

Taxonomic Studies of Podostemaceae of Thailand. 3. Six New and a Rediscovered Species

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Abstract

Podostemaceae is an ecologically and morphologically unusual aquatic plant family. By examination of new collections from Thailand, we describe seven species, two of which are new species assigned to *Terniopsis* of Tristichoideae (*T. chanthaburiensis*, *T. minor*), four are new species assigned to *Hydrobryum* and *Polypleurum* of Podostemoideae (*H. phetchabunense*, *P. insulare*, *P. prachinburiense*, *P. sisaketense*), and one is *Zeylanidium lichenoides* rediscovered. In total, two subfamilies, 10 genera, and 42 species with four varieties occur in Thailand. A key to all the species is provided.

Introduction

Podostemaceae is an aquatic angiosperm family distributed in the tropics and subtropics of the world. The family is unusual ecologically and morphologically. Plants grow submerged on rock surfaces during the rainy season, and they flower and set fruits, while protruding and drying above the water, during the following dry season when the water level becomes low. The plants either adhere to the rocks by ribbon-like or crustose roots developed from the hypocotyl in most species with rudimentary or no primary shoots and roots, or by crustose or multi-branched adventitious shoots in rootless species. Kato (2004, 2006) and Koi *et al.* (2008) reported nine genera and 35 species from Thailand, the largest species number in Asia. In this paper, we describe six new species referred to four genera and a poorly known species, based on new molecular and morphological data and new collections. Molecular phylogenetic data (S. Koi, unpubl. data) are useful to identify species that are morphologically slightly different from its close relatives. As a result, 10 genera and 42 species assigned to two subfamilies occur in Thailand, indicating again the highest diversity of Podostemaceae in Asia. A key to all the species of Thailand is provided.

Taxonomy

Terniopsis chanthaburiensis M. Kato & Koi, *sp. nov.*

Terniopsis malayana ramulis ramosis similis, sed pedicellis longioribus differt; *T. brevis plantis parvis, ramulis usque brevibus, ad 3.5 mm longis similis, sed pedicellis longioribus differt.* – **Holotypus**: Southeastern Thailand. Chanthaburi Prov., Klong Yai, Pong Nam Ron District, 150 m alt., 12°56' N, 102°28' E, fl. Mar 2005, *T. Wongprasert 771601* (BKF; isotype, TNS). **Fig. 1.**



Figure 1. *Terniopsis chanthaburiensis*. A. Ramuli on flank of root; B. Reproductive shoot unit (at right), a flower comprises lobed calyx, two stamens and an ovary on pedicel; Based on Kato *et al.* TL-1402 (1A), Wongprasert 771601 (1B). Scale bars = 1 mm.

Root creeping, monopodially branched, flattened-subcylindrical, 0.5-1 mm wide; **ramuli** on both flanks of root, 3-6 mm long, simple or to 5 times branched; **leaves** in 3 ranks, oblong-elliptic, univeined, middle leaf to 1 mm × 0.5 mm, lateral leaf to 1-2 mm × 0.5-0.8 mm. **Flowering shoots** 1-4 per shoot

unit, associated with 4-5 ramuli to 5 mm long; pedicel with 2 bracts at base, 5-10 mm long; calyx membranaceous, 3-lobed 1/2 to base, 2/3-3/4 length of ovary; stamens 2, as long as ovary or shorter, *ca* 1.5 mm long; ovary obovoid-ellipsoid, *ca* 2 mm long, *ca* 1 mm thick, 3-locular; stigmas 3, separated from each other, cristate, 0.3 mm long; **capsule** stalked (stalk to 10 mm long), trigonous, ribs 9.

Other specimens examined: Southeastern Thailand. Chanthaburi Prov.: Klong Yai, Pong Nam Ron District, 150 m alt., 12°56' N, 102°28' E, st. Mar, *M. Kato et al. TL-1402* (BKF, TNS); fl.-buds Jan, *M. Kato et al. TL-1607* (BKF, TNS).

Ecology and distribution: On rocks in stream; vegetative plants submerged in the rainy season, and reproductive plants exposed in the air in the dry season; known only from the type locality.

Notes: Phylogenetically, this is a sister taxon to *T. malayana*, *T. brevis* and *T. minor*, and together, sister to the clade of *T. ubonensis* in eastern Thailand and *T. sessilis* in eastern central China (S. Koi, unpubl. result). This indicates that small morphological changes occurred in the diversification of *Terniopsis*: Thai species, in particular, *T. brevis*, *T. chanthaburiensis*, and *T. minor*, are little distinguished from the Chinese *T. sessilis* (Chao, 1980; Kato and Kita, 2003), but *T. chanthaburiensis* is distinct in the long pedicel. Also, *T. chanthaburiensis* is similar to *T. malayana* in the branched ramuli on the floriferous root, bud differs in having the long pedicel.

Terniopsis minor M. Kato & Koi, *sp. nov.*

A T. brevis simile, sed radicibus latioribus, ramulis longioribus, ad 3.5 mm longis, stigmatibus linearis differt. – **Holotypus:** Southeastern Thailand. Trat Prov., Klong Kaeo waterfall, Bo Phloi village, Bo Rai Distr., 12°37'29" N, 102°34'54" E, 170 m alt., fl. Jan 2007, *M. Kato, S. Koi, N. Katayama & T. Wongprasert TL-1609* (BKF, isotype, TNS). **Fig. 2.**

Root creeping, monopodially branched, flattened-subcylindrical, 0.7-1.5 mm wide; **ramuli** on both flanks of root, 4-7 mm long, simple; **leaves** in 3 ranks, oblong-elliptic, middle leaf to 1 mm × 0.3 mm, lateral leaf to 1.1 mm × 0.3 mm. **Flowering shoot** associated with single ramulus 1-3 mm long; pedicel with 2 bracts at base, 1.5-3 mm long; calyx membranaceous, 3-lobed 1/4 to base, as long as ovary; stamens 2, as long as ovary, 1-1.5 mm long; ovary obovoid-ellipsoid, 1-1.5 mm long, *ca* 0.7 mm thick, 3-locular; stigmas 3, separated from each other, linear-oblong, apex cristate, to 0.4 mm long; ovules *ca* 20 per locule; **capsule** stalked (stalk 2-3 mm long), trigonous, ribs 9.

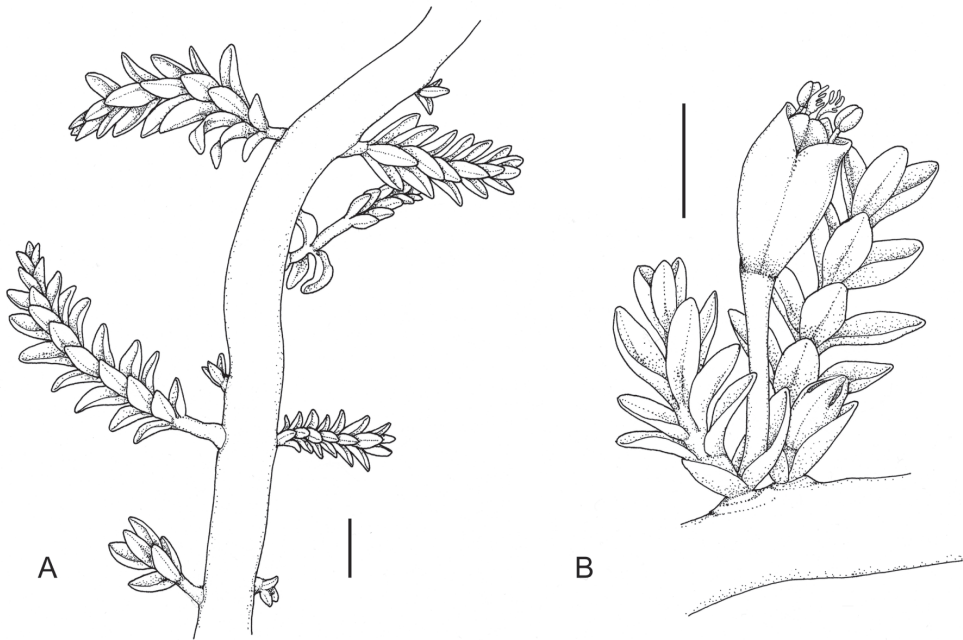


Figure 2. *Terniopsis minor*. A. Ramuli on flank of root; B. Two reproductive shoot units; left one with flower comprising lobed calyx, two stamens and ovary on pedicel; right one with flower bud. Based on *Kato et al. TL-1609*. Scale bars = 1 mm.

Other specimens examined: Nakhon Ratchasima Prov., Haew Narok Waterfall, Khao Yai National Park, 14°17' N, 101°24' E, 360 m, st. Dec, Jan, *Kato et al. TL-60, TL-309* (BKF, TNS); fl. Jan, *TL-1535* (BKF, TNS); st., fl. & fr. Jan, *R. Imaichi et al. TKF-25* (BKF, TNS). Chanthaburi Prov., Klong Yai, Pong Nam Ron District, 150 m alt., 12°56' N, 102°28' E, fl.-buds Jan, *M. Kato et al. TL-1608* (BKF, TNS). Trat Prov., Sato stream, Klong Sato, Bo Rai District, 12°42' N, 102°25' E, st., fl. & fr. Jan, *S. Koi et al. TKF-22* (BKF, TNS); Pong Nam Ron stream, Klong Yai, Pong Nam Ron District, 12°56' N, 102°28' E, st. Jan, *S. Koi et al. TKF-23* (BKF, TNS).

Ecology and distribution: On rocks in stream; vegetative plants submerged in the rainy season, and reproductive plants exposed in the air during the dry season; known only from the type locality and its vicinity.

Note: This species is phylogenetically sister to *T. brevis* and morphologically close to it also. However, it differs from *T. brevis* only in having wider roots, longer ramuli, and linear-oblong stigmas.

Polypleurum sisaketense M. Kato & Koi, *sp. nov.*

A congenris stigmatibus semiorbiculatis differt, P. wongprasertii, P. longifolii, P. phuwaensis et P. rubroradicans floris sessilibus, bracteis filiformibus, basi vanigatis simile, sed a P. wongprasertii ovulis plura, a P. longifolii foliis brevioribus, a P. phuwaensis spathellis brevioribus, a P. rubroradicans ovuliis plura differt. – **Holotypus:** Eastern Thailand. Si Sa Ket Prov., Phoolao waterfall, Kantharalak Dist., 14°27'17" N, 104°39'21" E, 180 m alt., fl. Jan 2006, M. Kato, S. Koi & T. Wongprasert TL-1502 (BKF; isotype, TNS). **Fig. 3.**

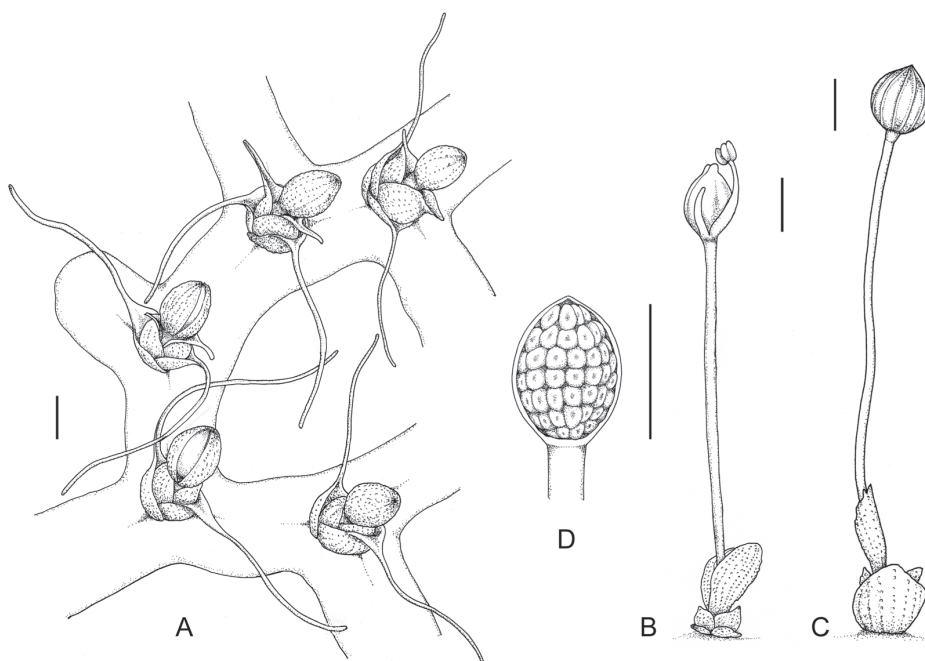


Figure 3. *Polypleurum sisaketense*. A. Flower buds enclosed by spathellas subtended by bracts at sinuses of root branches; two spathellas are rupturing; B. Flower comprising two tepals (one seen), one stamen and one ovary on pedicel with spathella and bracts at base; C. Fruit with spathella and bracts; D. Seeds in capsule with valve removed. All figures based on Kato *et al.* TL-1502. Scale bars = 1 mm.

Root ribbon-like, 2-3 mm wide, branched, with tufts of leaves on dorsal surface exclusively at sinuses between root branches; **leaves** 2-4 per tuft, 5-20 mm long, base sheath-like, scars forming mounds, distal part needle-like, relatively thick (*ca* 0.2 mm), caducous. **Flowering shoot** on dorsal surface at sinuses between root branches; bracts 2-4, sheath-like, papillate, needle-like with sheath-like base or ovate with needle-like part caducous; **flower** 1, bud covered by spathella, spathella 1.5-2 mm long, papillate, ruptured near apex

and also split longitudinally at anthesis, ellipsoid, narrowed to base; pedicel 4-8 mm long; tepals 2, 1 on each side of stamen, *ca* 0.5 mm long; stamen 1, inserted at base of ovary, 1.5-1.8 mm long, as tall as ovary; ovary 2-locular, globose-ellipsoid, slightly flattened, 1-1.5 mm long; stigmas 2, hemicircular, flattened, 0.1-0.2 mm long and wide, subequal (stigma facing stamen larger); ovules covering entire septum surface, 40-70 per locule; **capsule** stalked (stalk 5-10 mm long), subsymmetric, ribs *ca* 12.

Ecology and distribution: On rocks near waterfall; vegetative plants submerged in the rainy season, and reproductive plants exposed in the air in dry season; known only from the type locality.

Notes: Although it is difficult to distinguish this species from other congeners in most characters, it differs mainly in having semicircular, flattened stigmas. Phylogenetically it forms a clade together with *P. longifolium*, *P. phuwuaense* and *P. erectum*, but the clade has no obvious sister clade (S. Koi, unpubl. data).

Polypleurum prachinburiense M. Kato & Koi, *sp. nov.*

A congenris alabastris globosis differt. – **Holotypus:** Southeastern Thailand. Prachinburi Prov., Kaeng Wung Sai, Kaeng Hin Phoeng waterfall, Na Dee Dist. Prachinburi Prov., 14°10' N, 101°43' E, 70 m alt., fl. & fr. Jan 2007, *M. Kato, S. Koi, C. Tsutsumi, N. Kitagawa & T. Wongprasert TL-1601-1* (BKF; isotype, TNS). **Fig. 4.**

Root ribbon-like, 2-4 mm wide, branched, with tufts of leaves on dorsal surface exclusively at sinuses between root branches; leaves 2-4 or more per tuft, 10-25 mm long, base sheath-like, ovate, papillate, distal part needle-like. **Flowering shoots** on dorsal surface at sinuses between root branches; **flower** buds, along with bracts, globose; bracts 2(-4), ovate, mucronate or rarely needle-like, papillate, thick; flower 1, bud covered by spathella, spathella papillate, 1-1.5 mm long, ruptured near apex at anthesis; pedicel 4-8 mm long; tepals 2, 1 on each side of stamen, 0.7-1 mm long; stamen 1, inserted above base of ovary, 1.5-2 mm long, slightly longer than ovary; ovary 2-locular, ellipsoid, slightly flattened, 1-1.5 mm long; stigmas 2, narrowly conical, pointed, 0.2-0.4 mm long, subequal; ovules covering all or most of septum surface, 15-20 per locule; **capsule** stalked (stalk 5-9 mm long), subsymmetric, ribs 12-14.

Other specimens examined: Southeastern Thailand. Prachinburi Prov., Takro waterfall, 35 m alt., 14°11' N, 101°36' E, fl. & fr. Mar, *M. Kato et al. TL-1404* (BKF, TNS); fl. Jan, *M. Kato et al. TL-1611, TL-1612* (BKF, TNS);

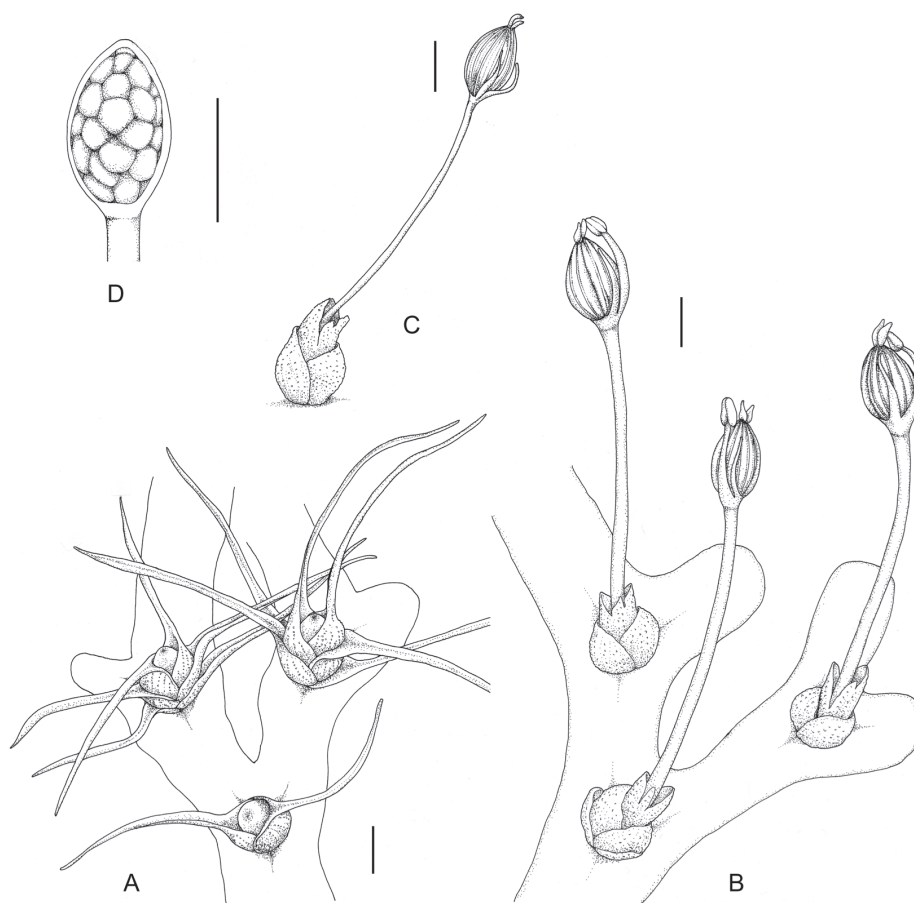


Figure 4. *Polypleurum prachinburiense*. A. Flower buds enclosed by spathe and bracts at sinuses of root branches; B. Flowers with spathe and bracts at sinuses of root branches; a flower comprises two tepals (one seen), one stamen and one ovary on pedicel with spathe and bracts at base; C. Fruit with spathe and bracts; D. Seeds in capsule with valve removed. Based on *Imaichi et al. TIK-20* (4A) and *Kato et al. TL-1601-1* (4B-D). Scale bars = 1 mm.

Kaeng Hin Phoeng waterfall, Na Dee Dist., 14°10' N, 101°43' E, 70 m alt., fl. Jan, *M. Kato et al. TL-1534* (BKF, TNS); fl. & fr. Jan, *M. Kato et al. TL-1601-2, TL-1601-3, TL-1602, TL-1603, TL-1604* (BKF, TNS); fl. Jan, *R. Imaichi et al. TIK-20* (BKF, TNS).

Ecology and distribution: On rocks in stream; vegetative plants submerged in the rainy season, and reproductive plants exposed in the air in the dry season; known only from the type locality and its vicinity.

Notes: This species is characterized by the globose flower-buds with usually a single pair of mucronate bracts. In this character it differs from the most closely related *P. wongprasertii* whose bracts are attenuate at the apex. In the other characters it is most similar to *P. wongprasertii*. *P. prachinburiense* forms a clade together with *P. wongprasertii*, *P. ubonense*, *P. sisaketense*, *P. longifolium*, *P. phuwuaense* and *P. erectum*, but their inter specific relationship are not clean (S. Koi, unpubl. data).

Polypleurum insulare M. Kato & Koi, *sp. nov.*

A P. wallichio, P. schmidtiano et P. longistyliso foliis et floribus supra radicibus ad omnem ramificatinem differt, a P. wongprasertii radicibus angustioribus, bracteis parvioribus, pedicellis brevioribus, ovariis parvioribus differt.

– **Holotypus:** Southeastern Thailand. Trat Prov., Khlong Phu waterfall, Ko Chang, 12°04'04" N, 102°18'53" E, 125 m alt., fl. & fr. Jan 2004, M. Kato, S. Koi & T. Wongprasert TL-1512 (BKF, isotype, TNS). **Fig. 5.**



Figure 5. *Polypleurum insulare*; A. Flowers with spathe and bracts at sinuses of root branches; a flower comprises two tepals (one seen), one stamen and one ovary on pedicel with spathe and bracts at base; B. Fruit with spathe and bracts. Based on Kato *et al.* TL-1512. Scale bars = 1 mm.

Root ribbon-like, 1-2 mm wide, branched, with tufts of leaves on dorsal surface exclusively at sinuses between root branches; **leaves** 3-5 per tuft, 5-15 mm long, base sheath-like, ovate, papillate, persistent, forming a mound around leaves, distal part needle-like, caducous. **Flowering shoot** on dorsal surface at sinuses between root branches; bracts 2-4, papillate, ovate, obtuse, small (to 0.7 mm long) or rarely with needle-like tips; **flower** 1, bud covered by spathe, spathe 1.5-2 mm long, papillate, appressed, ruptured near apex and also split longitudinally at anthesis; pedicel 2-3 mm long; tepals 2, 1 on each side of stamen, *ca* 1 mm long; stamen 1, *ca* 1 mm long, as tall as ovary; ovary 2-locular, ellipsoid, slightly flattened, *ca* 1 mm long; stigmas 2, linear, narrowed to apex, 0.2-0.3 mm long; ovules on septum surface except in central area, 10-12 per locule; **capsule** stalked (stalk 2.5-4 mm long), subsymmetric, ribs 8-12.

Other specimens examined: Southeastern Thailand. Trat Prov., Khlong Phu waterfall, Ko Chang, 12°04'04" N, 102°18'53" E, 90 m alt., st. Feb, *M. Kato et al. TL-1304* (BKF, TNS); Tharn Mayom waterfall, Ko Chang, 12°04'17" N, 102°20'57" E, 160 m alt., st. Jan, *M. Kato et al. TL-1521* (BKF, TNS); Tharn Mayom waterfall, Ko Chang, 12°04'17" N, 102°20'42" E, 235 m alt., st. Jan, *M. Kato et al. TL-1526* (BKF, TNS); Klong Phloo, Ko Chang, fr. Feb, *F. Konta & T. Wongprasert s.n.* (BKF, TNS); Ko Kut, 12°35' N, 101°31' E, *Charoenphol et al. 5115* (AAU, BKF, K).

Ecology and distribution: On rocks in streams; vegetative plants submerged in the rainy season, and reproductive plants exposed in the air during the dry season; known from Ko Chang and Ko Kut, the two offshore islands in southeastern end of Thailand.

Notes: Kato (2006) wrongly identified specimens (*F. Konta & T. Wongprasert s.n.*) from Ko Chang and *Charoenphol et al. 5115* from Ko Kut to be *P. wongprasertii*. *Charoenphol et al. 5115* was also wrongly identified as *P. schmidtianum* (Cusset, 1992). A comparison with new collections and a molecular phylogenetic result shows that plants of the islands are distinct from the continental species and are to be separated as a new species. In a phylogenetic tree, *P. insulare* is isolated from *P. wongprasertii* as equally as from *P. erectum*, *P. longifolium*, *P. phwuaense*, *P. prachinburiense* and *P. sisaketense*, and distant from *P. schmidtianum*. *Polypleurum insulare* differs from *P. wongprasertii* by its narrower roots, very short bracts, shorter pedicels, and smaller ovaries, and from those closely or distantly related species by the diagnostic characters shown in Key. There are now two species, *P. insulare* and *P. schmidtianum*, occurring on the small offshore islands in southeastern Thailand.

Zeylanidium lichenoides (Kurz) Engler

Nat. Pflanzenfam. 2nd ed. 18a (1930[1928]) 62; van Royen, Danks Bot. Arkiv 23 (1965) 165; Cusset, Adansonia 14 (1992) 31; Mathew & Satheesh, Aquat. Bot. 57 (1997) 265, f. 15, 16. – **Typus.** *Parish s.n.*, Martaban, Myanmar (CAL, not seen).

Roots ribbon-like, 1-2 mm wide, branched, with tufts of leaves or flowering shoots at sinuses of root branches; **leaves** linear, 20-30 mm long, ensiform, *ca* 5 per tuft in 2 files. **Flowering shoots** solitary, appressed; bracts 4-5 in 2 files, uniform but basal ones smaller, basal part ovate to ovate-lanceolate, 0.8-1.5 mm long, distal part linear, 5-7 mm long, caducous; each flower bud enclosed by spathe, spathe ellipsoidal, 1.2-1.8 mm long, longitudinally split at anthesis, persistent: **flowers** erect; pedicels horizontal at base, upright upwards, 1.2-1.5 mm long; tepals 2, one on each side of stamen, linear, 0.5-0.8 mm long; stamens 2 with flattened andropod, branched 1/3-1/4 from tip, 1.8-2.0 mm long, as long as pistil; anthers ellipsoidal, *ca* 0.5 mm long; ovaries single, sessile, unilocular, ellipsoidal, 1.2-1.8 mm long, *ca* 1.0 mm wide; stigmas 2, forked above or at base, equal, narrowly triangular, entire, *ca* 0.5 mm long; ovules 82-115 per ovary, born on whole flat placentas; **capsule** stalked (stalk 1.6-2.0 mm long), ellipsoidal, 1.5 mm long, *ca* 1.0 mm wide, 8-ribbed, dehiscent by 2 unequal valves.

Other specimens examined: Northern Thailand. Chiang Mai, Huay Kaew stream, Mae On, 600 m alt., 18°51.8' N, 99°18.0' E, st. fl.-buds, fl. & fr. Dec., *S. Koi & T. Wongprasert TK-02, TK-04, TK-05* (BKF, TNS); Huay Kaew stream, Mae On, 650 m alt., 18°52.9' N, 99°17.5' E, fl. & fr. Feb, *M. Kato et al. TL-1703, TL-1704* (BKF, TNS).

Ecology and distribution: On rocks in stream; sterile plants submerged and flowering and fruiting plants exposed; N Thailand, SE Myanmar, NE and S India.

Notes: This is the second report of *Zeylanidium* from Southeastern Asia, and northern Thailand is the eastern margin of distribution. It was recorded for the first time from Doi Suthep and Doi Inthanon, Chiang Mai, in northern Thailand (van Royen, 1965). But we have not collected the genus in these areas and did not examine specimens cited by van Royen. The identification here is based on our morphological observation and molecular data (*S. Koi*, unpubl. data).

Species identification is tentative, because we did not examine the type and authentic specimens, particularly from southeastern Myanmar and northeastern India. Comparison of Cusset's (1992) and Mathew

and Satheesh's (1997) descriptions and our collection suggests that the Thai specimens may be referable to *Zeylanidium lichenoides*, but final identification requires detailed comparison. The species delimitation is another issue, because our preliminary phylogenetic data suggest a large molecular difference between Thai and southern Indian plants.

Hydrobryum phetchabunense M. Kato & Koi, *sp. nov.*

Hydrobryum loeicum bracteis 2-4, spathellis irregulariter ruptis, stigmatibus linearibus, curvatis, acutissimibus, ovulis 5-8 in quoque loculo, capsulis 16-20-costatis simile, sed paginis radicibus circum folia annularibus, protrudentibus, pedicellis apicibus bracteis altioribus differt. – **Holotypus:** Northeastern Thailand. Phetchabun Prov., Thadphramba waterfall, Nam Nao Natl. Park, 750 m alt., 16°45' N, 101°39' E, fl. & fr. Feb 2004, M. Kato & T. Wongprasert TL-1102 (BKF; isotype, TNS). **Fig. 6.**

Root crustaceous, irregularly lobed, raised annually around tufts of patent leaves; leaves 1-4 per tuft, needle-like, terete, 2-3.5 mm long. **Flowering shoots** appressed, with **flower** solitary at tip; bracts uniform, 2-4, ovate, 1-1.5 mm long; spathella smooth-surfaced, irregularly ruptured near apex at anthesis; ovary-stalk (pedicel) 0.5-1.0 mm long, young one shorter; tepals 2, one on each side of stamen, linear, *ca* 1.5 mm long; stamens 2, branched below middle, 2-3.5 mm long, common andropod (filament) shorter than ovary; ovary 2-locular, ellipsoid, 1.5-2 mm long; stigmas 2, equal, *ca* 0.5 mm long, linear, pointed, curved; ovules on marginal surface of septum, 5-8 per locule; **capsule** stalked (stalk 1-1.5 mm long, higher than top of bracts), ellipsoid, flattened, ribs 16-20.

Other specimen examined: Northeastern Thailand. Phetchabun Prov., Thadphramba waterfall, Nam Nao Natl. Park, 750 m alt., 16°45' N, 101°39' E, fl. & fr. Jan, S. Koi *et al.* TKF-01 (BKF, TNS).

Ecology and distribution: On rocks in stream; vegetative plants submerged in the rainy season, and reproductive plants exposed in the air in the dry season; known only in type locality.

Notes: The plant TL-1102 was treated as *Hydrobryum loeicum* on the basis of its few and large ovules (4-8 per locule), many (16-20) ribs on the capsule, and linear, pointed stigmas (Kato, 2004). However, *H. phetchabunense* is distinguished from *H. loeicum* in the raised rings on the upper surface of root around the tufts of leaves, and the higher pedicels than the top level of the uppermost bracts. A molecular phylogenetic analysis shows that *H. phetchabunense* is sister to the clade of *H. loeicum* and *Diplobryum*

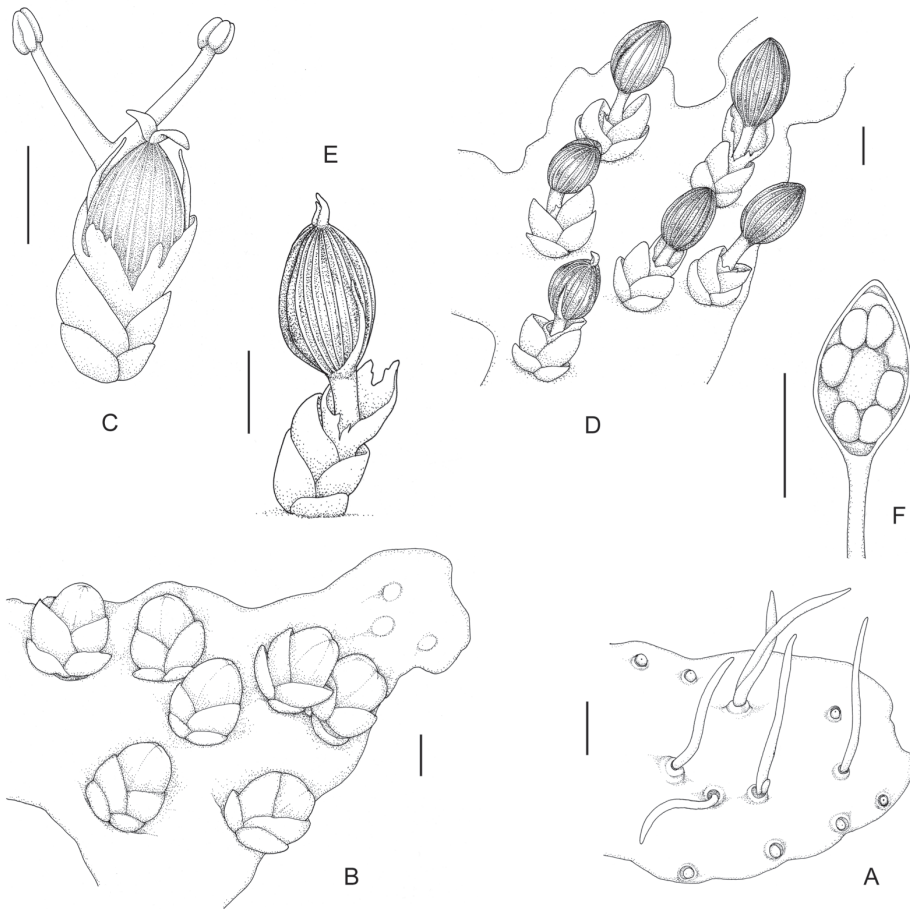


Figure 6. *Hydrobryum phetchabunense*. A. Leaves scattering on crustose root; B. Flower buds enclosed by spathellas subtended bracts appressed to crustose root; C. Flower comprising two tepals, two stamens with forked filament, and one ovary on short pedicel (not seen) subtended by spathella and bracts; D. Fruits with spathellas and bracts on crustose root; E. Fruit with spathella and bracts; F. Seeds (six on placenta) in capsule with valve removed. Based on Kato & Wongprasert TL-1102. Scale bars = 1 mm.

vientianense, but not very close to *H. loeicum* (S. Koi, unpubl. result). The three species are similar in having linear stigmas and up to 20 ribs on the capsule. However, in *H. phetchabunense*, like in *H. loeicum*, the spathella is smooth-surfaced (vs. papillate in *H. vientianense*), the stamens are shorter (vs. 4-5 mm), the ovules are fewer (vs. 9-27 per locule), and the stigmas are shorter (vs. 0.6-1 mm) (see also Key below). Thus, *H. phetchabunense* is similar to *H. loeicum*, although the latter is sister to *H. vientianense*.

Key to the species of Podostemaceae of Thailand

The key to all species of Podostemaceae of Thailand combines the results of studies of Kato (2004, 2006) and the present study.

1. Flowers 3-merous (perianth 3-lobed, stamens 2 or 3, ovary 3-locular, stigmas 3); leaves flattened, oblong or ovate, univeined
..... Subfamily **Tristichoideae** (2)
1. Flowers 2-merous (tepals 2, filiform, stamens 1-2, ovary 1-2-locular, stigmas 2); leaves filiform or vertically flattened, not veined
..... Subfamily **Podostemoideae** (12)
2. Root subcylindrical or ribbon-like; shoot subcylindrical, simple or ramified; cupule absent, flower bud instead embraced by bracts 3
2. Root absent; shoot crustose or rarely broadly ribbon-like, leafy on dorsal surface and at margin (not on ventral surface); flower bud covered by leafy cupule 9
3. Reproductive shoot-complex comprising 3 branches, middle vegetative, 2 laterals floriferous; flowering shoot 4-5 mm long with leaves below flower many, in 6 ranks, carinate **Cussetia diversifolia**
3. Reproductive shoot-complex comprising 1-4 floriferous and 1-5 vegetative branches, not arranged in above mode; flowering shoot short with 2 or several bracts thick or membranous, flat 4
4. Vegetative shoots to 5 cm long, many times branched, sparsely leafy, distal part comprising ramuli; bracts several *Terniopsis ramosa*
4. Vegetative shoots to 2 cm long, composed of ramuli with tristichous imbricate leaves, proximal part of shoot a few times branched; bra 5
5. Root 2-10 mm wide; ramuli 3-90 mm long; stamens 5-6 mm long; ovules 8-12 per locule **Terniopsis ubonensis**
5. Root 0.2-1.5 mm wide; ramuli less than 20(-30) mm long; stamens 1-4 mm long; ovules more than 13 6
6. Pedicels 5-10 mm long **Terniopsis chanthaburiensis**
6. Pedicels 1.5-4 mm long 7
7. Roots 0.2-1 mm wide; ramuli 2.2-3.5 mm long **Terniopsis brevis**
7. Roots 0.7-4 mm wide; ramuli 3-20 mm long 8
8. Ramuli 4-7 mm long; stamens 1-1.5 mm long **Terniopsis minor**

8. Ramuli 3-20 mm; stamens 2-4 mm long *Terniopsis malayana*
9. Shoot 3-10 mm wide or wider; dorsal leaves arranged in branched longitudinal rows; pedicel 5-8 mm long, 2.5-4 times as long as ovary... 10
9. Shoot to 2.5 mm wide; dorsal leaves in 1-2 inconspicuous rows; pedicel 1.5-4 mm long, 1-2 times as long as ovary 11
10. Dorsal leaves dense, fimbriate; lateral leaves narrowly deltoid, to 1.5 mm long; ovules *ca* 30 per locule *Dalzellia ubonensis*
10. Dorsal leaves sparse, separate; lateral leaves deltoid-lanceolate, to 2 mm long; ovules 50-60 per locule *Dalzellia ranongensis*
11. Shoots 1.5-2.5 mm wide; pedicel 1.5-2 mm long, as long as ovary; ovules 50-60 per locule *Dalzellia kailarsenii*
11. Shoots 1-1.5 mm wide; pedicel 2-7 mm long, longer than ovary (1.3-1.5 mm); ovules 30-50 per locule *Dalzellia angustissima*
12. Roots subcylindrical or ribbon-like 13
12. Roots crustose 29
13. Bracts 3-4-lobed or digitate; capsules globose, smooth (or weakly striped) or ellipsoid, ribbed 14
13. Bracts simple; capsules ellipsoid, slightly flattened, 8-15-ribbed 17
14. Holdfasts present on ventral surface of root under tufts of leaves; tufts of leaves and flowering shoots borne on flank of root between successive root branches and at sinuses of root branches 15
14. Holdfast absent; tufts of leaves and flowering shoots only at sinuses of root branches; bracts 3-4-lobed or digitate 16
15. Bracts linear-oblong, with 2 small lateral basal lobes; capsules globose, smooth *Paracladopus chiangmaiensis*
15. Bracts digitate; capsules ellipsoid, 12-14-ribbed
..... *Paracladopus chathaburiensis*
16. Bracts 3-4-lobed, lobes semicircular, thin, smooth *Cladopus taiensis*
16. Bracts digitate, segments finger-like, thick, papillate with silica
..... *Cladopus fallax*
17. Stamens 2; capsule-ribs 8 18
17. Stamen 1; capsule-ribs 8-15 20

18. Tufts of leaves and flowering shoots at sinuses between root branches; bracts ovate or ovate-lanceolate base, apex portion linear, caducous; capsule-valves unequal ***Zeylanidium lichenoides***
18. Tufts of leaves and flowering shoots on flanks of root between successive root branches; bracts lanceolate or ovate-lanceolate, apex obtuse or sometimes acute; capsule-valves equal ***Polypleurum wallichii*** (19)
19. Roots *ca* 5 mm wide; leaves to 5(-10) mm long; pedicels 5-8 mm long; ovary to 2.5 mm long **var. *wallichii***
19. Roots *ca* 3 mm wide; leaves to 2.5 mm long; pedicels to 2-4 mm long; ovary 1.2-1.5 mm long **var. *parvum***
20. Tufts of leaves borne between successive root branches; capsule-ribs 8-12 21
20. Tufts of leaves or shoots borne exclusively at sinuses of root branches; capsule-ribs 10-15 22
21. Roots 2-4 mm wide; pedicels 6-7 mm long; ovary protruding from spathella at anthesis, 2-locular; stigmas much shorter than ovary; capsule-ribs 8 ***Polypleurum schmidtianum***
21. Roots 1-1.5 mm wide; pedicels to 1 mm long; ovary mostly enclosed in spathella at anthesis, 1-locular; style plus stigmas as long as ovary or longer; capsule-ribs 10-12, inconspicuous ***Polypleurum longistylosum***
22. Shoots prominent with leaves exposed on elongate stems; flowers always or occasionally multiple per shoot 23
22. Shoots comprising tufts of leaves, lacking stems; leaf-bases embedded within root; flower always 1 per shoot 24
23. Roots 1-1.5 mm wide; shoots to 5 cm long, simple, erect; leaves 15-30 mm long; ovules 15-30 per locule ***Polypleurum erectum***
23. Roots 2.5-4 mm wide; shoots to 18 cm long, branched, bent at base and floating; leaves 30-70 mm long; ovules 50-70 per locule ***Polypleurum longicaule***
24. Bracts 4-6; pedicels 10-15 mm long; spathellas 4-6 mm long ***Polypleurum phuwaense***
24. Bracts 2-4(-6); pedicels 2-8 mm long; spathellas 2-3 mm long 25
25. Complex of flower bud and bracts not globose; bracts usually obvious, attenuate at apex or attenuate tip caducous ***Polypleurum wongprasertii***

25. Complex of flower bud and bracts globose; bracts inconspicuous (ovate or elliptic), not attenuate to apex, basal bracts rarely attenuate 26
26. Roots 1-2 mm wide; stalk of capsule 2.5-4 mm long
..... *Polypleurum insulare*
26. Roots 2-3 mm wide; stalk of capsule 4-10 mm long 27
27. Stigmas semicircular; ovules 40-70 per locule ... *Polypleurum sisaketense*
27. Stigmas narrowly conical, subdeltoid or deltoid-ovate; ovules 15-22 per locule 28
28. Leaves 20-40 mm long; stigmas subdeltoid or deltoid-ovate
..... *Polypleurum longifolium*
28. Leaves 10-25 mm long; stigmas narrowly conical, pointed
..... *Polypleurum prachinburiense*
29. Flowering shoots erect; bracts in 4 ranks, dimorphic, ventral (facing root) bilobed, dorsal simple 30
29. Flowering shoots appressed or oblique or only flowers erect; bracts in 2 ranks, uniform, simple or trilobed 31
30. Capsules 2-2.5 mm long, ribs 12-16 *Hanseniella heterophylla*
30. Capsules 1.5-2 mm long, ribs 8 *Hanseniella smitinandii*
31. Bracts trilobed with middle lobe much longer than lateral lobes
..... *Thawatchaia trilobata*
31. Bracts simple with tips obtuse or sometimes acute or acuminate 32
32. Stamens 2 with forked filament 33
32. Stamen 1 with simple filament 42
33. Bracts linear-lanceolate, acuminate; stigmas unequal 34
33. Bracts deltoid, elliptic or ovate, obtuse or acute; stigmas equal or subequal 35
34. Roots (crusts) *ca* 0.5 mm thick, not markedly raised around tufts of leaves; bracts 2-3; stigmas unequal, forked below middle
..... *Hydrobryum bifoliatum*
34. Roots (crusts) to *ca* 1 mm thick, prominently raised around tufts of leaves; bracts 4-6; stigmas markedly unequal, forked above middle
..... *Hydrobryum kaengsophense*

35. Leaves oblique or appressed, tough; bracts deltoid, acute at apex; stigmas subequal *Hydrobryum tardhuangense*
35. Leaves patent, soft (but tough in *H. khaoyaiense*); bracts ovate or elliptic, obtuse at apex; stigmas equal 36
36. Stigmas obovate, cristate *Hydrobryum griffithii*
36. Stigmas linear or oblong, entire 37
37. Spathella papillate 38
37. Spathella smooth 40
38. Ovary 1-locular *Hydrobryum somranii*
38. Ovary 2-locular 39
39. Ovules 4-8 per locule *Hydrobryum loeicum*
39. Ovules 8-28 per locule *Hydrobryum vientianense*
40. Ribs on capsule 16-20 *Hydrobryum phetchabunense*
40. Ribs on capsule 12-14 41
41. Stigmas subentire, oblong or narrowly deltoid-lanceolate, emarginated, truncate, or obtuse at tip; ovules 12-20 on septum surface except in small lower central area; leaves 10-20 mm long
..... *Hydrobryum Chiangmaiense*
41. Stigmas entire, linear, pointed at tip; ovules 11-15 on marginal surface of septum; leaves to 3 mm long *Hydrobryum japonicum*
42. Ovary 2-locular; placentation axile; leaves somewhat tough
..... *Hydrobryum khaoyaiense*
42. Ovary 1-locular; placentation pseudo-central; leaves soft
..... *Hydrobryum micrantherum* (43)
43. Roots (crusts) 0.1-0.2 mm thick; bracts 2-4; ovary ca 1.5 mm long; ovules 9-13 per placenta **var. micrantherum**
43. Roots (crusts) 0.2-0.3 mm thick; bracts 3-5; ovary 1.5-2 mm long; ovules 13-23 per placenta **var. crassum**

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