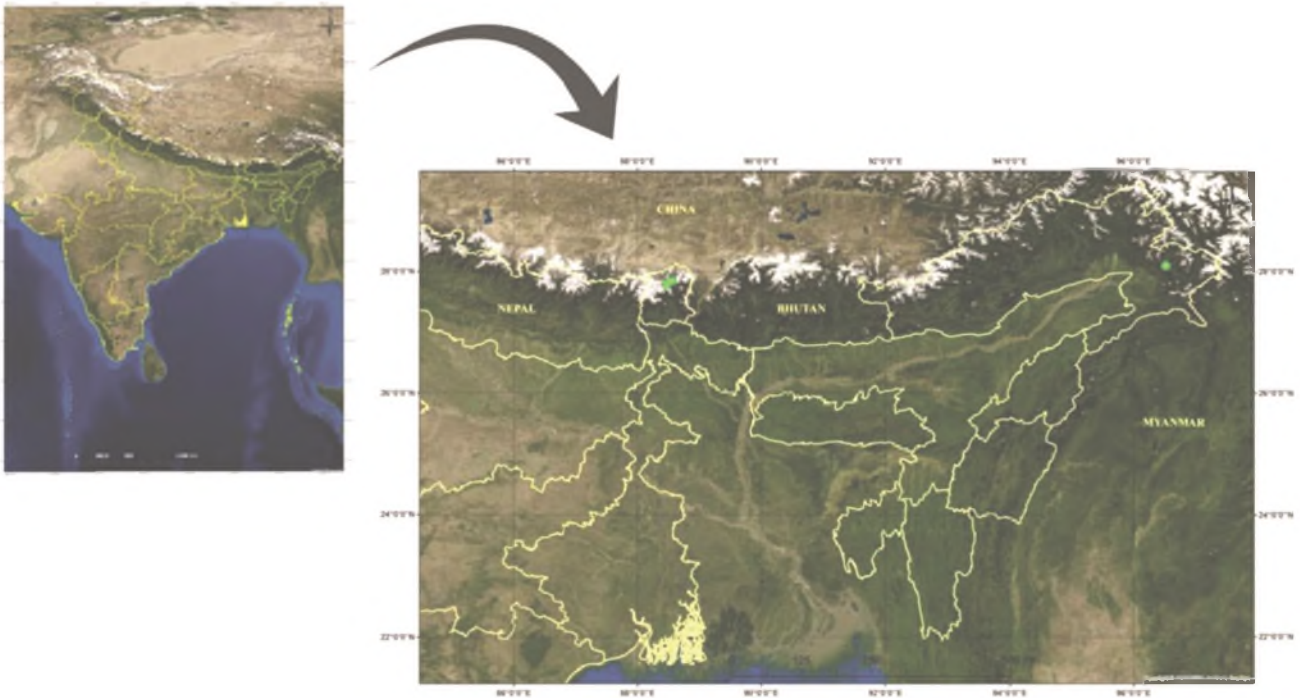
**Figure 3.** *Udaria lamellicaulis* D.K. Singh, S. Majumdar & D. Singh. *a*, Habit; *b*, A portion of plant in ventral view showing lamelliform projections; *c*, A portion of female plant with two sub-floral innovations in dorsal view; *d*, A portion of female plant with a single sub-floral innovation in ventral view; *e*, Transverse section of stem; *f*, A portion of plant under SEM showing lamelliform strips over stem and adaxial surface of leaf; *g*, A leaf showing lamellar outgrowths on adaxial surface; *h*, A portion of the same enlarged showing longitudinally and horizontally oriented lamellar outgrowths; *i*, Transverse section of leaf showing surface lamellae; *j*, Median leaf cells showing surface ornamentation; *k*, An underleaf with rhizoids under light microscope; *l*, The same underleaf under SEM, note the rhizoids emerging from laminar cells; *m*, A female bract showing lamellae and gemmae; *n*, A portion of the same enlarged showing lamellae; *o*, A female bracteole; *p*, Transverse section of perianth (Photomicrographs; *f-i*, *l* from S. Majumdar 47898; *b* from D. Singh 60571B; others from D. Singh 60533A; *g*, gemmae; *hl*, horizontal lamellae; *ll*, longitudinal lamellae).

diversity. This variation in its growing conditions is amply reflected in the morphology of the plants from these locations. Plants from Arunachal Pradesh are comparatively much larger (up to 28 mm long), with larger leaves (up to 0.7 mm long) and underleaves (up to  $0.51 \times 0.60$  mm with lobes up to 24-cells long) as compared to those from Sikkim which are only up to 12 mm long with smaller leaves (up to 0.45 mm long) and underleaves (up to  $0.35 \times 0.38$  mm with lobes only up to 16-cells long). However, plants from both the locations showed 1–9-celled, globose, or linear-filamentous gemmae borne at the apices of the leaf-lobes in the growing region.

*U. lamellicaulis* is remarkable for some of its vegetative features. The branching is both ventral and lateral intercalary, with the predominance of the former in Sikkim population and that of the latter in Arunachal population. The plants totally lack the terminal, ‘*Frullania*-type’ branching. The most defining feature of the new genus, and unique amongst the leafy liverworts, is the presence

of seriatly arranged, longitudinally oriented, 1–12 cells high lamellae on the stem surface (Figures 1 *a-e*; 2 *a*; 3 *b*, *e*, *f*). The only other members of Lophocoleaceae possessing lamellate armature are genera *Lamellocolea* J.J. Engel [*L. granditexta* (Steph.) J.J. Engel and *L. integrostitia* J.J. Engel & Glenn] and *Clasmatocolea* Spruce [*C. verrucosa* J.J. Engel and *C. notophylla* (Hook. f. & Taylor) Grolle]. But, these taxa exhibit longitudinal lamellae on the perianth in the former and lamellar outgrowths or ‘scales’ on the perianth in the latter<sup>11–13</sup>.

The new taxon is also interesting in often having lamellae on the adaxial surface of leaves (Figures 1 *c*, *d*, *g*, *m*, *n*; 3 *f-i*). Sometimes lamellae will also be present on the abaxial surface (Figure 1 *m*). While the lamellae extend up to 1/8–3/4 of the leaf length on the adaxial surface, abaxially it is just 1/9–1/8 of the leaf length. Lamellae present on the leaf surface are often branched, and are up to six cells high towards the leaf-base, tapering down to one cell at the distal end (Figure 1 *m*, *n*). The foliar lamellae may be continuous or discontinuous, and



**Figure 4.** *Udaria lamellicaulis* D.K. Singh, S. Majumdar & D. Singh. Map of India and the East Himalayan bryogeographical region showing the distribution of the taxon.

sometimes even perpendicular to the longitudinal axis of the leaves (Figures 1 g; 3 g–i). Occasionally, 3–4-celled filamentous outgrowths are also present on the adaxial surface of the leaves. Interestingly, however, the lamellae abruptly end at the base of underleaves and re-emerge from its axil, but never extend over it. The leaf cells are thin-walled throughout, but the apical cells exhibit inconspicuous, triradiate trigones, while those in the middle and basal region have conspicuous, nodulose trigones (Figures 1 i–k). Leaves towards the growing region of the plant are often gemmiparous with unicellular as well as linear-filamentous gemmae borne at their lobe apices (Figures 1 h, r, s).

The bracts and the bracteoles are considerably larger than leaves and underleaves, and are gemmiparous. Their lobe apices are, therefore, usually ragged because of detaching gemmae. The taxon is also interesting in having female bracts often with longitudinally as well as horizontally oriented, 1 (–4) cells high lamellae on their abaxial surface (Figures 3 m, n). The lamellae extend up to the base of the bract's sinus.

Rhizoids in the present taxon develop interestingly from the cells of underleaf lamina (Figures 1 p and 3 l) unlike most of the genera in the family where these originate from stem cells immediately at the base of underleaves. The only other genera of Lophocoleaceae with rhizoids originating from underleaf cells are *Conoscyphus* Mitt., *Leptophyllopsis* R.M. Schust. and *Otoscyphus* J. J. Engel, Bardat & Thouvenot<sup>14,15</sup>.

Thus, with the morphological features, like the presence of undifferentiated stem; 2-lobed, sub-transverse to succubous leaves with thin-walled cells; 2-lobed underleaves with 1–2 tooth at margin, occasionally with additional tooth along the inner margin of the lobe; gynoeceia on the main shoot; large female bracteoles more or less equal to the bracts, and long exserted, oblong trigonous perianth with dorsal third keel and 3-lobed mouth, the genus *Udaria* shows affinity with the family Lophocoleaceae. Further, in the absence of secondary pigmentation and presence of 1–2-celled or linear-filamentous gemmae and female bracts and bracteoles larger than leaves and underleaves respectively, it shows closer affinity with lophocoleoid elements of the family. However, in the presence of longitudinal, 1–12 cells high lamelliform strips on stem surface; striolate–rugulose and often lamellate leaf surface; rhizoids borne on the lamina of underleaves, gynoeceia with 1–2 sub-floral innovations, and gemmiparous female bracts (often also lamellate) and bracteoles, *Udaria* is remarkably distinct and occupies an entirely isolated position in the family Lophocoleaceae.

### Conservation status

*Udaria lamellicaulis* is presently known from three locations only, one in Anjaw district in Arunachal Pradesh and two in North district of Sikkim (Figure 4). The Arunachal and Sikkim (Yathang) population are

close to human habitation and road respectively, and hence the plants are vulnerable to anthropogenic disturbances. Whereas, the one at Zakthang in Sikkim occurs in Khangchendzonga Biosphere Reserve and is, therefore, protected *in situ* from any major biotic interference.

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ACKNOWLEDGEMENTS. This paper was presented at the XIX International Botanical Congress held at Shenzhen, China, 23–29 July 2017. We thank the Director, Botanical Survey of India, the Chief Wildlife Wardens of Arunachal Pradesh and Sikkim, Dr Anders Hagborg, (Field Museum, Chicago, USA), Dr Jörn Hentschel, (Georg-August-Universität, Göttingen, Germany), Prof. John J. Engel (Curator Emeritus, The Field Museum, Chicago, USA), late Prof. Jiří Váňa, Charles University (Czech Republic) and Dr Avishek Bhattacharjee (BSI, Howrah) for all the support and encouragement. We also thank the Ministry of Environment, Forests and Climate Change, New Delhi for financial assistance under the All India Coordinated Project on Capacity building in Taxonomy (AICOPTAX).

Received 21 December 2017; revised accepted 9 July 2018

doi: 10.18520/cs/v115/i8/1536-1542