

Taxonomic studies on Thai Anthocerotophyta II. The genus *Notothylas* (Notothyladaceae)

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Abstract – The genus *Notothylas* Sull. in Thailand is reviewed, based on herbarium specimens and field surveys. Eight species of the genus are recognized and two of them, *N. pandei* Udar et V. Chandra and *N. yunannensis* T. Peng et R.L. Zhu, are newly recorded in the country. The new species *Notothylas frahmii* Chantanaorr. is described and illustrated. A key to species, brief descriptions and selected illustrations for the species of *Notothylas* of Thailand are provided.

Anthocerotophyta / hornworts / *Notothylas* / taxonomy / Thailand

INTRODUCTION

The genus *Notothylas* was established by Sullivant (1846) based on *Notothylas orbicularis* (Schwein.) Sull. & A.Gray and comprises about 23 species worldwide (Singh, 2002; Villarreal *et al.*, 2010; Peng & Zhu, 2014; Chantanaorrapint, 2014). *Notothylas* is widely distributed in tropical to temperate regions, and the highest species diversity of the genus is in the Indian subcontinent (Singh, 2002). *Notothylas* is easily separated from other genera of hornworts by the combination of the following characters 1) small and solid thallus; 2) very short sporophytes, laying horizontally on the thallus and being mostly enclosed in the involucre, and 3) epidermal cells of sporophyte without stomata.

Despite a taxonomic treatment of the Asiatic species of *Notothylas*, the genus is still rather poorly studied in Thailand (Lai *et al.*, 2008; Sukkharak & Chantanaorrapint, 2014). The first report of *Notothylas* in Thailand was published by Hasegawa (1979), who described a new species, *N. depressispora* J. Haseg., based on a collection made by N. Kitagawa from Chiangrai province. Lai *et al.* (2008) reported three additional species to the Thai flora, namely *N. javanica* (Sande Lac.) Gottsche, *N. levieri* Schiffn. ex Steph. and *N. orbicularis*. More recently, Chantanaorrapint (2014) described *N. irregularis* Chantanaorr. based on material collected in Thailand. In the present study current knowledge on Thai *Notothylas* is summarized, and a new species is described.

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MATERIALS AND METHODS

This study is based on fresh specimens collected throughout Thailand (Fig. 1) as well as herbarium specimens housed in BCU, BKF, CMU, G, L, M, PSU and SING. Morphological and anatomical characters were studied using stereo and compound microscopes to illustrate the distinctive characters of the species. Mature spores of all species (excepted *N. depressispora*) were removed from sporangia and mounted on double-stick cellophane adhesive tape affixed on stubs. Spores were then plated with a thin layer of gold and examined with a FEI Quanta 400 scanning electron microscope. In addition, data on distribution and ecology were compiled. Taxonomic notes, selected illustrations and a key to species are also provided.

RESULTS AND DISCUSSION

In this study eight species of *Notothylas* are accepted for Thailand. *Notothylas pandei* Udar *et* V. Chandra and *N. yunnannensis* T. Peng *et* R.L. Zhu are new additions to the hornwort flora of Thailand. A new species, *Notothylas frahmii* Chantanaorr., is proposed based on its distinct spore morphology. Thai *Notothylas* are either terrestrials or lithophytes, and are often found in more or less disturbed areas, from lowland to over 2300 m above sea level. The genus is widely distributed in the northern half of the country (Fig. 1). The most common species of *Notothylas* in Thailand is *N. javanica*, which occurs throughout the country.

KEY TO SPECIES OF *NOTOTHYLAS* IN THAILAND

1. Capsule without a dehiscence line; pseudoelaters absent or disintegrated when capsule opened or spores released.....2
 2. Epidermal cells of capsule thick-walled; proximal facets of the spore without a central hollow*N. javanica*
 2. Epidermal cells of capsule slightly thick-walled; proximal facets of the spore with a central hollow.....*N. yunnannensis*
1. Capsule with a dehiscence line; pseudoelaters present or lacking.....3
 3. Mature spores dark brown to blackish, tuberculate, papillate or vermiculate ... 4
 4. Thalli bearing tubers; capsule up to 4 mm long, with 2-3 rows of thick-walled and reddish brown cells, columella present; pseudoelaters without helicoidal thickenings; proximal facets of the spore with central hollow*N. pandei*
 4. Thalli without tubers; capsule less than 2.5 mm long, with 4-8 rows of thick-walled and reddish brown cells, columella present, pseudoelaters with helicoidal thickenings; proximal facets of spore not as above
..... *N. levieri*
3. Mature spores yellowish to pale brown, vermiculate.....5
 5. Pseudoelaters well developed, with helicoidal thickenings; proximal facets of the spore without a central hollow.....*N. orbicularis*

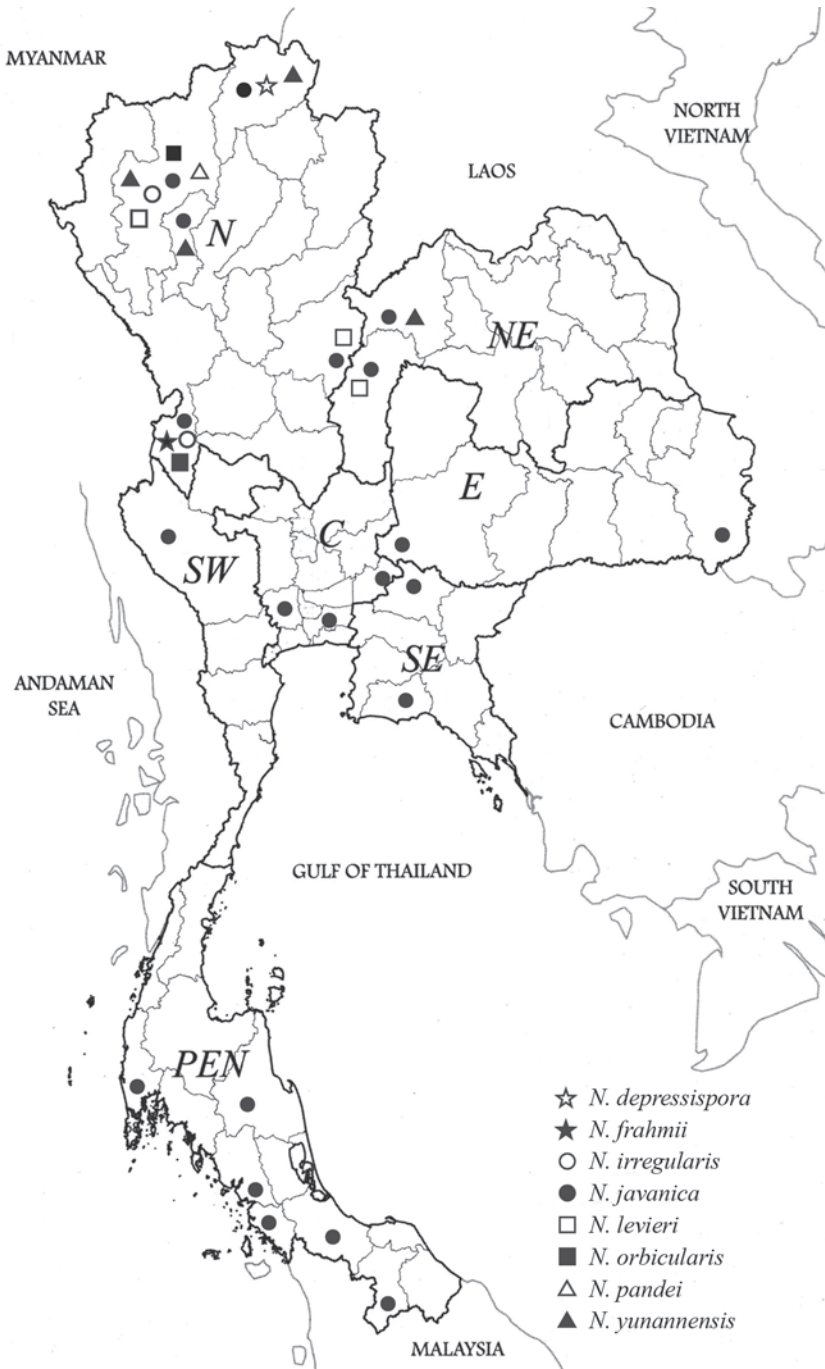


Fig. 1. Distribution of the species of *Notothylias* in Thailand. Thai Floristic regions N = Northern, NE = North-Eastern, E = Eastern, SE = South-Eastern, C = Central, SW = South-Western, PEN = Peninsular.

5. Pseudoelaters lacking or not well developed, when present without thickenings; proximal facets of the spore with a central hollow6
6. Epidermal cells of capsules extremely thick-walled (7.5-10 μm), narrowly rectangular; pseudoelaters often present at releasing stage *N. depressispora*
6. Epidermal cells of capsule slightly thick-walled (2.5-4.5 μm); subquadrate to subrectangular; pseudoelaters lacking or disintegrated at releasing stage7
7. Distal face of the spore bearing central hump-like structures...*N. frahmii*
7. Distal face of the spore convex without central hump-like structures.....
..... *N. irregularis*

1. *Notothylas depressispora* J. Haseg., *Acta Phytotax. Geobot.* 30: 26. 1979

Figs 2-9

Type: Thailand. Chiang Rai province, Doi Tung Mt., north of Chiang Rai, ca. 1000 m alt., middle elevation of the mountain, on soil, 24 September 1967, *N. Kitagawa T-12394* (holotype KYO; isotypes G!, L!, NICH).

Notothylas depressispora is characterized by 1) the epidermal cells of capsule narrow rectangular and strongly thick-walled, 2) the presence of thick-walled dehiscence lines on the capsule, 3) each proximal face of spores with a central hollow, and 4) the distal face with a large hump-like projection.

Habitat: This species grows on soil ca. 1000 m above sea level.

Distribution: Endemic to Thailand (Hasegawa, 1979, fig. 4a-f & h).

2. *Notothylas frahmii* Chantanaorr., sp. nov.

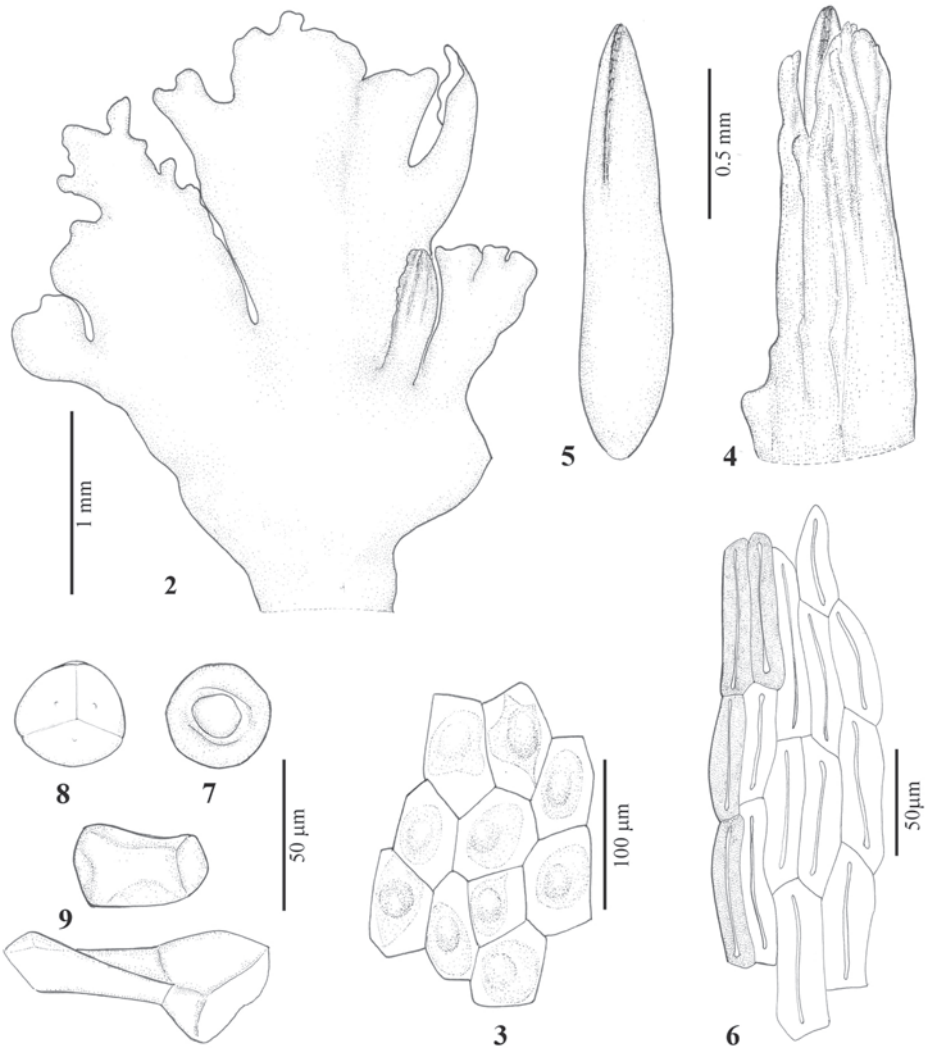
Figs 10-22

Diagnosis: *Notothylas frahmii* is similar to *N. irregularis* Chantanaorr., but differs in the distal face of the spore bearing a hump-like projection at its centre.

Type: Thailand. Tak province: Umphang district, Umphang Wildlife Sanctuary, Tee Lor Su Waterfall, 12 August 2013, *Chantanaorrapint & Promma 2735* (holotype PSU!, isotype BKF!).

Thalli yellowish-green to dark green in fresh material, forming orbicular or fasciculate rosettes, 8-20 mm in diameter, densely overlapping when well-developed, prostrate or moderately adhering to the substratum, irregularly branched, without tubers, flattened dorsally and convex on the ventral side in transverse section, 5-7 cells thick in the middle, with a smooth dorsal surface; margin deeply lobed, lobes narrow, apex truncate or shortly lacerate; dorsal epidermal cells subquadrate, rectangular, or irregularly hexagonal, 40-80 \times 30-60 μm , with a solitary chloroplast; pyrenoid present. *Nostoc* colonies irregularly found on the ventral side of thallus, appearing as dark dots. **Rhizoids** hyaline, inner wall smooth.

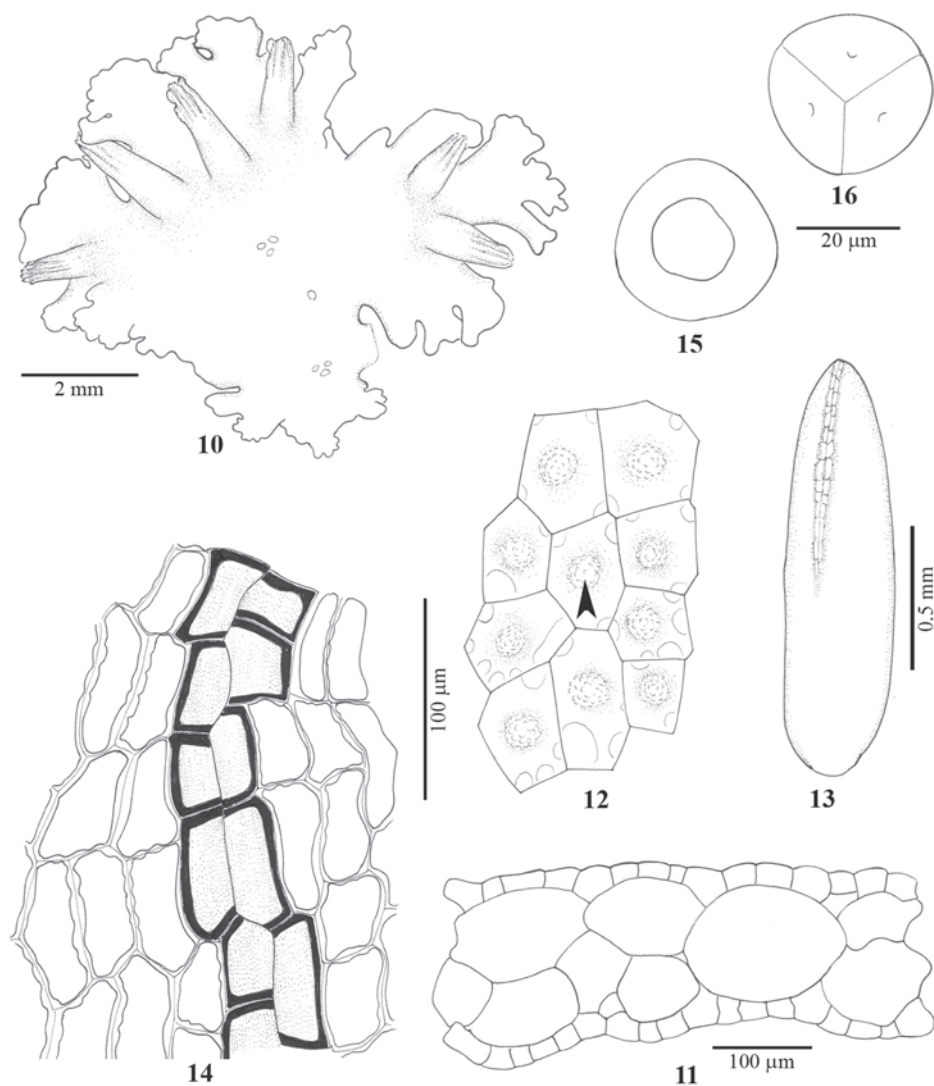
Monoicous (protandrous). **Androecia** scattered, antheridia 2-3 per cavity, subglobose, 85-105 μm in diameter. **Involucre**s usually solitary, spreading horizontally or slightly ascending, conical to cylindrical, rather thick, longitudinally plicate or lamellate. **Capsules** cylindrical or elliptic-oblong, 1.3-2.2 mm long, 0.3-0.4 mm in diameter, completely enclosed by the involucre, capsule dehiscing longitudinally along suture lines, with 2-3 rows of thick-walled and reddish brown cells; capsule wall 2-3(-4) cell layers thick; epidermal cells subquadrate to rectangular, 45-80 \times 20-40 μm ; moderately thick-walled, sometimes with irregularly nodulose thickenings; columella well-developed. **Spores** yellowish, rounded-triangular in



Figs 2-9. *Notothylos depressispora* J. Haseg. **2.** Thallus with young sporophyte. **3.** Dorsal epidermal cells of thallus showing a single chloroplast. **4.** Capsule and involucre. **5.** Capsule with dehiscence line. **6.** Epidermal cells of the capsule showing a row of thick-walled and reddish brown cells. **7.** Proximal view of spore. **8.** Distal view of spore. **9.** Pseudoelaters. All drawn from *N. Kitagawa T-12394* (isotype, G).

polar view, equatorial view fan-shaped, equatorial diameter 28-32.5 μm , vermiculate; proximal portion subpyramidal, each proximal facet with a central depression; distal face with a large hump-like projection at the centre. **Pseudoelaters** rarely present, usually disintegrated at the late stages of development.

Habitat: The type specimen was found growing with other hornworts such as *Anthoceros argillaceus* Steph., *A. subtilis* Steph., and *Phaeoceros carolinianus* (Michx.) Prosk., on disturbed soil along a walking trail ca. 300-500 m above sea level.



Figs 10-16. *Notothylas frahmii* Chantanaorr. **10.** Thallus with sporophytes. **11.** Transverse section of thallus. **12.** Dorsal epidermal cells of thallus showing a single chloroplast with a pyrenoid (label). **13.** Capsule with dehiscence line. **14.** Epidermal cells of the capsule showing a row of thick-walled and reddish brown cells. **15.** Proximal view of spore. **16.** Distal view of spore. All drawn from *Chantanaorrapint & Promma 2735* (holotype).

Additional specimens examined: Tak, Umphang, Umphang Wildlife Sanctuary, Tee Lor Su Waterfall, 12 August 2013, *Chantanaorrapint & Promma 2736B* (PSU!); Thung Yai Naresuan Wildlife Sanctuary, 14 August 2013, *Chantanaorrapint & Promma 2817A* (PSU!)

Distribution: *Notothylas frahmii* is known only from the type locality; however it may also occur in other areas in northern and south-western Thailand with similar climatic conditions.

Etymology: The epithet “*frahmii*” honours the late Prof. Dr. Jan-Peter Frahm.

Taxonomic notes: *Notothyas frahmii* is characterized by each proximal spore surface with a small central hollow, the distal face with a large hump-like projection, the epidermal cells of the capsule subquadrate to rectangular, irregularly arranged and moderately thick-walled; and presence of a special dehiscence line in the capsule.

Notothyas frahmii is morphologically similar to *N. irregularis*, and both species bear a dehiscence line on the capsule, the rest of the epidermal cells of the capsule are subquadrate to rectangular and irregularly arranged. Both species have vermiculate spores with a small hollow on each proximal face. The main diagnostic character of *Notothyas frahmii* is the presence of a large hump-like projection on the distal spore face. The new species also resembles *N. depressispora*, which also has vermiculate spores with a small hollow on each proximal facet, and the distal face bearing a large hump-like projection. However, they can be distinguished the shape of the epidermal cells of the capsule.

Depending on the presence or absence of a small hollow on each proximal facet of spore, Schuster (1992) divided *Notothyas* into two sections, *Notothyas* sect. *Depressisporae* R.M. Schust. and *Notothyas* sect. *Notothyas*. Based on this classification, *N. frahmii* fits sect. *Depressisporae* in having vermiculate spores with a small hollow on each proximal facet. These features are shared with *N. frahmii*, *N. depressispora*, *N. dissecta* Steph., *N. irregularis*, *N. pandei*, and *N. yunannensis*. The main morphological differences between these six species are summarized in Table 1. Within the classification of Asthana and Srivastava (1991), however, *N. frahmii* resembles the species in subgenus *Notothyas*, in having a well developed columella and a capsule wall with 2-3 rows of thick-walled and reddish brown cells. The infrageneric classification of the genus *Notothyas* is in need of a molecular phylogenetic study.

3. *Notothyas irregularis* Chantanaorr., *Acta Bot. Hung.* 56: 270, 2014

Figs 23-24

Type: Thailand. Chiang Mai, Chiang Dao District, Doi Chiang Dao Wildlife Sanctuary, 1633 m, 19°23'35.70"N, 98°53'11.26"E, 9 August 2012, *Chantanaorrapint & Inuthai 1615* (holotype PSU!, isotypes BKF!, EGR!, G!)

Notothyas irregularis is morphologically close to *N. yunannensis*, which also has vermiculate spores with a small hollow on each proximal facet, and subquadrate to rectangular, irregularly arranged epidermal capsule cells. *Notothyas irregularis* differs from *N. yunannensis* by the presence of a capsule dehiscence line and a more finely vermiculate proximal face of the spores.

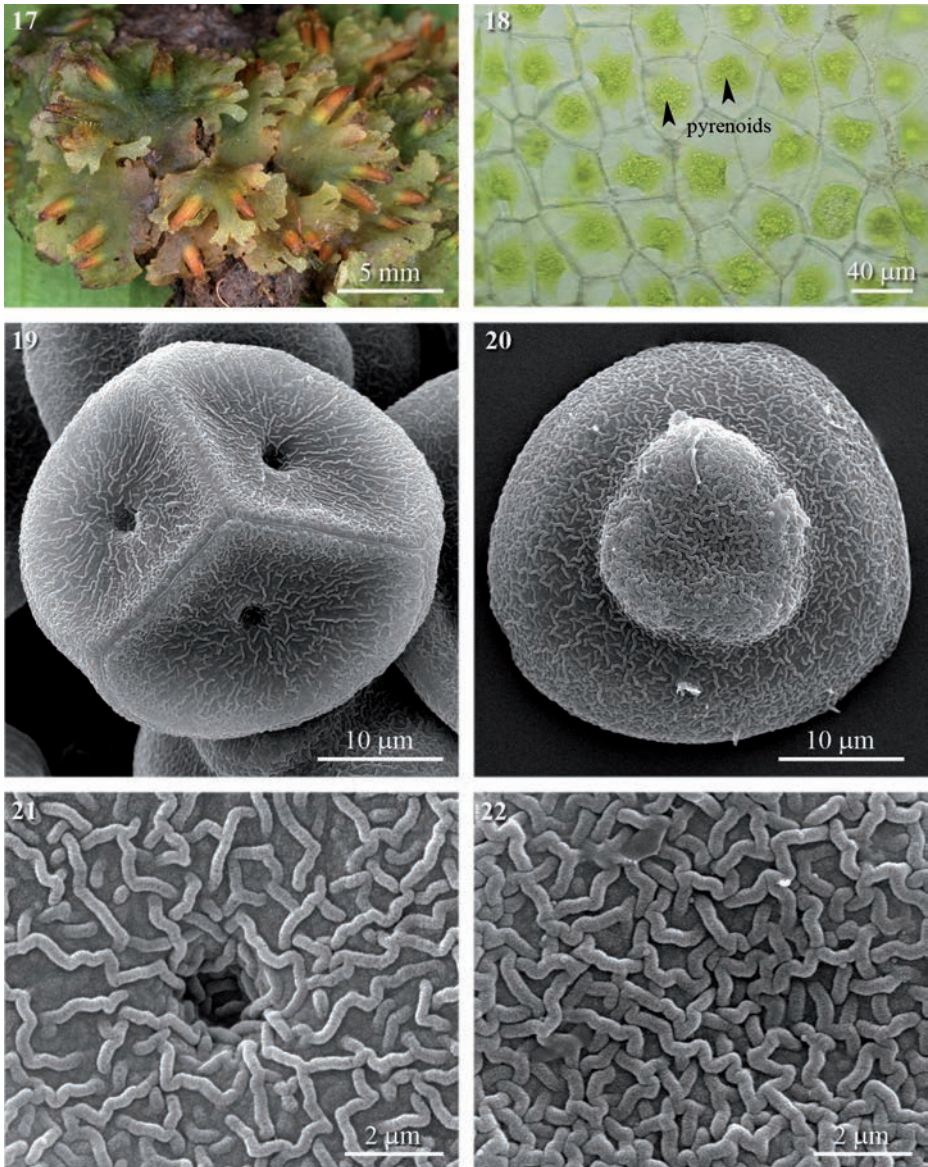
Habitat: This species was found growing with other hornworts such as *Anthoceros subtilis* Steph., *Notothyas orbicularis* and *Phaeoceros perpusillus* Chantanaorr., on disturbed soil along walking trails between 1600 and 1900 m in rainy season.

Distribution: Endemic to Thailand (Chantanaorrapint, 2014).

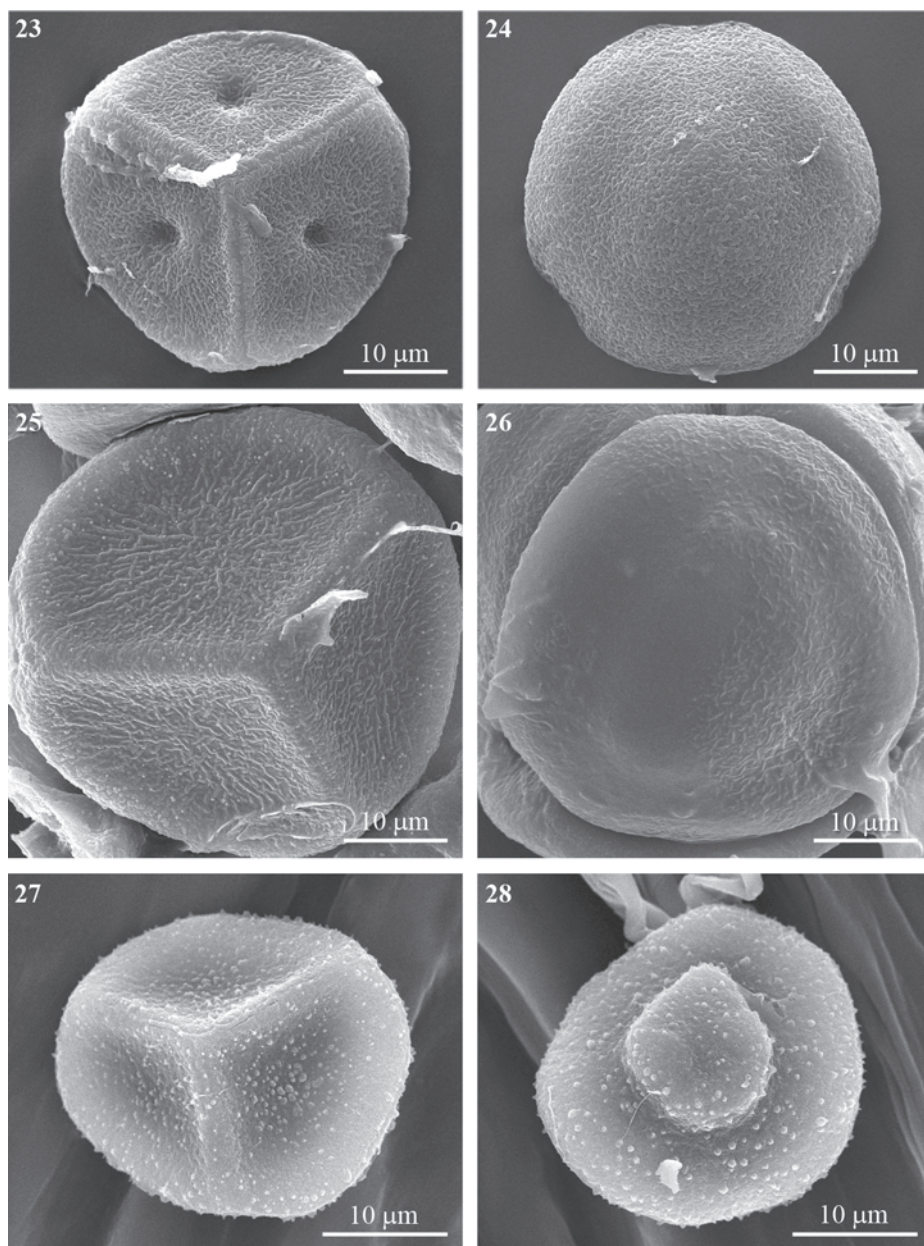
Additional specimens examined: Chiang Mai, Chiang Dao District, Doi Chiang Dao Wildlife Sanctuary, 19°39'269"N, 98°87'331"E, 8 August 2012, *Chantanaorrapint & Inuthai 1605* (paratype: PSU), 9 August 2012, *Chantanaorrapint & Inuthai 1614B* (PSU); 1884 m; Doi Suthep-Pui National Park, Doi Mon Long view point, 1400 m, 4 August 2005, *S. Chantanaorrapint et al. 03* (PSU).

Table 1. Morphological comparison of *Nothothylias depressisspora*, *N. dissecta*, *N. frahmii*, *N. irregularis*, *N. pandei*, and *N. yunannensis*: concerning the sporophyte characters

Characters	<i>N. depressisspora</i>	<i>N. dissecta</i>	<i>N. frahmii</i>	<i>N. irregularis</i>	<i>N. pandei</i>	<i>N. yunannensis</i>
Dehiscence line	present	present	present	present	present	absent
Epidermal cells	strongly thick walled	strongly thick walled	moderately thick walled	moderately thick walled	strongly thick walled	moderately thick walled
arrangement	regular	regular	irregular	irregular	regular	irregular
shape	rectangular	rectangular	subquadrate to subrectangular	subquadrate to subrectangular	rectangular	subquadrate to subrectangular
Pseudoelater	always present	always present	mostly disintegrated	mostly disintegrated	well developed	mostly disintegrated
helical thickenings	poorly developed	well developed	absent	absent	poorly developed	poorly developed
Spore						
color	yellowish to pale brown	brownish	yellowish	yellowish to pale brown	dark brown to blackish	pale yellow
ornamentation	finely vermiculate	tuberculate	finely vermiculate	finely vermiculate	vermiculate to finely granulate	coarsely vermiculate
distal face	with hump-like structures	with hump-like structures	with hump-like structures	without hump-like structures	with 1-3(-4) globular projection	without hump-like structures
proximal face	vermiculate with central hollow	tuberculate with central hollow	vermiculate with central hollow	vermiculate with central hollow	vermiculate with central hollow	depression with radiating vermiculate
size	30-32.5 µm	27.5-30 µm	28-32.5 µm	30-35 µm	28-32 µm	28-36 µm
Columella	poorly developed	well developed with helical thickenings	well developed without helical thickenings	well developed without helical thickenings	well developed without helical thickenings	well developed without helical thickenings



Figs 17-22. *Notothylas frahmii* Chantanaorr. **17.** Thalli with sporophytes. **18.** Dorsal epidermal cells of thallus showing a single chloroplast with a pyrenoid. **19-22.** SEM micrographs of spores. **19.** Proximal view of spore. **20.** Distal view of spore. **21.** Proximal spore surface with a small hollow in the centre and vermiculate structures. **22.** Close-up of the distal face showing densely vermiculate surface. All from *Chantanaorrapint & Promma 2735* (holotype).



Figs 23-28. SEM micrograph of spores. **23-24.** Spores of *Notothylas irregularis* Chantanaorr. from *Chantanaorrapint & Inuthai 1615* (holotype, PSU). 23. Proximal view. 24. Dorsal view. **25-26.** Spores of *Notothylas javanica* (Sande Lac) Gottsche from *Chantanaorrapint 2478* (PSU). 25. Proximal view. 26. Dorsal view. **27-28.** *Notothylas levieri* Schiffn. ex Steph. from *Frahm 2006571* (PSU). 27. Proximal view. 28. Dorsal view.

**4. *Notothylas javanica* (Sande Lac.) Gottsche, *Bot. Zeitung (Berlin)* 16: 20. 1858
Figs 25-26**

Basionym: *Blasia javanica* Sande Lac., *Syn. Hepat. Jav.*: 94. 1856. **Type:** Indonesia. Java, *D.G.Holle s.n.* (holotype L!).

The main features of *Notothylas javanica* include the irregularly ruptured capsule without special dehiscence line, absence of pseudoelaters, epidermal cells of the capsule moderately thick-walled and irregularly arranged, and yellowish spores. *Notothylas javanica* shares its spore sculpturing and the shape of the epidermal capsule wall cells with the African *N. decurva* (Mitt.) Steph. However, it differs from *N. decurva* in the absence of pseudoelaters (Stieperaere & Matcham, 2007). *Notothylas javanica* also resembles *N. orbicularis* in sporoderm ornamentation, the latter, however, is distinguished from the former by the presence of a special dehiscence line which consists of thick-walled cells, regularly arranged epidermal cells, and presence of pseudoelaters.

Habitat: In Thailand, *N. javanica* usually grows on more or less disturbed soil from 100 to 1500 m. It may grow associated with *Fissidens* spp. and *Riccia billardieri* Nees & Mont.

Distribution: China, Congo, Indonesia (Java), Japan, Philippines (Luzon), Thailand (Hasegawa, 1979; Stieperaere & Matcham, 2007; Lai *et al.*, 2008; Peng & Zhu, 2014).

Specimens examined: Chiang Rai, Doi Chang, 1200-1400 m, 14 August 2011, *Chantanaorrapint 2478* (PSU), Khun Korn waterfall, 200 m, 15 August 2011, *Chantanaorrapint 2496, 2497* (PSU), Doi Tung, 1200 m, 16 August 2011, *Chantanaorrapint 2504* (PSU); Chiang Mai, Doi Suthep-Pui National Park, Sirindhorn observatory area, ca. 800 m, 17 September 2005, *Manachit 171/2, 208* (CMU), 6 September 2011, *Printarakul 4706* (CMU), 12 November 2011, *Chantanaorrapint & Inuthai 346* (PSU); 6 October 2012, *Chantanaorrapint & Promma 1665, 1695* (PSU); TAK, Umphang, Umphang Wildlife Sanctuary, Tee Lor Su Waterfall, 13 August 2013, *Chantanaorrapint & Promma 2785, 2789* (PSU); Kanchanaburi, Thong Pha Phum national park, 200 m, 15 August 2007, *Chantanaorrapint 2000* (PSU); Yala, Betong, Ban Piyamit 2, on disturbed soil, 1000 m, 14 June 2013, *Chantanaorrapint & Promma 2488* (PSU).

5. *Notothylas levieri* Schiffn. ex Steph., *Sp. Hepat.* 5: 1021. 1917 Figs 27-28

Type: India. Eastern Himalaya, Kurseong, October 1898, *Rev. P. Decoly & Schaul s.n.* (holotype G-18906!, isotype M!).

Notothylas levieri is characterized by the 1) absence of a columella, 2) dark brown spores, 3) dehiscence lines consisting of 4-8 rows of thick-walled cells, 4) exine surface of spores tuberculate, and 5) distal surface of spores with 2-3 globular projections. It is easily separated from the other species of *Notothylas* in Thailand by the absence of a columella and tuberculate spores.

Habitat: On moist soil or sandy rocks in shaded environments, loosely fixed to the substratum, at altitudes between 1000 and 2200 m. This species often grows associated with other bryophytes such as *Anthoceros* spp., *Asterella khasyana* Pandé *et al.*, *Cyathodium cavernarum* Kunze, and *Fissidens* spp.

Distribution: China, India, Nepal, Thailand (Asthana & Srivastava, 1991; Singh, 2002; Lai *et al.*, 2008; Peng & Zhu, 2014).

Specimens examined: Chiang Mai, Doi Chiang Dao, 1400-2200 m, 11 December 2011, *Chantanaorrapint 2536B* (PSU), 6 September 2012, *Chantanaorrapint & Inuthai 1562* (PSU), 7 October 2012, *Chantanaorrapint & Promma 1702, 1710, 1711, 1793* (PSU), 29 October 2013, *Chantanaorrapint & Promma 3092, 3099, 3100, 3106A* (PSU); Doi Suthep-

Pui national park, road side of Phu Ping Palace, ca 1000 m, 4 September 2008, *Kornochalert 688* (CMU), 23 October 2011, *Printarakul 4972* (CMU), 12 November 2011, *Chantanaorrapint & Inuthai 371* (PSU), 6 October 2012, *Chantanaorrapint & Promma 1687* (PSU); Petchaboon, Khao Kho district, Khao Ya, ca 1000 m, on wet sandy rocks, *Chantanaorrapint, Inuthai & Promma 50* (PSU); Pitsanolok, Phu Hin Rong Khla national park, ca 1100-1400 m, on wet sandy rocks, 27 September 2016, *Frahm 2006571* (PSU) October 2010, *Chantanaorrapint, Inuthai & Promma 197, 203* (PSU).

**6. *Notothylas orbicularis* (Schwein.) Sull. ex A. Gray, *Amer. J. Sci. Arts* 1: 75. 1846
Figs 29-30**

Basionym: *Targionia orbicularis* Schwein., *Sp. Fl. Amer. Crypt.* 23: 1821.

Type: U.S.A. North Carolina, Forsyth, Salem, on moist earth, *L.D. Schweinitz s.n.* (holotype PH).

This species is characterized by the involucre distally lamellate, columella well developed and persistent, with irregular helicoidal thickening bands, and spores with vermiculate surface. These features characterize also *N. indica* Khasyap. An examination of neotype material of *N. indica* (*A.C. Joshi, s.n.*) in the herbaria M and SING pointed to a possible conspecificity of *N. indica* and *N. orbicularis*. However, more samples of these two taxa are needed to arrive at a more definite conclusion on their relationships.

Habitat: This species was found growing with other hornworts such as *Anthoceros subtilis* Steph., *Notothylas irregularis* and *Phaeoceros perpusillus*, on disturbed soil along walking trails between 1000 and 2300 m.

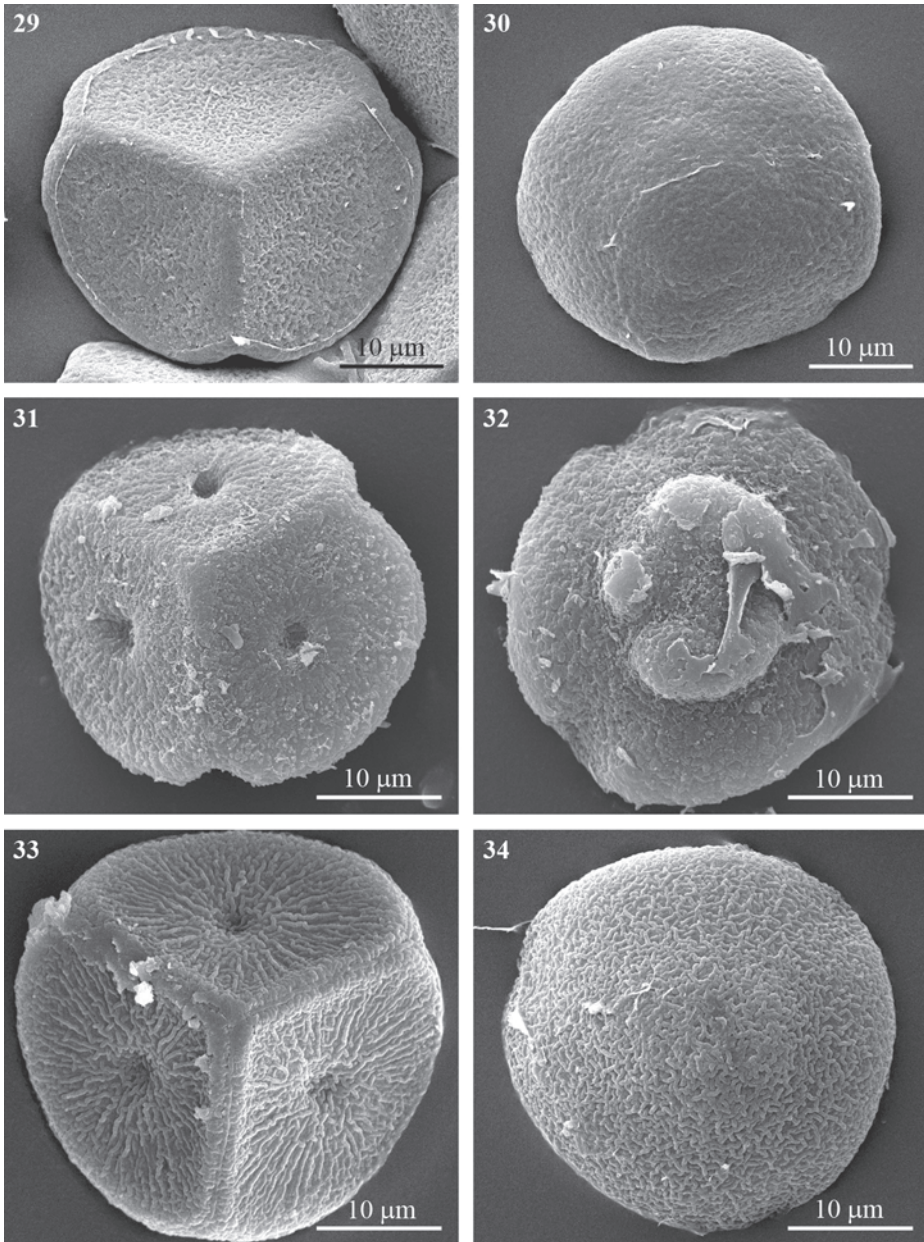
Distribution: *Notothylas orbicularis*, the most common species of *Notothylas*, is known from Africa, America, Asia and Europe (Hasegawa, 1979; Schuster, 1992; Stotler & Crandall-Stotler, 2005; Stieperaere & Matcham, 2007; Lai *et al.*, 2008; Peng & Zhu, 2014).

Specimens examined: Chiang Mai, Doi Chiang Dao, 1400-2300 m, 11 December 2011, *Chantanaorrapint 2536A* (PSU), 9 September 2012, *Chantanaorrapint & Inuthai 1558, 1559, 1587, 1600, 1616* (PSU), 31 October 2013, *Chantanaorrapint & Promma 3148* (PSU), 1 November 2013, *Chantanaorrapint & Promma 3220* (PSU); Doi Suthep-Pui national park, Sirindhorn observatory area, ca. 800 m, 8 August 2011, *Printarakul 4422* (CMU); road side of Phu Ping Palace, 1000 m, 6 October 2012, *Chantanaorrapint & Promma 1673, 1677, 1678, 1679, 1680* (PSU).

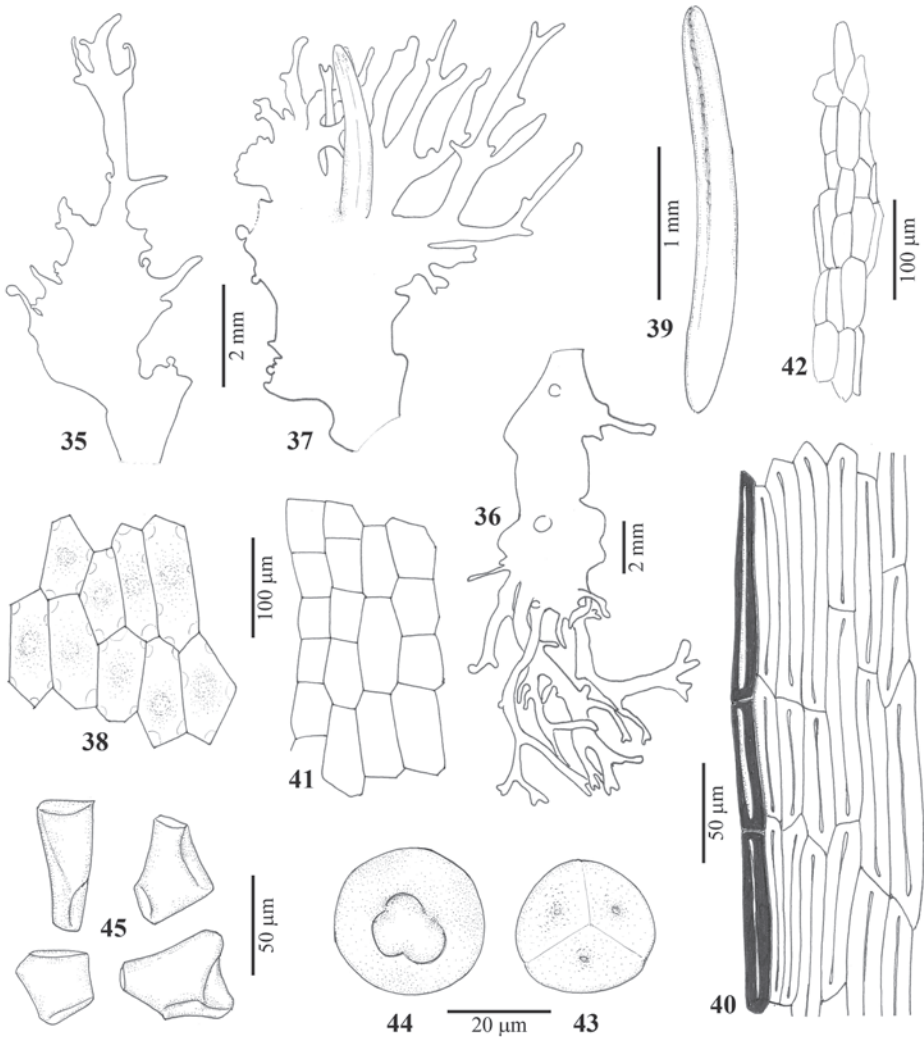
**7. *Notothylas pandei* Udar et V. Chandra, *Geophytology* 7: 142. 1977
Figs 31-32, 35-45**

Type: India, Shimoga, Jog falls, ca 500 m, October 1962, *R. Udar & V. Chandra NS528* (holotype LWU).

Thalli yellowish-green to dark green in fresh material, pale brown to blackish when dry, prostrate or moderately adhering to the substratum, ecostate, linear-oblong to obcordate, 8-12 mm long, 4-5 mm wide at apex, irregularly branched, 3-4(-5) cells thick in the middle, with a smooth dorsal surface; apex deeply lobed or lacinate, often attenuate with apical and ventral tubers; dorsal epidermal cells subquadrate, rectangular, or irregularly hexagonal, 55-120 × 30-60 μm, with a solitary chloroplast; pyrenoid present. *Nostoc* colonies irregularly on the ventral side of thallus, appearing as dark dots. **Rhizoids** hyaline, inner wall smooth.



Figs 29-34. SEM micrograph of spores. **29-34.** Spores of *Notothyas orbicularis* (Schwein.) Sull. ex A. Gray from *Chantanaorrapint & Promma 1679* (PSU). **29.** Proximal view. **30.** Dorsal view. **31-32.** Spores of *Notothyas pandei* Udar et V. Chandra from *Chantanaorrapint & Promma 1666* (PSU). **31.** Proximal view. **32.** Dorsal view. **33-34.** *Notothyas yunannensis* T. Peng et R.L. Zhu from *Chantanaorrapint & Promma 2882* (PSU). **33.** Proximal view. **34.** Dorsal view.



Figs 35-45. *Notothylas pandei* Udar et V. Chandra **35-36.** Sterile thalli. **37.** Thallus with sporophytes. **38.** Dorsal epidermal cells of thallus. **39.** Capsule with dehiscence line. **40.** Epidermal cells of the capsule showing the special row of thick-walled and reddish brown cells. **41.** The innermost of capsule wall. **42.** Columella. **43.** Proximal view of spore. **44.** Distal view of spore. **45.** Pseudoelaters. All drawn from the *Chantanaorrapint & Promma 1666* (PSU).

Monoicous. **Androecia** scattered, antheridia not seen. **Involucres** solitary, spreading horizontally or slightly ascending, conical to cylindrical, rather thick, smooth or slightly plicate. **Capsules** cylindrical or elliptic-oblong, up to 6 mm long, 0.3-0.5 mm in diameter, often completely enclosed by the involucre, capsule dehiscing longitudinally along suture lines, with 2-3 rows of thick-walled and dark brown cells; capsule wall 2-3(-4) cell layers thick; epidermal cells rectangular, 45-80 × 20-40 µm; strongly thick-walled; the inner most capsule wall cells dark brown,

subquadrate, rectangular, or irregularly hexagonal, 45-100 × 40-60 μm; columella well-developed, dark brown, lacking helicoidal band. **Spores** dark brown to blackish, rounded-triangular in polar view, equatorial view fan-shaped, equatorial diameter 28-32 μm, vermiculate to finely granulate; proximal portion subpyramidal, each proximal facet with a central depression; distal face with 1-3(-4) globular projection at the centre. **Pseudoelaters** well developed, pale to dark brown, subquadrate to rectangular, 30-55 × 25-40 μm, helicoidal band indistinct.

Habitat: In Thailand, *N. pandei* grows on moist soil and rock at 800-1000 m. in undisturbed area. It may grow associated with other bryophytes such as *Cyathodium cavernarum*, *Fissidens* spp. and *Targionia hypophylla* L.

Distribution: India (Asthana & Srivastava 1991; Singh, 2002), new to Thailand.

Specimens examined: Chiang Mai, Doi Suthep-Pui national park, Monthatarn waterfall, 700 m, 8 September 2009, *Printarakul 4972* (CMU), 6 October 2012, *Chantanaorrapint & Promma 1664* (PSU); Ru See Cave, 1100 m, 8 September 2009, *Printarakul 2146* (CMU), 12 November 2011, *Chantanaorrapint & Inuthai 350* (PSU), 6 October 2012, *Chantanaorrapint & Promma 1666* (PSU).

Taxonomic notes: *Notothyas pandei* is easily separated from other Thai species by the presence of tubers at the apical regions of the thallus lobes. The epidermal cells of the capsule are rectangular and strongly thick-walled, the proximal surface of the spores is finely granulate with a hollow at its center. The distal surface of spores has 1-3(-4) globular structures. Pseudoelaters are provided with a poorly developed helicoidal band. This species may be confused with *N. dissecta* because of the similar spore morphology. The latter species, however, is easily separated by its different inner capsule wall and pseudoelaters with a well developed helicoidal band.

8. *Notothyas yunnanensis* T.Peng et R.L.Zhu, *Phytotaxa* 156: 157. 2014

Figs 33-34

Type: China. Yunnan: Mengla Co., Menglun to Mengbang, 636 km, on moist soil by road, 27°49.833'N, 101°20.303'E, 1155 m, 15 July 2012, *T. Peng et al. 20120715-7* (holotype HSNU!).

Notothyas yunnanensis is characterized by 1) each proximal surface of spores with a central hollow, 2) the irregularly arranged, subquadrate to subrectangular epidermal cells of the capsule, 3) the absence of the special dehiscence lines of the capsule consisting of thick-walled cells, 4) the vermiculate ornamentation of spores radiating from a central hollow in each proximal surface, and 5) the presence of a columella. *Notothyas yunnanensis* is very similar to *N. irregularis*. For separation from the similar *N. irregularis*, see there.

Habitat: In Thailand, *Notothyas yunnanensis* grows on disturbed soil at 600-1200 m and is usually associated with other bryophytes, especially *Fissidens* spp., *N. javanica* and *Phaeoceros carolinianus*.

Distribution: China (Tao & Zhu, 2014), new to Thailand.

Specimens examined: Chiang Rai, Doi Chang, 1200 m, 13 August 2011, *Chantanaorrapint 2475* (PSU); Doi Tung, Doi Tung Royal Villa, 1005 m, 6 September 2013, *Chantanaorrapint & Promma 2832* (PSU); Lampang, Wang Nuea, Wang Kaew waterfall, 636 m, 7 September 2013, *Chantanaorrapint & Promma 2851* (PSU); Loei, Phu Kradueng National park, 600 m, 17 October 2013, *Chantanaorrapint & Promma 3084B* (PSU).

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