Taiwania 62(1): 33–42, 2017
DOI: 10.6165/tai.2017.62.33

Two new species of *Riccardia* (Aneuraceae, Marchantiophyta) from Eastern Himalaya, India with notes on the genus in Sikkim

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(Manuscript received 18 July 2016; accepted 24 October 2016; online published 25 January 2017)

ABSTRACT: The genus *Riccardia* Gray is represented in Sikkim by 10 species, including *R. lachungensis* D.Singh & D.K.Singh and *R. udarii* D.Singh & D.K.Singh described here as new from North and South district respectively. *R. lachungensis* is characterized by 9–10 mm long, 0.25–0.35 mm wide plants with usually bipinnate or sometimes tripinnately branched thalli with mamillate–papillate dorsal and ventral epidermal cells, mucilage papillae scattered on ventral surface of thallus, main thalli 10–12 cells thick in the middle with unistratose alar portion 1-celled, and the absence of gemmae. Whereas, *R. udarii* is distinct in dichotomously branched thalli with distinct midrib, or sometimes indistinct in apical portion, main thalli 6–8 (–9) cells thick in the middle in transverse section, unistratose alar portion of wing 4–9 cells wide and often presence of pigmented cells in the thallus. Sporophytic details in *R. elata* (Steph.) Schiffn. are provided for the first time and *R. levieri* Schiffn. is newly recorded from the State of Sikkim. *Riccardia cardotii* (Steph.) Pande & K.P.Srivast., earlier reported from the State by several workers, has been excluded from the *Riccardia* flora of Sikkim.

KEY WORDS: Aneuraceae, India, New Species, *Riccardia lachungensis*, *Riccardia udarii*, Sikkim.

INTRODUCTION

The genus *Riccardia* Gray is represented by about 302 taxa in the world (Söderström *et al.*, 2016) distributed widely from tropical to boreal and antipodal regions in northern as well as southern hemispheres respectively, with *Riccardia georgiensis* (Steph.) Hässel and *R. georgiensis* subsp. *sympodea* R.M.Schust. reaching as far south as sub Antarctic islands (Schuster, 1992; Bednarek-Ochyra *et al.*, 2000). But, there are only few regional taxonomic revisions, like that of parts of South America and sub Antarctic islands (Hässel, 1972), Australia and New Guinea (Hewson, 1970, 1970a), India (Srivastava & Udar, 1976), New Zealand (Brown & Braggins, 1989), Japan (Furuki, 1991), parts of North America (Schuster, 1992), Philippines (Furuki, 2006), Singapore (Furuki & Tan, 2013), etc., so far.

The first record of the genus from Sikkim comes through the publication of Mitten (1861), who described *Sarcomitrium multifidium* Mitt. (= *R. multifida* (L.) Gray based on the specimens collected by Sir J.D. Hooker. Today the genus is represented in the State by seven taxa out of 13 recorded from India (Schiffner *et al.*, 1959; Srivastava & Udar, 1976; Singh & Singh, 2006, 2007; Singh *et al.*, 2008, Singh & Singh, 2015). These are *Riccardia elata* (Steph.) Schiffn., *R. multifida* (L.) Gray subsp. *multifida*, *R. palmata* (Hedw.) Carruth., *R. palmatiformis* Schiffn., Pande & K.P. Srivast., *R. sikkimensis* (Steph.) Pande & K.P. Srivast., *R. tenuicostata* Schiffn. and *R. villosa* (Steph.) Pande & K.P. Srivast. ex S.C. Srivast. & Udar.

The ongoing study on liverwort and hornwort flora of Sikkim revealed another two interesting populations of the genus from Lachung in North District and Shimkharkha in South District. These plants, based on their morphological characteristics, merit the status of new species. These are described here as *R. lachungensis* sp. nov. and *R. udarii* sp. nov. respectively. The study also revealed, for the first time, the occurrence of *R. levieri* Schiffn. - a species so far known in Indian bryoflora from Himachal Pradesh, Uttarakhand, Meghalaya, West Bengal, Karnataka, Kerala, Tamil Nadu and Madhya Pradesh, in North and West districts of the State. The paper provides detailed description and illustration of the new taxa and the sporophytic details of *R. elata* along with notes on salient morphological features, habitat, distribution and exsiccate of all the species of the genus so far recorded from Sikkim. With these new discoveries the number of species of the genus occurring in India has increased to 15 and that in Sikkim to ten.

Key to the species of *Riccardia* in Sikkim

1a. Plants dichotomously branched, with distinct midrib or sometimes indistinct in apical portion; unistratose alar portion of the wing 4–9 cells wide ……..…… ***R. udarii***
1b. Plants pinnately–palmately branched, without distinct midrib; unistratose alar portion of the wing 1–3 cells wide ……..……..2
2a. Dorsal and ventral epidermal cells of thallus mamillate–papillate; mucilage papillae scattered on ventral surface of thallus ……..
……..……..……..……..…….. ***R. lachungensis***
2b. Epidermal cells of thallus smooth; mucilage papillae present only at the apex on ventral side of thallus ……...… 3

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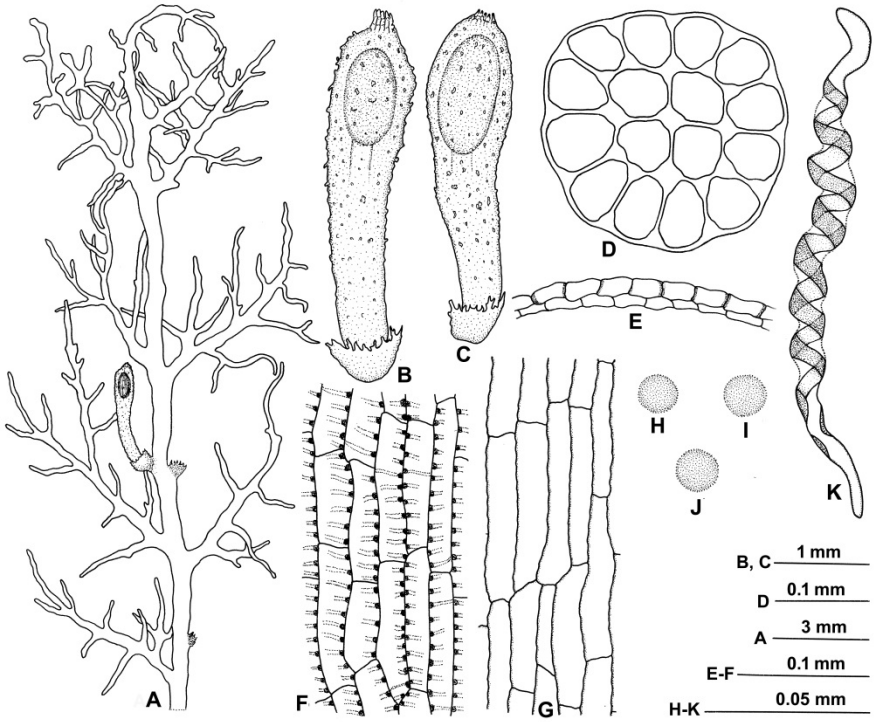


Fig. 1. ***Riccardia elata*** (Steph.) Schiffn. **A:** A female thallus bearing gynoecial branches. **B, C:** Calyptra. **D:** Transverse section of seta. **E:** Transverse section of capsule wall. **F:** Outer layer of capsule wall. **G:** Inner layer of capsule wall. **H–J:** Spores. **K:** An elater (All figures drawn from *D. Singh & M. Dey* 35845).

3a. Transverse section of main thallus 7–13 cells thick …..…..…..…4
3b. Transverse section of main thallus 4–7 (–8) cells thick …..…..……6
4a. Plants 50–80 mm long; usually 3-pinnate or sometimes 2-pinnate; pigmented cells in the thallus absent ……..……..... ***R. elata***
4b. Plants 8–16 mm long; 1–2-pinnate; pigmented cells in the thallus present ……..…….....5
5a. Plants 0.4–0.9 mm wide; transverse section of main thallus 11–13 cells thick, pigmented cells 1–2, scattered ..... ***R. sikkimensis***
5b. Plants 0.15–0.35 mm wide; transverse section of main thallus 8–10 cells thick, pigmented cells in 1–2 layers ……..……..***R. villosa***
6a. Plants 0.35–0.45 mm wide ……..……..……7
6b. Plants 0.45–1.2 mm wide ……..……8
7a. Plants dioicous, palmately branched..... ***R. palmatiformis***
7b. Plants monoicous, pinnately–bipinnately branched ……..... ……..……..... ***R. tenuicostata***
8a. Transverse section of main thallus 4–6 cells thick…….. ……..… ***R. multifida*** subsp. ***multifida***
8b. Transverse section of main thallus 6–8 cells thick ……..……..9
9a. Plants 5–11 mm long, usually palmately branched; gemmae present ……..……***R. palmata***
9b. Plants 15–22 mm long, usually pinnately branched; gemmae absent ……..... ***R. leveri***

TAXONOMIC TREATMENTS

1. ***Riccardia elata*** (Steph.) Schiffn., Kaiserl. Akad. Wiss. Wien, Math.-Naturwiss Kl., Denkschr. 67: 17. 1898. *Aneura elata* Steph., Hedwigia 19. 1893**.**

Figs. 1 & 2

Description and illustrations: Singh and Singh (2007)

Dioicous (?). **Male** plants not seen. Female branches solitary, wing consisting of scales of variable form; scales filamentous to triangular–lingulate, 3–6 cells high, 1–4 cells wide at base, archegonia in two rows. **Calyptrae** clavate–cylindrical, 3.1–3.7 mm long, 0.6–0.8 mm wide, thick and fleshy, surface papillose, apex with distinct corona. **Seta** circular in outline in transverse section, 0.25–0.30 mm in diameter, 4 cells across with 12 outer and 4 inner cells, cells angular, thin-walled with bulging trigones. **Capsule** blackish brown, ovoid, 0.8–1.0 × 0.5–0.6 mm, dehiscing into 4-valves, each bearing a piece of elaterophore at the apex; valve 1.1–1.2 mm long, 0.3–0.5 mm wide; elaterophore 1/2 of the length of capsule; wall bistratose; cells of the outer layer of capsule wall rectangulate, 75.0–175.0 × 17.5–27.5 μm with thickenings on abaxial side of the radial walls, except the median wall where it is present on both sides, partially or fully extending on inner tangential walls appearing semiannular in surface view; those of the inner layer rectangulate, 62.5– 187.5 ×12.5–22.5 μm with uniform, more or less sinuate thickenings on the radial walls. **Spores** light yellowish brown, globose, 10–15 μm in diameter, finely papillose. **Elaters** yellowish brown, 80–200 μm long, 10.0–12.5 μm wide, broadest at middle, unispiral.

Under SEM, the sporoderm shows tuberculate–baculate ornamentation with the tubercles and the bacula having secondary punctate projections over them. The sporoderm appears to be structurally weak as it shows irregular foldings (Figs. 2: C, D).

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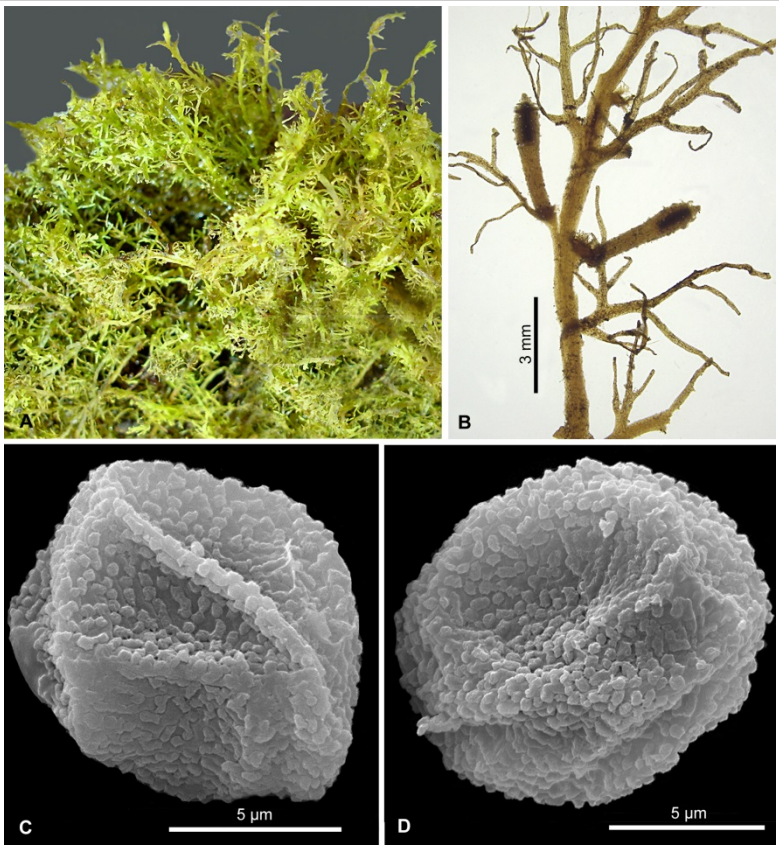


Fig. 2. ***Riccardia elata*** (Steph.) Schiffn. **A:** Habit. **B:** A female thallus bearing gynoecial branches. **C, D:** Spores under SEM (Photomicrograph A from D. Singh 36855; others from *D. Singh & M. Dey* 35845).

Habitat: Terrestrial, growing in moist and shady places under slowly dripping water, in association with *Heteroscyphus bescherellei* (Steph.) S.Hatt., *Pellia endivifolia* (Dicks.) Dumort. and *Tichocolea tenera* Udar & D.K.Singh.

Distribution: India [Eastern Himalaya (Sikkim)], Indonesia, Malaysia, Philippines Singapore (Meijer, 1959; Furuki, 2006; Singh and Singh, 2007; Chuah-Petiot, 2011; Furuki and Tan, 2013).

Specimens examined: **INDIA**: Eastern Himalaya, Sikkim, East Sikkim: Busuk (Near Pamtenj military house), c. 1340 m, 10 Nov. 2005, *D. Singh* 36855; 22 Feb. 2006, *D. Singh* 36925, 36926, 36933 (CAL); 4 Jun. 2006, *D.K. Singh & D. Singh* 39735, 39745 (CAL); Burtak falls, c. 1650 m, 4 Jan. 2005, *D. Singh & M. Dey* 35844B, 35845 (CAL); West district, between Hilley–Barsey, 27°11′26.2″N, 88°07′23.5″E c. 2729 m, 17 Jul. 2010, *D. Singh* 49037 (CAL); Thusey, 27°22′35.5″N, 88°14′27.2″E, c. 1766 m, 30 Dec. 2012, *D. Singh* 52237A (CAL); North district, Akar, 27°42′46.81″N, 88°33′20.8″E, c. 2603 m, 21 Mar. 2013, *D. Singh* 60454 (CAL); Thulung, 27°38′13.3″N, 88°26′29″E, c. 2449 m, 3 Apr. 2013, *D. Singh* 60632A (CAL).

Note: *Riccardia elata* is characterized by large plants, 50–100 mm long, 0.5–0.8 mm wide, usually tri-pinnately branched; main thallus 8–10 (–11) cells thick in the middle; primary branches 3–5 cells thick in middle; endogenous bicelled gemmae; clavate–cylindrical, 3.1–3.7 mm long calyptrae with papillose surface and distinct corona at apex; '*R. multifida*'-type capsule wall thickenings with the cells of the outer layer of the capsule wall with thickenings on abaxial face of radial walls, except in the median axis of the valve where it is present on both abaxial as well as adaxial faces, partially extending on tangential wall, and tuberculate–baculate spores with secondary ornamentation.

Singh and Singh (2007) recorded this species for the first time in Indian bryoflora from Sikkim and provided detailed description and illustrations of its vegetative features. The sporophytic details have been apparently unknown in the species so far. Further identifications of the collections of the genus from the State revealed the presence of mature sporophyte bearing plants in one of the gatherings. The details of calyptrae, capsule wall structure and the sporoderm pattern are provided here for the first time in this species.

Srivastava and Udar (1976) recognized two types of thickening patterns in the capsule wall of Indian species of the genus *Riccardia*, viz. '*Riccardia levieri*'-type and '*Riccardia multifida*'-type. In the former condition, thickenings are not always restricted to abaxial side of radial walls in the outer layer of capsule wall as some radial walls also have thickenings on both abaxial as well as adaxial sides similar to the median axis of the valve. In the latter type, the thickenings are always confined to abaxial side of the radial walls in the cells of outer layer, except along the median axis. The cells

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of the inner layer in both the types have more or less sinuately thickened radial walls. *R. elata*, thus exhibits '*R. multifida*'-type capsule wall thickening and, amongst the Indian taxa, shares this feature with *R. graeffei* (Steph.) Hewson, *R. multifida* and *R. sikkimensis* (see also Srivastava and Udar, 1976; Singh and Singh, 2015).

Among the Indian species of the genus, *R. elata* comes somewhat close to *R. santapaui* Udar & S.C. Srivast. in large size of plants and closely pinnate branching. However, it differs in having 50–100 mm long plants, 8–10 (-11) cells thick in the middle, and the presence of endogenous 2-celled gemmae as against 30–45 mm long plants with main thallus 6–7 cells thick in the middle and the absence of gemmae in the latter (Srivastava and Udar, 1976). In the presence of endogenous 2-celled gemmae, *R. elata* also resembles *R. sikkimensis*, but the latter differs from the former in having very small, 15–35 mm long plants with the main thallus and the primary branches up to 14 and 7 cells thick in the middle respectively, and the presence of pigmented cells in the thallus (see also Srivastava and Udar, 1976).

2. *Riccardia lachungensis* D. Singh & D.K. Singh, ***sp. nov.*** **Fig. 3**

Holotype: India. Eastern Himalaya, Sikkim, North district, 12 km from Lachung towards Katau, 27°40′53.5″N, 88°46′19.8″E, c. 3118 m, 24 May 2011, *D. Singh* 52130A (CAL).

Plants light brownish green when fresh, yellowish brown in herbarium, 9–10 mm long, 0.25–0.35 mm wide, hyaline at the margins, usually bipinnately or sometimes tri-pinnately branched; branches short or long, apices obtuse–slightly retuse. **Mucilage** papillae scattered throughout on the ventral surface of thallus, more prominent near the apex, clavate, 45.0–62.5 × 17.5–30.0 µm, usually 1-celled or sometimes 2-celled. **Main** thalli biconvex in transverse section, 10–12 cells thick (180–220 µm) in the middle; wing multistratose, unistratose alar portion of the wing 1–2 cell wide; dorsal and ventral epidermal cells mamillate–papillate, papillae strongly developed on the dorsal surface as compared to those on ventral surface, internal cells thin–very slightly thick-walled; primary branches biconvex in transverse section, 8–9 cells thick (150–190 µm) in the middle, epidermal cells mamillate–papillate; secondary branches 6–7 cells thick (110–140 µm) in the middle, epidermal cells mamillate–papillate; tertiary branches 4–5 cells thick (70–100 µm) in the middle, epidermal cells mamillate–papillate; marginal epidermal cells of thallus rounded–hexagonal, 17.5–35.0 × 15.0–32.5 µm, mamillate–papillate, thin-walled; median dorsal epidermal cells of thallus rounded–hexagonal 12.5–27.5 × 12.5–22.5 µm, mamillate–papillate, thin-walled; median ventral epidermal cells of thallus rounded–hexagonal 10–25 × 10–20 µm, mamillate–papillate, thin-walled. **Rhizoids**, stolons, gemmae not seen.

Dioicous (?). **Male** plants not seen. Female branches solitary, lateral, wing consisting of scales; scales filamentous to triangular-lingulate, 2–4 cells high, 1–2 cells wide at base. **Calyptrae**, cylindrical, 1.6–1.9 mm long, 0.5–0.6 mm wide, fleshy, 7–10 cells thick in transverse section, surface mamillate–papillate, covered with loose enlarged cell mass at apex. **Seta** circular in outline in transverse section, 175–200 µm in diameter, 4 cells across with 12 outer and 4 inner cells, cells angular, thin-walled with slightly bulging trigones. Mature sporophytes not seen.

Habitat: Terrestrial, growing in moist and shady places in loose patches in temperate forest in association with *Anastrophyllum minutum* (Schreb.) R.M. Schust. and *Lophocolea sikkimensis* (Steph.) Herzog & Grolle.

Distribution: India [Eastern Himalaya (Sikkim)], probably endemic.

Etymology: The species has been named after its type locality.

Note: *Riccardia lachungensis* is characterized by smaller thalli, 9–10 mm long, 0.25–0.35 mm wide, usually bipinnate or sometimes tripinnately branched (Figs. 3: A, B); main thalli 10–12 cells thick in the middle in transverse section (Figs. 3: L–N); primary branches 8–9 cells thick in middle; mamillate–papillate dorsal and ventral epidermal cells (Figs. 3: D–O), and the mucilage papillae scattered throughout the ventral surface of thallus (Figs. 3: H–J).

R. lachungensis closely resembles *R. colensoi* W.Martin in having mamillate–papillate epidermal cells and also the thickness of the main thallus. But, it is considerably distinct in much larger thalli (up to 65 mm long and 1.2 mm wide), mucilage papillae usually not persisting more than 1–2 mm behind the thallus apex and presence of gemmae in the latter (Brown and Braggins, 1989). In the presence of strongly biconvex thalli with mamillate–papillate epidermal cells; mucilage papillae scattered throughout on the ventral surface of the thallus, and massive, 7–10 cells thick calyptra with mamillate-papillate surface, *R. lachungensis* widely differs from hitherto all the known Indian species of the genus.

3. *Riccardia levieri* Schiffn., Oesterr. Bot. Z. 49: 130. 1899. *Aneura levieri* Schiffn. ex Steph., Bull. Herb. Boissier 7: 751. 1899 & Sp. Hepat. 1: 261. 1900.

Description and illustrations: Srivastava and Udar (1976)

Note: *Riccardia levieri* is characterized by dioicous plants 15–22 mm long, 0.45–1.2 mm wide, pinnately branched; main thallus 6–7 (–8) cells thick in the middle; primary branches 3–4 cells thick in the middle; male branches with 3–6-paired antheridial chambers; clavate, 3.0–4.8 mm long calyptrae with slightly papillose apical portion; '*R. levieri*'-type capsule wall thickenings, and spores with granulose–shortly tuberculate ornamentation.

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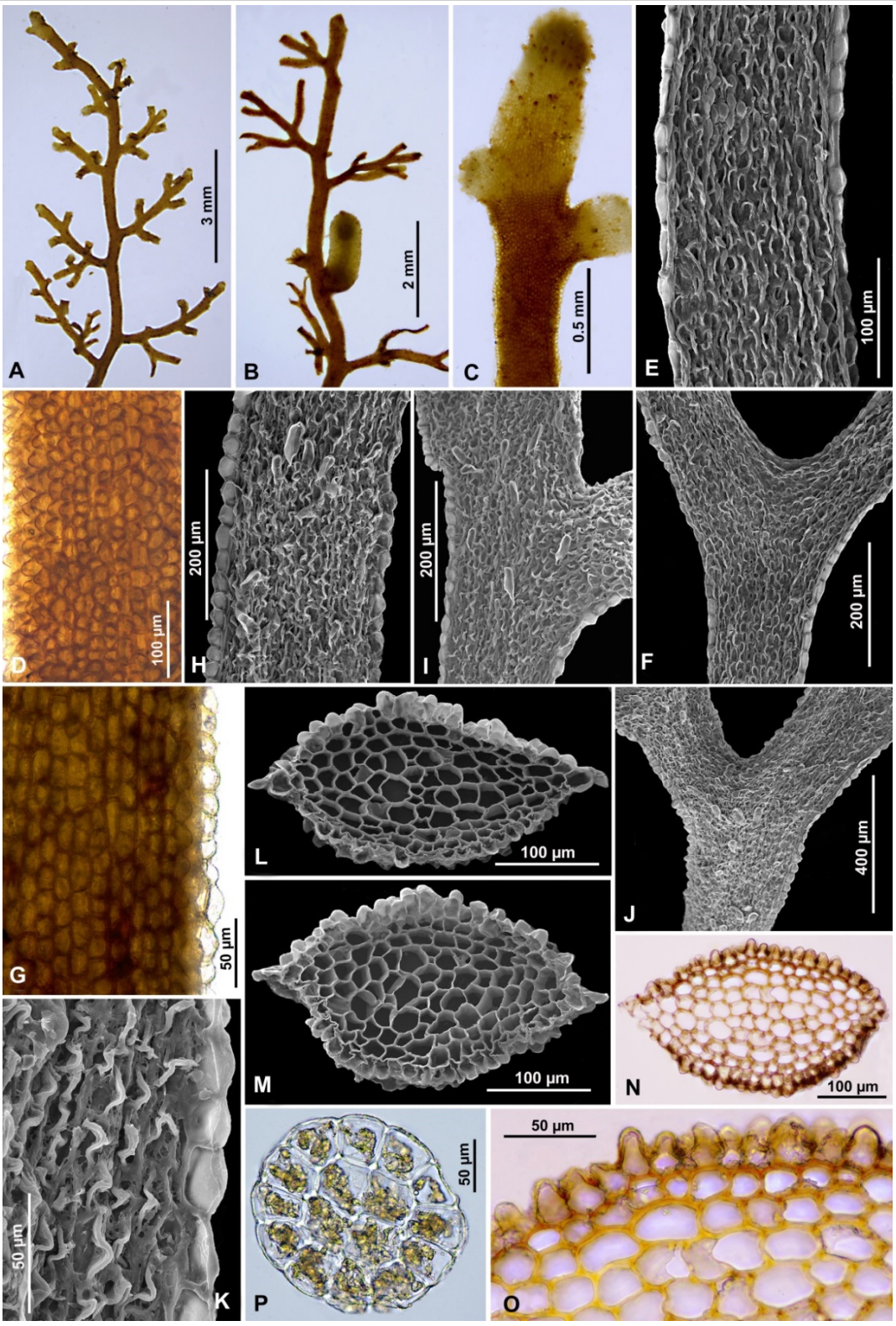


Fig. 3. ***Riccardia lachungensis*** D.Singh & D.K.Singh **A:** A portion of vegetative thallus. **B:** A female thallus bearing young calyptra. **C:** Apical portion of thallus in ventral view showing mucilage papillae. **D:** Dorsal epidermal cells of thallus under light microscope (LM). **E–F:** The same under SEM. **G:** Ventral epidermal cells of thallus under LM. **H–K:** The same under SEM showing mucilage papillae. **L, M:** Transverse sections of main thallus under SEM. **N:** The same under LM. **O:** A portion of the same enlarged. **P**: Transverse section of seta (All photomicrographs from Holotype).

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The present study records this species for the first time from the Indian State of Sikkim.

R. levieri closely resembles *R. cardotii* (Steph.) Pande & K.P.Srivast. in the thickness of the main thallus and ultimate branches of thallus. However, *R. cardotii* can be easily separated from it in having smaller plants (13 mm long, 0.15–0.5 mm wide) and profusely branched thalli (Srivastava and Udar, 1976).

Habitat: Terrestrial, growing in moist and shady places in association with *Anastrepta orcadensis* (Hook.) Schiffn., *Heteroscyphus bescherellei*, *Metacalypogeia alternifolia* (Nees) Grolle, *Metzgeria macrocellulosa* Kuwah., *Scapania ciliata* Sande Lac. and *Solenostoma comatum* (Nees) C.Gao.

Distribution: India [Western Himalaya (Himachal Pradesh, Uttarakhand), Eastern Himalaya (Meghalaya, Sikkim – present study, West Bengal), Western Ghats (Karnataka, Kerala, Tamil Nadu), Central India (Madhya Pradesh)], Bhutan (Kashyap, 1932 as *Aneura levieri*; Chopra, 1938a, b, 1943 as *A. levieri*; Srivastava and Udar, 1976; Manju *et al*., 2005; Singh and Nath, 2007; Singh and Singh, 2009; Sharma and Alam, 2011; Daniels and Daniel, 2013).

Specimens examined: **INDIA**: Eastern Himalaya, Sikkim, West district, 12 km from Hilley to Okharey, c. 2388 m, 27°13′46.8″N, 88°06′07.7″E, 12 Mar. 2010, *D. Singh & S. Majumdar* 47712, 47726B (CAL); Uttrey, 27°16′08.2″N, 88°05′58.3″E, c. 1901 m, 8 Jun. 2011, *D. Singh* 51820 (CAL); Gomchen, 27°26'59.2"N, 88°10′28.8″E, c. 3010 m., 29 Dec. 2011, *D. Singh* 52285A (CAL); North district, Passidong, 27°33′06.7″N, 88°27′32.1″E, c. 923 m, 29 Nov. 2009, *D. Singh* 46754 (CAL).

4. *Riccardia multifida* (L.) Gray, Nat. Arr. Brit. Pl. 1: 684. 1821. *Jungermannia multifida* L., Sp. Pl. 1136. 1753. subsp. ***multifida***

Description and illustrations: Srivastava and Udar (1976)

Note: *Riccardia multifida* subsp. *multifida* is characterized by monoicous plants, 12–20 mm long, 0.45–0.80 mm wide, bi–tripinnately branched; main thallus 4–6 cells thick in the middle; 3–5-paired androecial chambers; cylindrical, 1.5–1.8 mm long calyptrae with papillae or scaly outgrowths, and '*R. multifida*'-type capsule wall thickenings.

R. multifida subsp. *multifida* resembles *R. tenuicostata* Schiffn. in monoicous plants and branching pattern of the thallus. However, it differs in smaller, 6–10 mm long, 0.30–0.40 mm wide thalli and 4–10-paired androecial chambers in the latter (see also Srivastava and Udar, 1976).

Habitat: Terrestrial, growing in moist and shady places in dense mixed forest.

Distribution: India [Western Himalaya (Uttarakhand), Eastern Himalaya (Arunachal Pradesh, Assam, Sikkim, West Bengal), Western Ghats (Kerala, Maharashtra, Tamil Nadu), Central India (Madhya Pradesh], China, Hawaii, Micronesia, Nepal, Russia, Sri Lanka, Taiwan, Turkey, Africa, Europe, North America (Mitten, 1861; Srivastava and Udar, 1976; Stotler and Stotler, 1977; Piippo, 1990; Singh, 1996; Manju *et al*., 2005; Staples and Imada, 2006; Singh *et al.*, 2008; Konstantinova *et al.*, 2009; Pradhan and Joshi, 2009; Wigginton, 2009; Daniels, 2010; Sharma and Alam, 2011; Wang *et al*., 2011; Singh and Barbhuiya, 2012; Asthana and Sahu, 2013; Daniels and Daniel, 2013; Long and Rubasinghe, 2014).

Specimens examined: **INDIA**: Eastern Himalaya, Sikkim, East district, Burtak falls, c. 1650 m, 4 Jan. 2005, *D. Singh & M. Dey* 35856 (CAL); West district, 3 km from Barsey to Lasune camp, 27°12′36.8″N, 88°08′10.7″E, c. 2785 m, 9 Mar. 2010, *D. Singh & S. Majumdar* 47620 (CAL).

5. *Riccardia palmata* (Hedw.) Carruth., Seemann, J. Bot. 3: 302. 1865. *Jungermannia palmata* Hedw., Theor. Gen. (ed.1): 87. 1784.

Description and illustrations: Singh and Singh (2006)

Note: *R. palmata* is characterized by plants 5–10 mm long, 0.6–1.1 mm wide, pinnately branched; main thallus 7–8 cells thick in the middle, primary branches 4–5 cells thick in the middle and presence of endogenous, 2-celled gemmae confined towards apical portion of the dorsal surface of thallus.

Singh and Singh (2006) recorded this species for the first time in Indian bryoflora. Among the Indian species of the genus, *R. palmata* partially resembles *R. lachungensis*, *R. palmatiformis*, *R. perssonnii* and *R. tenuicostata* in small, up to 10 mm long plants, but differs considerably from them in the presence of gemmae. It further differs from *R. lachungensis* in strongly biconvex thallus with mamillate-palillate epidermal cells in the latter.

Habitat: Terrestrial, growing in moist, shady places in association with *Scapania verrucosa* Heeg and mosses.

Distribution: India [Eastern Himalaya (Sikkim)], China, Japan, Russia, Taiwan, Europe, North America (Stotler and Stotler, 1977; Piippo, 1990; Furuki, 1991; Schuster, 1992; Singh and Singh, 2006; Yamada and Iwatsuki, 2006; Ros *et al.*, 2007; Konstantinova *et al.*, 2009; Wang *et al.*, 2011).

Specimens examined: **INDIA**: Eastern Himalaya, Sikkim, East district, Pangthang, c. 1988 m, 5 Mar. 2005, *D. Singh* 36466 (CAL); Gaurigaon, c. 1650 m, 29 Oct. 2005, *D. Singh* 36695 (CAL); North district, Hemkhula, c. 2300 m, 1 May 2004, *D. K. Singh & D. Singh* 35302A (CAL).

6. *Riccardia palmatiformis* Schiffn., Pande & K.P. Srivast., J. Indian Bot. Soc. 38: 538. 1959.

Description and illustrations: Schiffner *et al.* (1959)

Note: *Riccardia palmatiformis* is characterized by dioicous plants, 6–8 mm long, 0.35–0.45 mm wide, palmately branched, branches long, fan-shaped; main thallus 4–5 cells thick in the middle; primary branches 3 cells thick in the middle, and female branches with filamentous–triangulate-lingulate scales.

Srivastava and Udar (1976) considered *R. palmatiformis* very close to *R. levieri*. However, it is

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distinct in 15–22 mm long, 0.4–1.2 mm wide, pinnately branched plants, with main thallus 6–7 (–8) cells thick in the middle, and female branches with fringed-laciniate scales in the latter (see also Schiffner *et al.*, 1959).

Habitat: Terrestrial, growing in moist and shady places in association with *Conocephalum japonicum* (Thunb.) Grolle, *Heteroscyphus hyalinus* (Steph.) S.C. Srivast. & Abha Srivast., *Riccardia tenuicostata* and *R. udarii* D.Singh & D.K.Singh.

Distribution: India [Eastern Himalaya (Sikkim, West Bengal)], endemic (Schiffner *et al.*, 1959; Singh *et al.*, 2008).

Specimens examined: **INDIA**: Eastern Himalaya, Sikkim, East district, Pangthang, c. 1988 m, 27 Oct. 2005, *D. Singh* 36652A (CAL); North district, Chungthang, 27°47′45.5″N, 88°33′18.6″E, c. 1874 m, 5 May 2004, *D.K. Singh & D. Singh* 35487 (CAL); 25 Nov. 2009, *D. Singh* 46694 (CAL); South district, Shimkharkha, 27°14′21.3″N, 88°25'31.1″E, c. 1421 m, 14 Dec. 2013, D. Singh 60673, 60674B (CAL).

7. *Riccardia sikkimensis* (Steph.) Pandé & K.P.Srivast., J. Indian Bot. Soc. 37: 417. 1958. *Aneura sikkimensis* Steph., Sp. Hepat. 6: 42. 1917.

Description and illustrations: Srivastava and Udar (1976)

Note: *R. sikkimensis* is characterized by dioicous plants, 8 – 16 mm long, 0.4–0.9 mm wide, pinnately branched; main thallus 11–13 cells thick in the middle; primary branches 6–7 cells thick; pigmented cells in the thallus 1–2, scattered; bicelled, endogenous gemmae confined towards apical portion on dorsal surface of thallus, and female branches with filamentous–triangular-lingulate scales.

R. sikkimensis resembles *R. elata* and *R. palmata* in the presence of endogenous gemmae. However, while it differs from the former which has much larger (50–80 mm long), 3-pinnately branched plants devoid of pigmented cells in the thallus tissue, it is distinct from the latter having 7–8 cells thick main thallus lacking pigmented cells (see also Srivastava and Udar, 1976). Srivastava and Udar (1976) reported the species from Western Himalaya without any specific locality or literature reference. But, it has never been collected or reported again from anywhere in this territory.

Habitat: Terrestrial, growing in moist and shady places in association with *Calypogeia aeruginosa* Mitt., *Herbertus aduncus* (Dicks.) Gray subsp. *aduncus* and *Metacalypogeia alternifolia* (Nees) Grolle often under slowly dripping water or near moist and shady places.

Distribution: India [Western Himalaya (without specific locality), Eastern Himalaya (Arunachal Pradesh, Meghalaya, Sikkim, West Bengal)], endemic (Srivastava and Udar, 1976; Singh, 1996; Singh and Nath, 2007; Singh *et al*., 2008).

Specimens examined: **INDIA**: Eastern Himalaya, Sikkim, East district, Pangthang, c. 1988 m, 1 May 2004, *D.K. Singh & D. Singh* 35296B (CAL); 5 Mar. 2005, *D. Singh* 36512, 36516 (CAL); 11 Jun. 2006, *D.K. Singh & D. Singh* 40905, 40909 (CAL); 3 Mar. 2008, *D. Singh* 41066, 41078 (CAL); Fatak, c. 1900 m, 5 Mar. 2005, *D. Singh* 36468 (CAL); 3 km from Padamchen towards Zaluk, c. 2273 m, 5 Jun. 2006, *D.K. Singh & D. Singh* 39769 (CAL); West district, Barsey *Rhododendron* Sanctuary 27°12′34.7″N, 88°08′04.2″E, c. 2875 m, 10 Mar. 2010, *D. Singh & S. Majumdar* 47666, 47667, 47686 (CAL); North district, Hemkhula, c. 2300 m, 1 May 2004, *D. K. Singh & D. Singh* 35304 (CAL); Manul, c. 1500 m, 2 May 2004, *D. K. Singh & D. Singh* 35337 (CAL); Bansoi, 27°44′05″N, 88°31'40″E, c. 2310 m, 3 May 2004, *D. K. Singh & D. Singh* 35358 (CAL); 23 May 2010, *D. Singh* 52090 (CAL); Toong, c. 2800 m, 5 May 2004, *D.K. Singh & D. Singh* 35504 (CAL); Shinghik, 27°30′39.7″N, 88°29′51.7″E, 1321 m, 5 May 2004, *D. K. Singh & D. Singh* 35526 (CAL); Passidong, 27°33′06.7″N, 88°27′32.1″E, c. 923 m, 28 Nov. 2009, *D. Singh* 47714 (CAL); Dobang Valley, 27°43′35.2″N, 88º45′15.2″E, c. 2920 m, 21 May 2011, *D. Singh* 52022A (CAL); Tendoong, 27°33′06.7″N, 88°27′32.1″E, c. 923 m, 17 Dec. 2013, *D. Singh* 62413A (CAL); Shingba *Rhododendron* Sanctaury, 27º44'03.5"N, 88º44′23.3″E, c. 3208 m, 25 May 2011, *D. Singh* 52082 (CAL); Lachen, 27°45′12.4″N, 88°32′30″E, c. 2698 m, 20 Mar. 2013, *D. Singh* 62417A (CAL); Akar, 27°42′46.81″N, 88°33′20.8″E, c. 2603 m, 21 Mar. 2013, *D. Singh* 60455 (CAL).

8. *Riccardia tenuicostata* Schiffn., Kaiserl. Akad. Wiss. Wien, Math.- Naturwiss Kl., Denkschr. 67: 166. 1898.

Description and illustrations: Srivastava and Udar (1976)

Note: *R. tenuicostata* is characterized by monoicous plants, 6–10 mm long, 0.3–0.4 mm wide, pinnately–bipinnately branched, frequent presence of stoloniferous branches, main thallus 5–6 cells thick in the middle, 3 cells thick ultimate branches, and 4–10-paired androecial chambers.

Habitat: Terrestrial or corticolous, growing in moist and shady places in association with *Riccardia palmatiformis* Schiffn., Pande & K.P.Srivast. and *Scapania ferrguinea* (Lehm. & Lindenb.) Gottsche *et al.*

Distribution: India [Western Himalaya (Himachal Pradesh, Uttarakhand), Eastern Himalaya (Arunachal Pradesh, Meghalaya, Sikkim, West Bengal), Western Ghats (Kerala, Tamil Nadu)], Indonesia (Srivastava and Udar, 1976; Singh, 1996; Manju *et al.*, 2005; Singh and Nath, 2007; Singh *et al.*, 2008; Singh and Singh, 2009; Daniels, 2010; Söderström *et al.*, 2010).

Specimens examined: **INDIA**: Eastern Himalaya, Sikkim, East district, Pangthang, c. 1988 m, 27 Oct. 2005, *D. Singh* 36652B (CAL); West district, Tulodhop, 27°13′46.8″N, 88°06′07.7″E, c. 2751 m, 16 Jul. 2010, *D. Singh* 49021 (CAL); South district, Maenam Wildlife Sanctuary (Nidali), 27°18′40.2″N, 88°21″52.4″E, c. 2220 m, 19 Dec. 2011, *D. Singh* 51922A, 51938 (CAL).

9. *Riccardia udarii* D. Singh & D.K. Singh, ***sp. nov.***

Figs. 4 & 5

Holotype: India. Eastern Himalaya, Sikkim, South district, Shimkharkha, 27°14′21.3″N, 88°25′31.1″E, c. 1421 m, 14 Dec. 2013, *D. Singh* 60674A (CAL).

Plants light green–green when fresh, yellowish green in herbarium, 15–30 mm long, 1.2–1.5 mm wide, dichotomously branched, margin flat, entire; branches short or long, retuse or sometimes emarginate. **Mucilage** papillae present only at apex on the ventral surface of thallus, clavate, 37.5–62.5 × 12.5–17.5 µm, usually 2-celled. **Main** thallus with distinct midrib, or sometimes indistinct in apical portion, usually biconvex or plane at dorsal side and convex on ventral side in transverse section, 6–8 (–9) cells thick (250–325 µm) in

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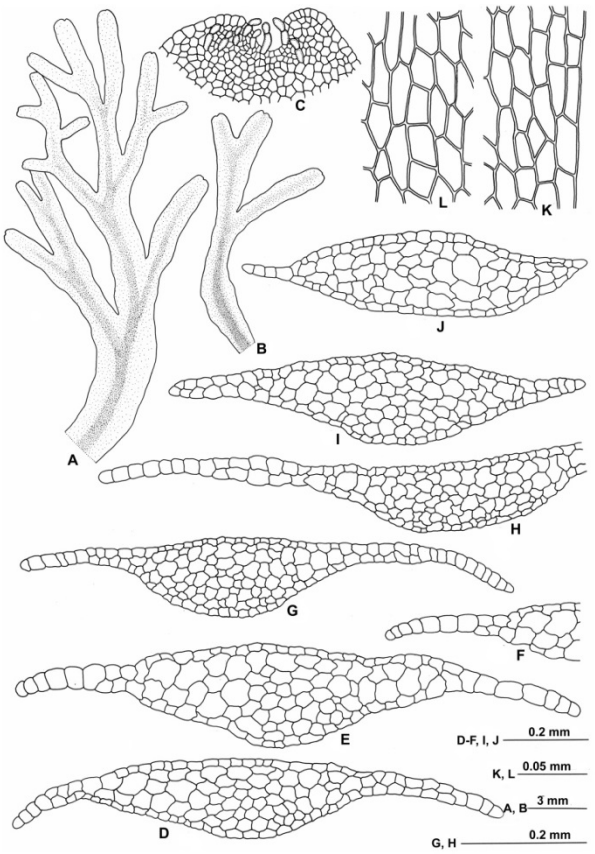


Fig. 4. ***Riccardia udarii*** D. Singh & D.K. Singh **A, B:** Vegetative thallus with midrib. **C:** Apical portion of thallus showing mucilage papillae. **D, E:** Transverse section of main thallus from older portion of thallus. **F:** The same from the margin showing wing. **G, H:** Transverse section of main thallus from middle. **I, J:** The same from ultimate branches. **K:** Marginal epidermal cells of thallus. **L:** Median epidermal cells of thallus (All figures drawn from Holotype)

the middle; unistratose alar portion of the wing 4–9 cells wide, bistratose or in 3 layers, 3–5 cells wide in middle portion near midrib; epidermal cells smaller than inner cells, cells in the central region of midrib often with purple pigmented walls; ultimate branches 6–12 mm long, 1.0–1.3 mm wide, biconvex in transverse section, 6–8 cells thick (225–300 µm) in the middle, margin usually unistratose or sometimes, bistratose; marginal epidermal cells of main axis, rectangulate, 62.5–112.5 × 15.0–30.0 µm, thin-walled; median epidermal cells pentagonal–hexagonal or polygonal, 50.0–112.5 × 20.0–50.0 µm, thin-walled with indistinct trigones. **Rhizoids** often present on ventral side at older portion of the plants, brownish. **Stolons** absent. **Gemmae** absent. **Androecial** and gynoecial branches not seen.

Habitat: Terrestrial, growing in very moist and shady places under slowly dripping water, in association with *Conocephalum japonicum*, *Heteroscyphus hyalinus* and *Riccardia palmatiformis*.

Distribution: India [Eastern Himalaya (Sikkim)], probably endemic.

Etymology: The species has been named after late Prof. Ram Udar, F.N.A., of the University of Lucknow, Lucknow for his outstanding contributions to Indian hepaticology.

Note: *Riccardia uadrii* is characterized by dichotomously branched thalli with distinct midrib (sometimes indistinct in apical portion) (Figs. 4: A, B; 5: A–C); main thallus 6–8 (–9) cells thick in the middle; unistratose alar portion of the wing 4–9 cells wide (Figs. 4: D–H; 5: E–J); 6–8 cells thick ultimate branches (Figs. 4: I, J; 5: K), and often presence of pigmented cells in the thallus (Figs. 5: E, I, J).

R. udarii resembles *R. robbinsii* Hewson & Grolle in having distinct midrib, but differs in gigantic plants, up to 120 mm long with quadripinnate branches; wings unistratose throughout and the ventral epidermal cells of midrib closely papillose in the latter (Grolle, 1966). In its thallus morphology and anatomy, *R. udarii* widely differs from hitherto all the known Indian species of the genus.

10. ***Riccardia villosa*** (Steph.) Pande & K.P. Srivast. ex S.C. Srivast. & Udar [J. Indian Bot. Soc. 37: 417. 1958; *nom. inval.*: Art. 32.2], Biol. Mem. 1: 129. 1976. *Aneura villosa* Steph., Sp. Hepat. 6: 45. 1917.

Description and illustrations: Srivastava and Udar (1976)

Note: *R. villosa* is characterized by small, dioicous plants, 6–14 mm long, 0.15–0.35 mm wide, pinnately branched; main thallus 8–10 cells thick in the middle; 5–7 cells thick ultimate branches, and the presence of pigmented cells in only 1–2 layers of thallus.

R. villosa is distinct among the Indian species of the genus in having pigmented cells in only 1–2 layers of the thallus.

Habitat: Terrestrial, growing in very moist and shady places in association with *Delavayella serrata* Steph., *Odontoschisma denudatum* (Nees) Dumort. and *Plagiochila vexans* Schiffn. ex Steph.

Distribution: India [Eastern Himalaya (Arunachal Pradesh, Meghalaya, Sikkim, West Bengal)], Bhutan (Srivastava and Udar, 1976; Long and Grolle, 1990; Singh, 1996; Singh and Nath, 2007).

Specimens examined: **INDIA**: Eastern Himalaya, Sikkim, Barsey *Rhododendron* Sanctuary (Lasune camp), c. 2738 m, 27°12′26.2″N, 88°08′22.5″E, 9 Mar. 2010, D. Singh & S. Majumdar 47396B (CAL); North district, 12 km from Lachung towards Katau, 27°40′53.5″N, 88°46′19.8″E, c. 3118 m, 24 May 2011, D. Singh 52136A (CAL).

Of the 10 species of the genus now recorded from Sikkim, *R. elata*, *R. lachungensis*, *R. palmata*, *R. palmatiformis*, *R. udarii* and *R. villosa* are so far known only from the East Himalayan bryogeographical region in Indian bryoflora, *R. sikkimensis* is doubtfully common with Western Himalaya, whereas the remaining taxa are common between Eastern Himalaya, Western Himalaya, Western Ghats and the Central India.

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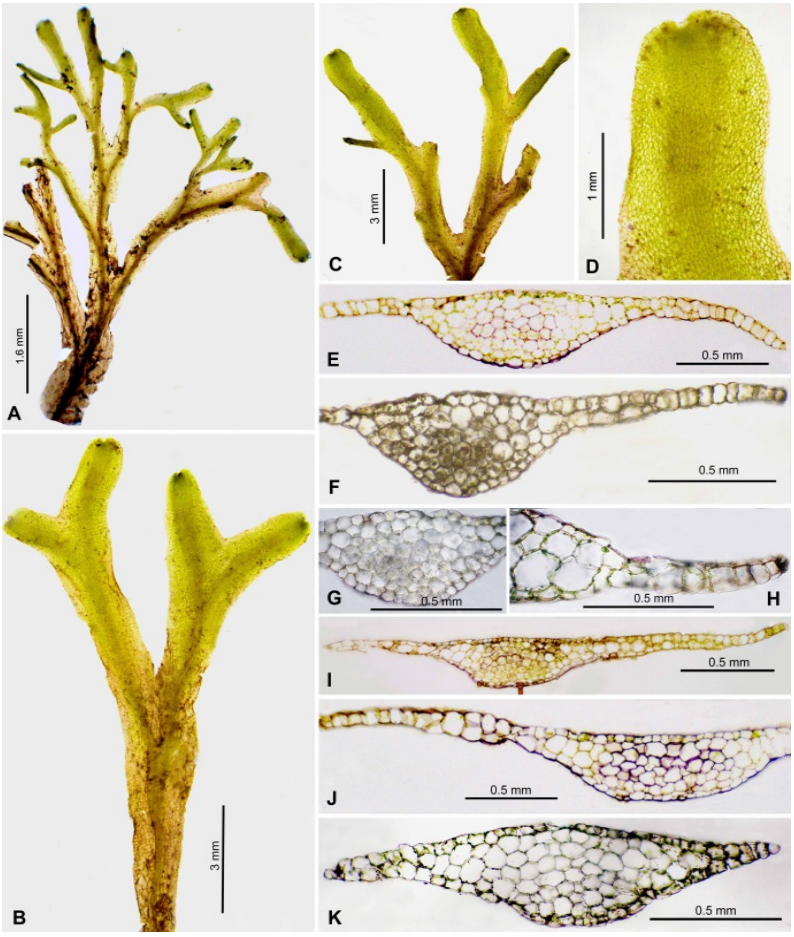


Fig. 5. ***Riccardia udarii*** D.Singh & D.K.Singh **A–C:** Vegetative thallus. **D:** Apical portion of thallus. **E, F:** Transverse section of main thallus from older portion. **G:** A portion of the same enlarged at middle. **H:** The same from the margin showing wing. **I, J:** Transverse section of main thallus from middle. **K:** The same from ultimate branches (All photomicrographs from Holotype).

EXCLUDENDA

Riccardia cardotii (Steph.) Pande & K.P. Srivast., J. Indian Bot. Soc. 37: 417. 1958. *Aneura cardotii* Steph., Bull. Soc. Roy. Bot. Belgique 41: 118. 1904.

This species was orginally described from India by Stephani (1904) from Kurseong (Sikkim), as *Aneura cardotii* Steph., based on the collections made by Stevens in 1900. Stephani (1917) later mentioned the distribution of the species Himalaya, Sikkim which was also followed by subsequent workers (Chopra, 1943; Srivastava & Udar, 1976). But, as Kurseong is presently part of Indian State of West Bengal, all previous records of *R. cardotii* from Sikkim are erroneous.

ACKNOWLEDGEMENTS

The authors thank the Director, Botanical Survey of India for facilities and encouragement and to the Chief Wildlife Warden, Sikkim Forest Department for facilitating the exploration work in Sikkim.

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