

Two new species of *Thismia* subsect. *Odoardoa* (Thismiaceae) from Borneo

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Background – Two new species of the sect. *Thismia* subsect. *Odoardoa*, *Thismia cornuta* Hroneš, Sochor & Dančák and *Thismia pallida* Hroneš, Dančák & Rejžek, from Malaysian Borneo are described and illustrated. The former species is distributed in the Bario area of the Kelabit Highlands of Sarawak, and the latter occurs in the SAFE (Stability of Altered Forest Ecosystem) Project area, northwest of Tawau in Sabah.

Methods – This study is based on field observations in several forest localities in Sarawak and Sabah and herbarium material deposited in SAN, SAR and OL. Both conventional herbarium techniques and comparison with protologues of described species were applied.

Results – *Thismia cornuta* is morphologically closely related to *T. inconspicua* Sochor & Dančák from Brunei Darussalam and *T. chrysops* Ridl. from the Malay Peninsula but it differs from both species by the presence of only two appendages at apical margin of the connective, by horn-like projection on each side of the lateral appendage and by white colour of perianth tube. It was found at three localities and is preliminarily treated as endangered (EN). *Thismia pallida* is morphologically close to *T. filiformis* Chantanaorr. from Thailand but differs by the presence of five appendages at apical margin of connective, by box-shaped lateral appendage exceeding apex of connective and by shorter filiform appendage of perianth lobe. It was found at a single locality within twice logged secondary forest and it is preliminarily treated as critically endangered (CR). This is only the second record of *Thismia* species inhabiting secondary forests in tropical Asia.

Key words – Malesia, mycoheterotrophy, Sabah, Sarawak, tropical rain forest.

INTRODUCTION

Thismia Griff. (family Thismiaceae, sometimes included also into Burmanniaceae; Merckx et al. 2006, The Angiosperm Phylogeny Group 2016) is a genus of delicate mycoheterotrophic monocot plants. The genus comprises about 70 accepted species (Nuraliev et al. 2015, Chantanaorrapint et al. 2016, Cowie & Liddle 2016, Kumar et al. 2017, Sochor et al. 2017, Suetsugu et al. 2017, Sujanapal et al. 2017, Tsukaya et al. 2017) and is distributed mostly in the tropical regions of Asia, Australia and South America and extending into the subtropical or even temperate regions of Japan, New Zea-

land, Australia and the USA (Maas et al. 1986, Merckx et al. 2013). Two main centres of its diversity in Southeast Asia are located in the Malay Peninsula and Borneo, both with thirteen recognized species (Jonker 1948, Chantanaorrapint et al. 2016, Sochor et al. 2017, Suetsugu et al. 2017, Sujanapal et al. 2017). Ranges of the majority of species are very small areas and most of the species are even reported as being steno-endemic (Jonker 1948, Jarvie 1996, Dančák et al. 2013, Mar & Saunders 2015). It is also commonly believed that *Thismia* species are confined to primary virgin rainforests where they grow in the leaf litter and therefore may be

easily overlooked (Stone 1980, Merckx et al. 2006, Chantanaorrapint et al. 2016, Sochor et al. 2017).

Vegetative organs of *Thismia* are highly modified due to the full mycoheterotrophy and the individuals are probably able to persist underground for a considerable period during the year gaining all nutrients from their fungal “symbiont” (Stone 1980, Mar & Saunders 2015). Aboveground parts probably emerge only for a short period of time during the rainy season (Stone 1980). Flowers of *Thismia* are highly specialized, most likely for the pollination by small flies (Stone 1980, Mar & Saunders 2015). Stamens of Old World species usually have flattened connectives which are fused together and forming a “tunnel” for the pollinators. The connectives are furnished by variously shaped appendages, which possibly direct the move of the pollinator and restrict self-pollination (Mar & Saunders 2015). These appendages are generally considered species-specific and are used as discriminating morphological character for separating the species (e.g. Ridley 1895, Jonker 1948, Chantanaorrapint 2012, Dančák et al. 2013, Chantanaorrapint et al. 2016, Sochor et al. 2017).

Current infrageneric classification of the genus is based mostly on the morphology of the roots and perianth lobes (Jonker 1948, Kumar et al. 2017). Two subgenera (Old-World *Thismia* subgen. *Thismia* and neotropical *Thismia* subgen. *Ophiomeris* (Miers) Maas & Maas) and seven to eight sections are recognized (Maas et al. 1986, Kumar et al. 2017). Four major groups are recognized in the Old World: *Thismia* sect. *Thismia* with vermiform creeping roots and free perianth lobes, *Thismia* sect. *Rodwaya* (F.Muell.) Schltr. and *Thismia* sect. *Gaziocharis* (Taub. ex Warm.) Hatusima with vermiform roots and outer perianth lobes fused together to form a mitre, and *Thismia* sect. *Sarcosiphon* (Blume) Jonker with clustered coralloid roots and outer perianth lobes also fused together to form a mitre. The first section is further divided into two subsections: *Thismia* subsect. *Brunonithismia* Jonker with perianth lobes of two different sizes and shapes and *Thismia* subsect. *Odoardoa* Schltr. with perianth lobes all equal in shape and size (Jonker 1948, Dančák et al. 2013, Hroneš 2014, Hunt et al. 2014, Hroneš et al. 2015).

During our field trips to Pulong Tau National Park in the Kelabit Highlands of Sarawak and experimental plots of SAFE project in Sabah (both Malaysian Borneo) in early 2017, we have discovered two species of *Thismia* clearly belonging to the sect. *Thismia* subsect. *Odoardoa* by their vermiform roots and all six perianth lobes free and of same length and size. However, the combination of their morphological characters did not match any of the described taxa and we, therefore, describe them here as new species.

MATERIALS AND METHODS

Material

This study is based on material collected during January and February 2017 in the Bario area, Kelabit Highlands, Sarawak and in LFE block of the SAFE (Stability of Altered Forest Ecosystem) Project (Ewers et al. 2011) near Tawau, Sabah. Morphological characters were studied using hand lens (30–60× magnification), stereo microscope and macro photogra-

phy. Collected specimens were thoroughly compared with original drawings and descriptions given in protologues of representatives of *Thismia* sect. *Thismia*. Herbarium vouchers for this study are deposited in SAN, SAR and OL.

Terminology

Morphological terminology used to describe *Thismia* flowers is sometimes confused as various authors use different terms for the same floral part, e.g. adaxial appendage vs. abaxial appendage vs. lateral appendage. We prefer to use the term lateral appendage as it describes the structure which is attached to the flat surface of the connective (although not on its margin) in contrast to apical appendages which occur on the apical margin of the connective. Strictly the use of the term lateral is not correct but it is perfectly understandable and established (see e.g. Mar & Saunders 2015). On the other hand, the term adaxial appendage suggested by several authors (e.g. Nuraliev et al. 2015) is confusing as the connective was turned down during evolution from his original erect position so that its adaxial side became abaxial.

While describing the perianth tube sometimes the term hypanthium (or floral tube) is used. However, this is not generally accepted, as hypanthium should include also ovary and vegetative tissues (i.e. upper part of floral receptacle, e.g. Hickey & King 2000, Beentje 2010). In *Thismia* the ovary and peduncle are clearly free from the rest of the flower and moreover the perianth tube is caducous. It is thus formed only by tepals and anther filaments. Therefore, we prefer use of the term perianth tube.

TAXONOMIC TREATMENT

Thismia cornuta Hroneš, Sochor & Dančák, *sp. nov.*

It differs from its congeners by the combination of following morphological characters: stem very short or absent, flower slightly zygomorphic, perianth tube white and verrucose outside, annulus pinkish, only two appendages at apical margin of the connective and small horn-like projection arising from each side of the lateral appendage. – Type: Borneo, Sarawak (Malaysia), Kelabit Highlands, Pa’Umor village, Anak Kadi Ridge, 4.4 km SSE of the village, 3°42’1”N, 115°31’28”E, 1195 m alt., 13 Jan. 2017, Sochor et al. BOR2/17, whole plant in spirit (holo-: SAR) and pressed (iso-: OL).

Small perennial achlorophyllous herbs. Roots creeping, vermiform, ± horizontal, hardly branched, pale brown. Stem very short or absent, white, 0–15 mm long, ascending, glabrous. Leaves spirally arranged, reduced, scale-like, triangular, acute, c. 3 mm long, 1–3 per stem. Bracts 3, similar to leaves but larger, 6–7 mm long. Flowers usually solitary (rarely 2), slightly zygomorphic, sessile. Perianth of 6 tepals fused to form perianth tube apically with 6 free tepal lobes. Perianth tube urceolate, c. 15 mm long, 9 mm wide at upper third, translucent-white, sometimes with 12 inconspicuous pinkish longitudinal stripes in the upper part, without transverse bars inside, verrucose outside, basally bent or inclined at an angle to the ovary, thus the upper part of the perianth displaced from the ovary axis. Apex of perianth tube fused with stamen bases to form thin, pinkish, circular, slightly

raised annulus 3 mm in diameter. Perianth lobes 6, all equal in shape and size, long triangular, 5–6 mm long, 2–3 mm wide at base, white, tapering into white, filiform appendage, 8–10 mm long. Stamens 6, pendent from the annulus, translucent; filaments short, free, curved downwards; connectives laterally connate, forming a tube; each connective with 2 club-shaped appendages of the same shape and size inserted at apical margin and large cap-shaped lateral appendage on the distal part protruding towards perianth tube; lateral ap-

pendage with irregularly dentate apex and 2 horn-like projections arising from the middle part of each side; projections apically with cluster of hairs. Style short, stigma 3-lobed, papillose, lobes apically shallowly bilobed. Ovary white, inferior, cup-shaped, almost entirely surrounded by bracts. Fruit a cup-shaped white capsule, 5 mm long, 4.5–9 mm in diameter, topped by withered style and borne on elongated, 35–85 mm long, white fruiting pedicel. Seeds not seen. Figs 1 & 2.

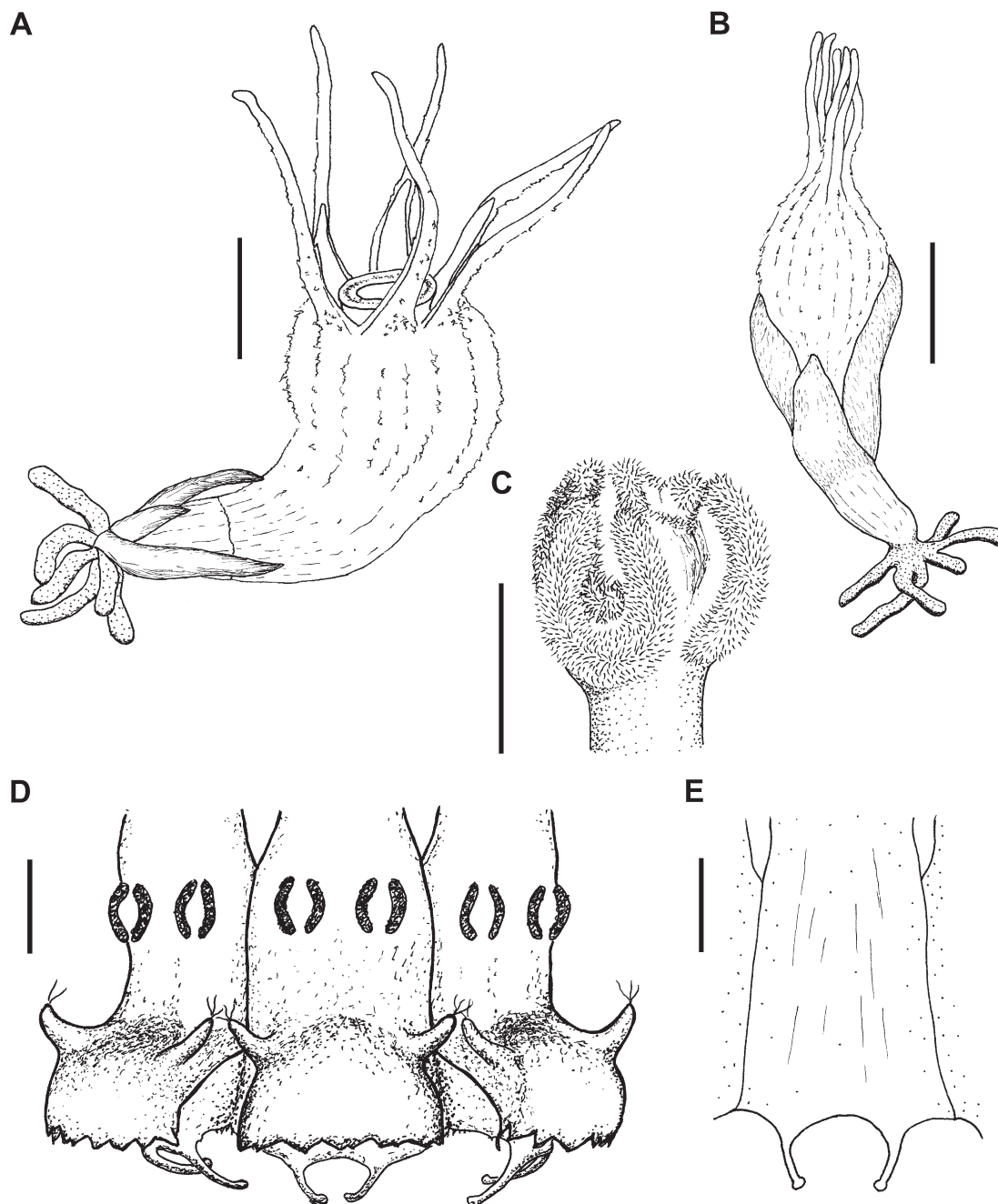


Figure 1 – *Thysmia cornuta*: A, habit of flowering plant; B, habit of plant with flower bud; C, style with stigma; D, outer view of stamens; E, inner view of stamen. Scale bars: A & B = 5 mm, C–E = 1 mm. Drawn by Kateřina Janošíková. A from Sochor *et al.* BOR10/17; B–E from Sochor *et al.* BOR2/17 (type).

Additional specimens examined – Borneo, Sarawak (Malaysia): Kelabit Highlands, Pa'Lungan village, Arur Bedalawid, 3.3 km N of the village, 3°50'22"N, 115°30'57"E, 1218 m alt., 15 Jan. 2017, *Sochor et al.* BOR24/17 (SAR); Kelabit Highlands, Pa'Lungan village, Arur Bedalawid, 3.1 km N of the village, 3°50'18"N, 115°31'06"E, 1136 m alt., 16 Jan. 2017, *Sochor et al.* BOR10/17 (OL).

Distribution and habitat – So far known only from the Bario area, Kelabit Highlands, Sarawak, north-western Borneo (possibly endemic). Although most of the *Thismia* species are reported from a single locality (e.g. Jonker 1948, Stone

1980, Chantanaorrapint 2012), we have discovered *T. cornuta* in two valleys which are located 15 km apart. This naturally raises a question on its real distribution. As we found the two sites more or less by chance and a plenty of similar localities exist across the Bario area, we believe it might occur elsewhere in this region. The habitat of the species was the same in both localities – river ravine in the primary rain-forest, in humus-rich soil, at elevations c. 1190–1220 m a.s.l. (fig. 2I).

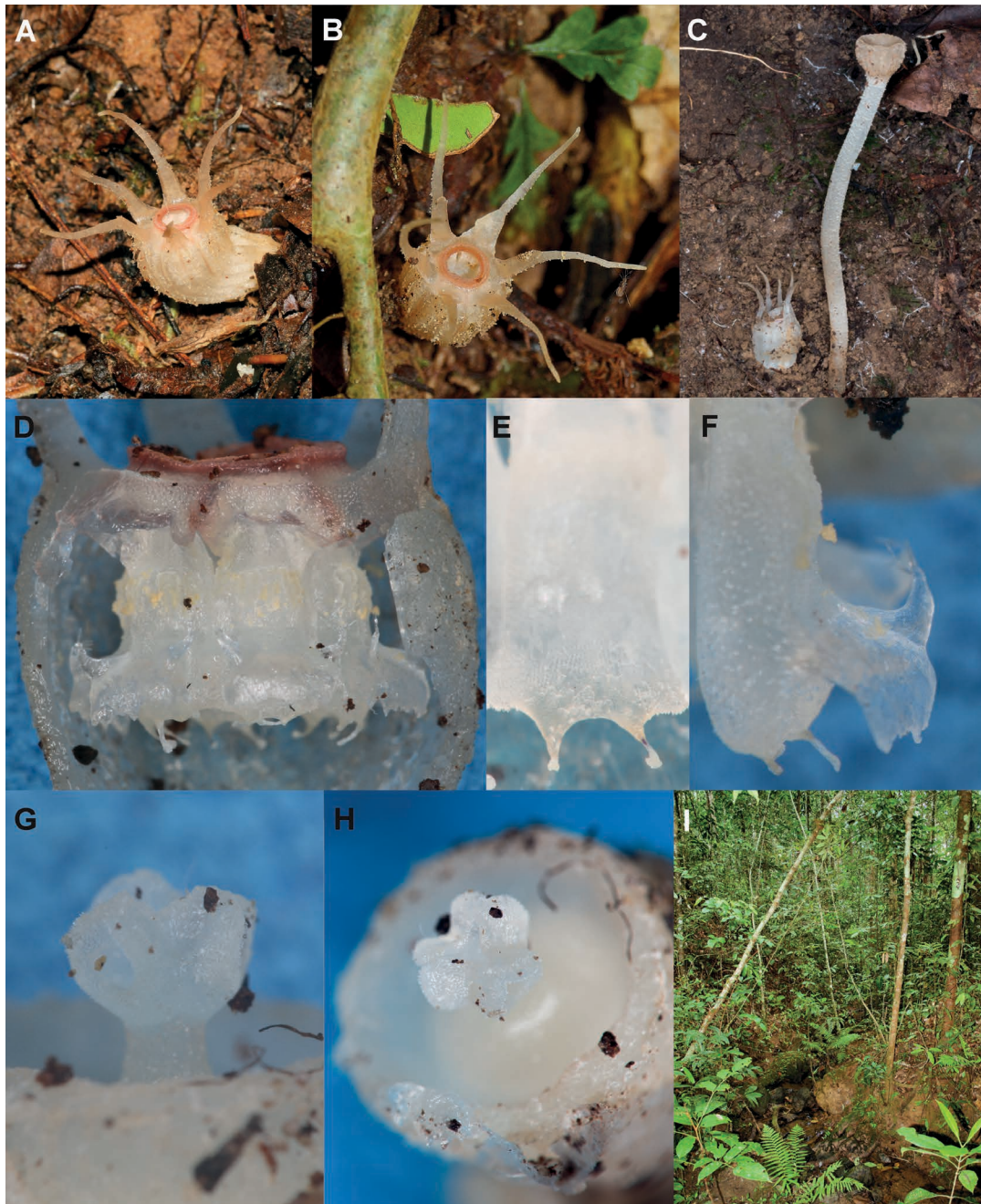


Figure 2 – *Thismia cornuta*: A & B, habit of flowering plant; C, habit of flowering and fruiting plant; D, perianth tube with removed part showing stamens with anthers and lateral appendages; E, apical part of connective with appendages; F, horn-like projection on lateral appendage; G & H, style with stigma; I, type locality. Photographs: Michal Sochor (A & C–H), Michal Hroneš (B & I). A from *Sochor et al.* BOR10/17; B from *Sochor et al.* BOR24/17; C–H from *Sochor et al.* BOR2/17 (type).

Preliminary conservation status – Endangered [EN 2ab(iii,v)]. The extent of occurrence (EOO) of *T. cornuta* was not estimated but its minimal area of occupancy (AOO) could be estimated to be 12 km² (within the limits for Endangered status under the criterion B2). *Thismia cornuta* is endemic to Borneo and is known from three specimens. Two were collected in protected forests of Pulong Tau National Park, without immediate threats, but the third one was collected outside the national park, and might be potentially threatened by commercial logging. The species is

thus known from three specimens that represent three subpopulations. These three subpopulations represent a total of two “locations” (*sensu* IUCN 2012), falling within the limit for Endangered status. We project that the ongoing loss of its habitat will induce a continuous decline in the number of subpopulations and mature individuals. *Thismia cornuta* is therefore assigned a preliminary status of EN 2ab(iii,v).

Etymology – From the Latin *cornutus* (horned). The name points to the horn-like projections on lateral appendage re-

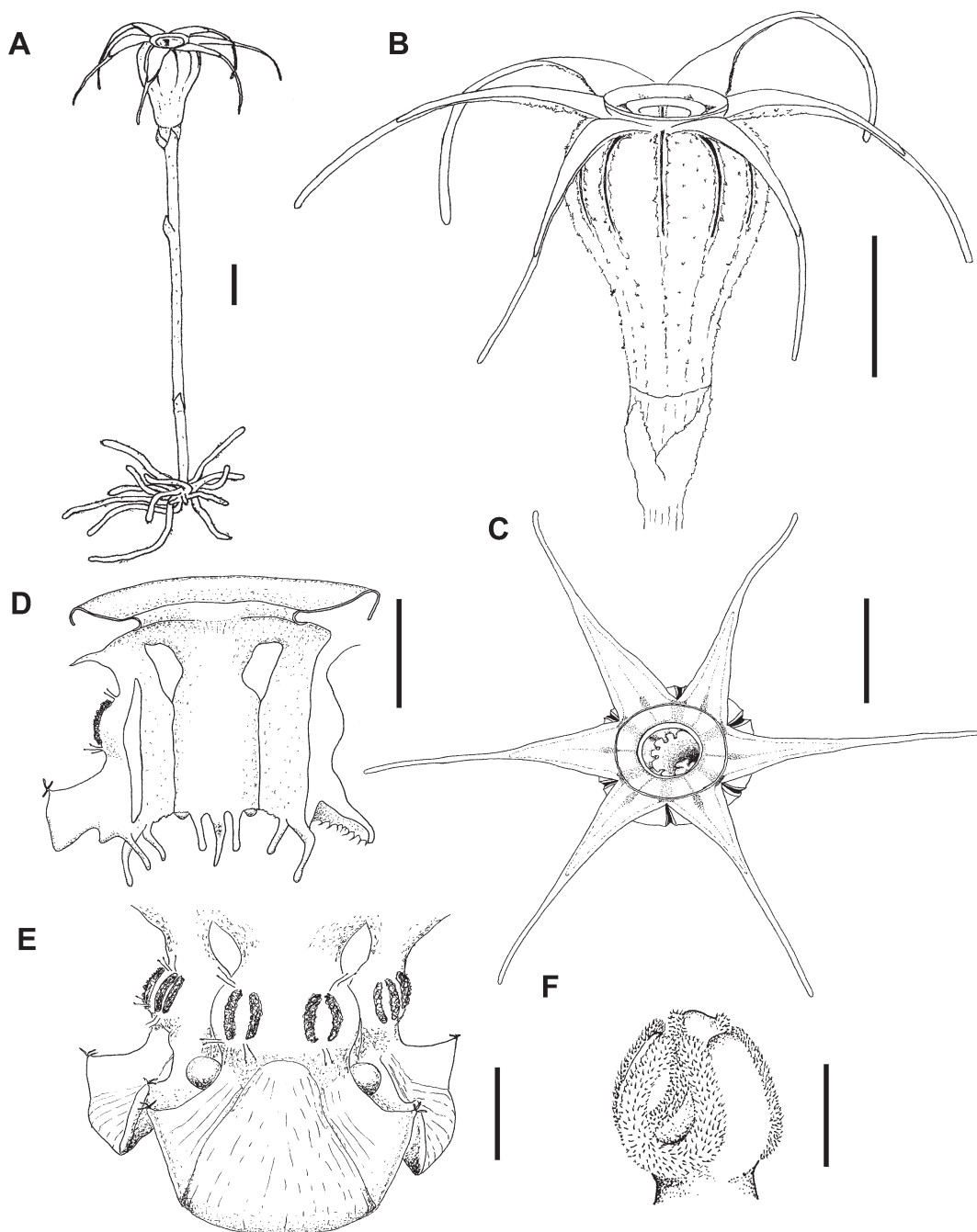


Figure 3 – *Thismia pallida*: A, habit of flowering plant; B, side view of flower; C, top view of flower; D, inner view of stamens; E, outer view of stamens; F, style with stigma. Scale bars: A–C = 5 mm, D–F = 1 mm. Drawn by Kateřina Janošíková. A–F from Nilus & Svátek SAN 158204 (type).

sembling horns on a Viking helmet, a morphological trait so far not known in the genus.

***Thismia pallida* Hroneš, Dančák & Rejžek, sp. nov.**

Similar to *Thismia filiformis* Chantanaorr. but differs in the presence of 5 (vs. 3) appendages at apical margin of the connective, by box-shaped lateral appendage exceeding apex of the connective, by longer perianth tube and shorter appendages of the perianth lobes. – Type: Borneo, Sabah (Malaysia), Kalabakan, SAFE project, plot LFE-10, 4°44'36.41"N, 117°35'16.93"E, c. 485 m alt., 3 Feb. 2017, *Nilus & Svátek* SAN 158204, whole plant in spirit (holo-: SAN).

Small perennial achlorophyllous herbs. Roots creeping, vermiform, \pm horizontal, hardly branched, pale brown. Stem white to pale cream brown, 25–45 mm tall, erect, glabrous. Leaves spirally arranged, reduced, scale-like, triangular, acute, 2–3 mm long, 5–6 per stem. Bracts 3, similar to leaves but 4–5 mm long, lanceolate-triangular, acute, surrounding the base of the ovary. Flowers solitary (rarely 2) at the

top of the stem, actinomorphic, sessile. Perianth of 6 tepals fused to form perianth tube apically with 6 free tepal lobes. Perianth tube urceolate, c. 9 mm long, cream to pale brown, sparsely verrucose, with 12 vertical grooves on outer surface, apically with 12 orange-brown longitudinal stripes, without transverse bars inside. Apex of perianth tube fused with stamens bases to form fleshy, circular to weakly hexagonal funnel-shaped, yellow-brown to pale brown annulus. Perianth lobes 6, all equal in shape and size, narrowly triangular, c. 5 mm long, c. 2 mm wide at base, cream brown, tapering into a filiform appendage, c. 3 mm long. Stamens 6, translucent, pendent from the annulus; filaments free, short, curved downwards; connectives broad and flattened, laterally connate, forming a tube; each connective with 5 appendages at apical margin, large box-shaped lateral appendage on the distal part protruding towards perianth tube and interstaminal gland inserted on the line of fusion between connectives; appendages on the apical margin arranged as follows: outer pair of appendages very short, rounded, pointing outwards, inner pair ca. 4 times longer than the outer one, \pm straight,



Figure 4 – *Thismia pallida*: A, habit of flowering plant; B, habit of fruiting plant; C, top view of flower showing annulus and perianth appendages; D, two-flowered plant with root system; E, outer view of stamens; F, inner view of stamens. Photographs: Michal Hroneš (A–F). A–F from *Nilus & Svátek* SAN 158204 (Type).

Table 1 – Comparison of morphological characteristics in *Thismia cornuta*, *T. chrysops* (Ridley 1895) and *T. inconspicua* (Sochor et al. 2017).

	<i>Thismia cornuta</i>	<i>Thismia chrysops</i>	<i>Thismia inconspicua</i>
length of perianth tube	c. 15 mm	c. 8 mm	c. 7 mm
perianth coloration	translucent-white, with 12 pale pinkish longitudinal stripes in the upper part	rose pink with longitudinal stripes, in the upper part chocolate-brown	(light) brownish with 12 sepia-brown longitudinal stripes
annulus protrusion degree, shape and coloration	slightly raised, pinkish, circular	slightly raised, bright yellow, hexagonal	moderately raised, sepia-brown on the outer margin, brownish-orange to light orange on the inner margin and greyish in between, circular
length of perianth appendages	8–10 mm	c. 7 mm	c. 2 mm
appendages at apical margin of connective	2 club-shaped	2 club-shaped and several shorter	2 club-shaped and 2 tooth-shaped

Table 2 – Comparison of morphological characteristics in *Thismia pallida* and *T. filiformis* (Chantanaorrapint 2012).

	<i>Thismia pallida</i>	<i>Thismia filiformis</i>
length of perianth tube	c. 9 mm	4.5–5.5 mm
perianth coloration	cream to pale brown, apically with 12 orange-brown longitudinal stripes	creamy white, with 12 pale brown to orange-brown longitudinal stripes
annulus coloration	yellow-brown to pale brown	orange-brown
length of perianth appendages	c. 3 mm	5–8 mm
number and length of appendages at apical margin of connective	5; middle one the longest	3; middle one the shortest
lateral appendage of connective	box-shaped, exceeding apex of connective	skirt-like, with central lobe notched, not exceeding apex of connective

cylindrical to slightly club-shaped, obtuse, pointing inwards, the middle (unpaired) appendage longest, acute, curved. Style short, stigma 3-lobed, papillose. Ovary pale brown, inferior, obconical, indistinctly ribbed. Fruit a conical to cup-shaped pale brown, ribbed capsule, 4–5 mm long, topped by withered style, borne on elongated, 7–20 mm long fruit stalk. Seeds small, fusiform, brown. Figs 3 & 4.

Distribution and habitat – So far known only from small population of seven individuals in twice selectively logged forest near SAFE Project base camp (LFE blocs), south of Danum Valley Conservation Area and northwest of Tawau, Sabah, at elevation c. 485 m a.s.l. Secondary forest species of *Thismia* are very rare globally. Among Neotropical species only *T. pannamensis* (Standl.) Jonker is reported to grow also in secondary or fragmented forests (Guilherme et al. 2016). Among Old World species only two species were reported from secondary forests: *T. rodwayi* F.Muell. often occurs at sites that have been subjected to intensive and relatively recent human activities, including clear-cutting and regeneration burns (Roberts et al. 2003) and *T. hongkongensis* Mar & R.M.K.Saunders is only known from the secondary forest in Hong Kong (Mar & Saunders 2015). Therefore, *T. pallida* is probably only the second *Thismia* species discovered in a secondary forest in tropical Asia.

Preliminary conservation status – The species is given a Red List status of Critically Endangered [CR B2ab(iii, v)]. The extent of occurrence (EOO) of *T. pallida* cannot be estimated because the species is only known from the type collection. Its area of occupancy (AOO) is estimated to be

4 km², which falls within the limits for Critically Endangered status under criterion B2. The only known subpopulation is from non-protected forest on a logging concession, so it might be potentially threatened by commercial logging. This subpopulation represents thus one location (*sensu* IUCN 2012), which is the upper limit for Critically Endangered status under subcriterion ‘a’ of criterion B2. The site where *T. pallida* has been collected was recently included into a research area which should be prevented from logging in the future (Ewers et al. 2011), however the past destruction of its habitat has probably already affected the population. Then, even if the species might be more widespread in the region, the loss of the habitat of *T. pallida* has led to a continuing decline in the number of mature individuals. We then assigned to *T. pallida* a preliminary status of CR B2ab(iii, v).

Etymology – From the Latin *pallidus*. The name refers to the pale colour of the whole plant.

DISCUSSION

Borneo harbours about 15 000 vascular plant species with c. 37% being endemic (Raes et al. 2009). Among them 20 genera are mycoheterotrophic (e.g. Tsukaya et al. 2011, Tsukaya & Suetsugu 2014, Dančák et al. 2017) and *Thismia* with its thirteen species being one of the largest (Sochor et al. 2017, Tsukaya et al. 2017). From the systematic point of view, five species belong to the sect. *Sarcosiphon*, one species to the sect. *Thismia* subsect. *Brunonithismia* and seven species to the sect. *Thismia* subsect. *Odoardoa*, respectively (Jonker

1948, Hroneš et al. 2015, Sochor et al. 2017, Tsukaya et al. 2017). Both new species described here have creeping vermiform roots and free equal perianth lobes, therefore they belong to sect. *Thismia* subsect. *Odoardoa* as well.

Given its unusual morphology, *Thismia cornuta* is well separated from all known *Thismia* species. *Thismia inconspicua* Sochor & Dančák from Brunei Darussalam and *T. chrysops* Ridl. from the Malay Peninsula seems to be morphologically closest to *T. cornuta* as they share several morphological traits, such as perianth tube bent or displaced from its axis resulting in flower zygomorphy and presence of club-shaped appendages at apical margin of the connective (Ridley 1895, Sochor et al. 2017; table 1). Moreover, flowers of *T. cornuta* are almost sessile like in *T. inconspicua*. However, *T. cornuta* differs substantially from both species by its white perianth, by only slightly raised pinkish annulus, by presence of only two appendages (vs. at least four in *T. inconspicua* and *T. chrysops*) at the apical part of the connective (fig. 2E) and by the presence of a pair of horn-like projections on lateral appendage (fig. 2F) which has not been reported for any *Thismia* species so far. *Thismia chrysops* and *T. grandiflora* Ridl. may have similar projections according to their illustrations (Ridley 1895) although it is not mentioned in written descriptions. However, it is almost impossible to judge from the illustrations if the depicted structures are identical with those seen in *T. cornuta*.

Flowers of *T. cornuta* open just above the ground and they are sometimes almost completely covered by the leaf litter or even soil. Mar & Saunders (2015) reported that the flowers of *T. hongkongensis* were visited by small dipteran flies. In the case of *T. cornuta*, the pollinators may as well be some small ground invertebrates, however we failed to observe any visitors of the flower.

The second discovered species, *Thismia pallida*, resembles *T. filiformis* Chantanaorr. from Thailand by its indistinctive pale brown colour and rather short perianth appendages (Chantanaorr. 2012). However, these two species differ in the inner architecture of the flower. While the connective of *T. filiformis* bears three appendages on its apical margin, the middle one being the shortest, *T. pallida* bears five appendages of three different shapes, the middle one being the longest (figs 3D & 4E). Both species also differ in shape and size of lateral appendage of connective which is box-shaped and exceeding apical part of the connective in *T. pallida* (vs. skirt-like appendage with central lobe notched and not exceeding apex of the connective in *T. filiformis*). While *T. filiformis* has perianth tube up to 5.5 mm long and perianth appendages 5–8 mm long, *T. pallida* has perianth tube up to 9 mm long and much shorter perianth appendages (c. 3 mm long; table 2). Other two somewhat similar species from sect. *Thismia* subsect. *Odoardoa* that occur in Borneo are *T. bifida* M. Hotta and *T. ophiuris* Becc. (Beccari 1878, Hotta 1967). Both species differ from *T. pallida* by having a lower number of appendages at apical margin of the connective (three and two, respectively), by more prominent annulus, longer perianth appendages (more than 10 mm) and also by colour (the perianth tube is mostly yellow to yellow-orange).

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