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SUWIDJI WONGSO1, JAN D. BASTMEIJER2, HENDRA BUDIANTO1, ISA B. IPOR3, KAREN RYSBJERG MUNK4, MARIAN ØRGAARD4 & NIELS JACOBSEN4

Six new Cryptocoryne taxa (Araceae) from Kalimantan, Borneo

Introduction

The first thorough study of the genus Cryptocoryne Fisch. ex Wydler (Araceae) in Borneo was by the Italian botanist Odoardo Beccari in 1865 and 1867, surveying the species of Sarawak. He collected C. ciliata (Roxb.) Schott, C. cordata Griff. (that collection now referred to C. cordata var. grabowskii (Engl.) N. Jacobsen), and eight new species, which were subsequently described by Engler (1879) and elaborated on three years later (Engler 1883) (C. auriculata Engl., C. bullosa Engl., C. ferruginea Engl., C. lingua Engl., C. longicauda Engl., C. pallidinervia Engl., C. spathulata Engl. [now referred to C. lingua] and C. striolata Engl.). Brown (1880) described C. caudata N. E. Br. (now referred to C. longicauda) and Engler (1898) described C. grabowskii Engl. (now referred to C. cordata var. grabowskii), and a total of nine species were recognized in Borneo by the turn of the century. Cryptocoryne grandis Ridl. (now referred to C. cordata var. grabowskii) was described by Ridley (1905).

In 1970 J. Schulze (Schulze 1971) travelled around Sarawak and recollected Beccari’s and Engler’s nine species at the original localities and added a number of...
new localities. Starting in the 1970s, the work of H. C. D. de Wit (see, e.g., Wit 1971, 1990), Rataj (1975) and Jacobsen (1985) added another four currently accepted taxa to the Cryptocoryne flora of Borneo: the triploid C. ciliata var. latifolia Rataj (Rataj 1975), C. edithiae De Wit (now referred to C. xpurpurea nothovar. borneoenensis N. Jacobsen & al.), C. fuscata De Wit and C. keei N. Jacobsen. This increased the number of recognized taxa to 13, whereas another five taxa described by de Wit (now referred to C. ×purpurea nothovar. borneoenensis N. Jacobsen & al.), C. fuscata De Wit and C. keei N. Jacobsen. This increased the number of recognized taxa to 13, whereas another five taxa described by de Wit and Rataj are now considered to be synonyms of taxa already known for Borneo: C. gracilis De Wit (now referred to C. striolata), C. pontederiifolia subsp. sarawacensis Rataj (now referred to C. ferruginea Engl.), C. tortilis De Wit (now referred to C. fusca), C. venemae De Wit (now referred to C. pallidinervia) and C. zonata De Wit (now referred to C. cordata var. grabowskii).

Ipor & al. (2009) further surveyed the Cryptocoryne flora of Sarawak adding about 140 new Cryptocoryne localities to the previously known about 80 (Jacobsen 1985). At the beginning of the new millennium there were further surveys by H. Budianto, T. Idei, H. Kishi, Y. Sasaki, N. Takahashi and S. Wongso in Kalimantan (Indonesian Borneo), resulting in six additional taxa (C. yujii Bastm. [a new record for Borneo], C. ideii Budianto, C. noritoi Wongso, C. ×purpurea nothovar. borneoenensis N. Jacobsen & al., C. uenoi Y. Sasaki, C. yujii Bastm. and C. zaidiana Ipor & Tawan). During the next ten years another three taxa were added (C. aurata Wongso & Ipor, C. ×batangkayanensis Ipor & al. and C. ferruginea var. sekaaduensis Bastm. & al.) making a total of 23 recognized taxa on the island.

Recently an intensified investigation of Bornean Cryptocoryne has been undertaken, resulting in the discovery of several new taxa, especially in connection with surveying the Schwaner mountains and the Müller mountains, in which C. aurata was described. Another six new taxa are described here (Fig. 1), increasing the total number of currently accepted Cryptocoryne taxa for Borneo to 30, with more than 500 documented records.

Material and methods

The present work is the result of a successful cooperation between the authors contributing various specialist inputs, viz. S.W. and J.B.I. with fundamental fieldwork and habitat information, K.R.M. and M.O. with cytological work, all authors with morphological and ecological information for taxon characterization, and J.D.B., H.B. and S.W. with cultivation and photographs (far from all contributed pictures are included). S.W., M.O. and N.J. initiated writing the main text, after which all authors took part in discussions and writing the manuscript.

The collections were made and herbarium material deposited as stated in the descriptions.

Chromosome numbers were determined at somatic metaphase of root-tips. Preparation of root-tips followed the protocol in Ørgaard & al. (1995), pre-treated in a water-saturated monobromenaphthalene solution for four hours, then fixed in Clarke (3 : 1 absolute ethanol : glacial acetic acid) for four hours. The root tips were then washed again in 5 °C citrate buffer (0.0021% citric acid and 0.0029% trisodium-citrate-dehydrate dissolved in demineralized water, adjusted to pH 4.6) and incubated in 37 °C enzyme solution (citrate buffer added 2% cellulose, Onozuka RS and 10% pectinase, Sigma P-5146) for 12 minutes. Root tips were then washed again in 5 °C citrate buffer for 30 minutes, placed individually in a drop of 45% acetic acid on a microscope slide and squashed. The slides were frozen in liquid nitrogen, the cover-slips were lifted off using a razor blade, and the slides were air-dried. The preparations were stained in DAPI (4’, 6-diamidino-2-phenylindole) solution (1µg µl⁻¹) for five minutes and mounted in citifluor (Citifluor Ltd.) before examination with a Zeiss Axiophot with appropriate filters for DAPI.

For the chromosome counting, plants were cultivated submerged or halfway emergent in an acid layer of leaf-litter soil.

Fig. 1. Distribution map of the six new Cryptocoryne taxa from the Schwaner mountains and Müller mountains. Higher elevations are shown in dotted outlines. – B = C. bastmeijeri; E = C. erwinii; H = C. yujii var. hendrikii; I = C. isae; R = C. regina; S = C. sahalii.
Results and Discussion

Habit and ecology

Vegetative propagation by subterranean stolons penetrating and colonizing the soil between the thin tree roots along a river bank or in forest floor pools is a characteristic associated with Cryptocoryne.

The habitats of most of the presently described taxa are small streams or creeks with slowly running water, or water seeping through larger areas of muddy flats in shady forest swamps. Such habitats are limited in number, and inhabited by only a few other plant species adapted to seeping water, muddy soil and low light intensity. In such places one often sees the Cryptocoryne populations as many-leaved rosettes throughout the forest swamps. In this kind of habitat reproduction by seed is important, while propagation by stolons is more limited. This noticeabled seed propagation and single plant distribution is known from a few Cryptocoryne species in similar habitats, viz. C. bogneri Rataj (Sri Lanka; Jacobsen 1987a; Kasselmann 2003), C. elliptica Hook. f. (Peninsular Malaysia; Jacobson 1987b), in some localities with C. striolata (Borneo), and most recently in populations of C. aura from the Schwaner mountains (Wongso & al. 2016).

The habitat types found in the lower foothills of the Schwaner mountains and the Müller mountains at altitudes of 50–200 m are generally different from most other Cryptocoryne habitats in Borneo (Fig. 1), although the widespread C. striolata is often found in the same regions in the Schwaner mountains. Similarly, several new species of Bucephalandra Schott (Araceae) (Wong & Boyce 2014), have been described from these mountains.

Before and after the turn of the millennium, the number of new discoveries of Cryptocoryne in Borneo was low. The considerable size of Borneo taken into consideration, it is possible that the number of Cryptocoryne species might well be far higher, thus being in line with the predictions given for Bucephalandra (Wong & Boyce 2014).

Chromosome numbers

Chromosome numbers have proven to be an important taxonomic character in Cryptocoryne (Jacobsen 1977; Arends & al. 1982; Bastmeijer 2017). They form a diploid series of reductions in numbers, and several taxa have a polyploid (euploid) series of additions as well (Table 1). The number 2n = 36 is considered as a secondary basic number; reduction by fusions of chromosomes have taken place (diploid series), a phenomenon also known from, e.g., palms (Dransfield & al. 2008) and grasses (Moore & al. 1995; Devo 2010). Diploid chromosome series have also been recognized within the Araceae (Petersen 1989; Cusimano & al. 2012). Recently chromosome fusions have also been shown for Typhonium Schott (Araceae), in which new, low chromosome numbers have been reported (Wang & al 2002; Dao & al. 2007; Sousa & al. 2014).

Table 1. Presently known chromosome numbers of the genus Cryptocoryne exemplified by some of the representative species and morphological groups (names and numbers from the present investigation are in bold).

<table>
<thead>
<tr>
<th>2n</th>
<th>Species</th>
</tr>
</thead>
<tbody>
<tr>
<td>36</td>
<td>C. crispatula Engl. and the narrow-leaved species from mainland Asia</td>
</tr>
<tr>
<td>34</td>
<td>C. thwaitesii Schott group, Sri Lanka</td>
</tr>
<tr>
<td>34</td>
<td>C. lingua Engl. and C. zaidiana Ipor &amp; Tawan, Sarawak</td>
</tr>
<tr>
<td>51</td>
<td>C. cordata Griff. and many others from the Malesian region, Vietnam and Philippines</td>
</tr>
<tr>
<td>30</td>
<td>C. longicauda Engl., Johor, Sumatera and Borneo: C. pontederifolia Schott, Sumatera; C. villosa N. Jacobsen, Sumatera</td>
</tr>
<tr>
<td>28</td>
<td>C. beckettii Thwaites ex Trimen group, Sri Lanka</td>
</tr>
<tr>
<td>28</td>
<td>C. regina Wosong &amp; Ipor, W Kalimantan</td>
</tr>
<tr>
<td>26</td>
<td>C. aura Wosong &amp; Ipor, WKalimantan</td>
</tr>
<tr>
<td>26</td>
<td>C. erwinii Wosong &amp; Ipor, W Kalimantan</td>
</tr>
<tr>
<td>22</td>
<td>C. ciliata (Roxb.) Schott, SE Asia</td>
</tr>
<tr>
<td>22</td>
<td>C. sahalii Wosong &amp; Ipor, W Kalimantan</td>
</tr>
<tr>
<td>14</td>
<td>C. bastmeijeri Wosong, W Kalimantan</td>
</tr>
<tr>
<td>10</td>
<td>C. isae Wosong, W Kalimantan</td>
</tr>
</tbody>
</table>

Chromosome numbers are shown associated with species groups and geographical distribution (Table 1).

New taxa

Cryptocoryne bastmeijeri Wosong, sp. nov. – Fig. 2–4. Holotype: Indonesia, W Kalimantan, Schwaner mountains, Ketapang Regency, S of Sekadau, 22 Sep 2015, S. Wosong SW 1567 (BO; isotypes: C, L).

Diagnosis — Cryptocoryne bastmeijeri differs from C. auriculata and C. isae by having up to 40 spreading
green leaves, with a triangular-ovate blade, and by the short spathe limb. Its chromosome number of $2n = 14$ has hitherto not been recorded for *Cryptocoryne*.

**Description** — Aquatic to amphibious herbs, c. 10 cm tall. *Rhizome* thick, notched, with only a few thin stolons. *Leaves* 20–40 together in a rosette, spreading ± horizontally from upright petiole, 5–15 cm long; *blade* dark green, lighter green to purplish abaxially, triangular-ovate, 2–3 × 3–5 cm, smooth. *Cataphylls* whitish, c. 1.5 cm long 2-keeled, usually situated below soil surface. *Peduncle* 2–3 cm long. *Spathe* whitish outside in proximal part, distal ⅓ purplish; *kettle* cylindric, to 1 cm long, white inside, *flap* light yellowish; *tube* c. 0.75 cm long, white inside; *limb* purple to reddish, ovate, shortly pointed, forward obliquely twisted, to 1.5 cm long, surface with a few rounded protuberances, with an indistinct, darker collar, sometimes with a white line running distally from collar as a result of a folding of limb in young stage, red colour continuing in a more intensive hue a few mm into tube. *Spadix* c. 1 cm long, with usually 5 whitish *female* flowers with broadly ellipsoid to emarginate *stigmas* sometimes with a slight purplish tinge along margin; *olfactory bodies* yellow, irregular; *male flowers* 25–30, whitish yellowish. *Syncarp* on an up to 3 cm long peduncle, brownish purplish, lighter spotted, broadly ovoid, c. 1 cm wide, smooth, persistent stigmas clearly visible. *Seeds* with germinating embryo emerging c. ⅓ from distal end with c. 5 plumulary processes.

**Chromosome number** — $2n = 14$, reported here for *SW 1567*.

**Distribution** — As far as known endemic to W Kalimantan, Schwaner mountains, SW of Sintang, where it has been observed in one locality additional to the type locality.

**Ecology** — The type specimen was collected in a swamp forest streamlet with clear, slow-running water, with the leaves spreading over the mud and sand. Altitude range 175–200 m.

**Eponymy** — Named after Jan D. Bastmeijer, of Emmen, The Netherlands, who has for decades meticulously gathered information on *Cryptocoryne*, and most importantly disseminates this information on his website (Bastmeijer 2017), thereby establishing contacts between enthusiasts worldwide.

**Remarks** — The embryo resembles that found in *Cryptocoryne aura* (Wongso & al. 2016) and *C. isae* S. Wongso by having the germinating embryo emerging c. ⅓ from the distal end with c. 5 plumulary processes.

The chromosome number of $2n = 14$ is a new number and unique within *Cryptocoryne*.
Cryptocoryne erwinii Wongso & Ipor, sp. nov. — Fig. 5–7.


Diagnosis — Cryptocoryne erwinii superficially resembles \textit{C. lingua} in the leaves, but the leaf blade is more horizontally oriented, with the abaxial surface distinctly lighter than the adaxial one. The 6–9 cm long spathe is exceptional and differs from all other \textit{Cryptocoryne} species in being white, with the distal part of the limb subulate and purple inside, first bent backward to upright, later bending forward over the white, widely expanded, funnel-shaped entrance, which lacks a collar. Its chromosome number of 2\(n = 26\) has hitherto only been reported for the recently described \textit{C. aura}.

Description — Amphibious herbs 8–10 cm tall. \textit{Rhizome} thick, stout, notched, with long, stout subterranean stolons. \textit{Leaves} 5–10 together in a rosette, 6–10 cm long, \textit{blade} spreading ± horizontally from upright petiole, green adaxially, lighter abaxially, ovate, to 3 × 6 cm, superficially smooth but with small rounded protuberances, base slightly cordate. \textit{Cataphylls} greenish, to 2 cm long, 2-keeled. \textit{Peduncle} 1–2 cm long. \textit{Spathe} 6–9 cm long, red-brownish outside; \textit{kettle} white inside, cylindric, with a broad constriction at middle, 1.5–2.5 cm long, \textit{flap} white; \textit{tube} 2–4 cm long, twisting after opening; limb subulate, 2–3 cm long, backward bent to upright at opening, next day bending forward, protecting opening of white, expanded funnel-cone-shaped tube opening (unusual tube opening may originate from a collar that has expanded and formed dilated opening). \textit{Spadix} 1.5–2.5 cm long, with 4 or 5 white \textit{female flowers} with broadly ellipsoid stigmas; \textit{olfactory bodies} yellowish white; \textit{male flowers} 30–40, yellowish; \textit{appendix} white. \textit{Syncarp} not observed.

Chromosome number — 2\(n = 26\), reported here for SW 1560.

Distribution — As far as known endemic to W Kalimantan, Schwanner mountains, Sintang Regency, SW of Sintang, where it has
been found only at the type locality.

Ecology — The type specimen was collected in a small humus-rich muddy-peaty streamlet in a swamp forest, where the population was growing among tree roots. The habitat conditions indicate that the water flow is constantly low so that dead leaves accumulate to form a muddy-peaty, loose, organic substrate. Water parameters: pH 5.5, conductivity 25 μS/cm, temperature 25 °C. Altitude 60 m.

Eponymy — Named after Erwin Syahputra, who has a keen eye for plants, and discovered the habitat of this unique species.

Remarks — The colour and structure of the spathe of Cryptocoryne erwinii is unique, no other species having anything like the limb of this species. The chromosome number of 2n = 26 is the same as that found in C. aura, but the morphology of the two species is very different.

Cryptocoryne isae Wongso, sp. nov. – Fig. 8–10. 

Diagnosis — Cryptocoryne isae usually has fewer than 10 upright leaves to 25 cm long, with a green, narrowly ovate, somewhat spongy blade, which could resemble C. zaidiana; the c. 6 cm long spathe has a short, forward obliquely twisted, purple limb with an indistinct, darker collar, whereas C. zaidiana has a long-tubed spathe with a broad, white, rugose limb and a purple throat. Its chromosome number of 2n = 10 has hitherto not been recorded for Cryptocoryne.

Description — Amphibious herbs, c. 20 cm tall. Rhizome thick, firm, notched, with long, stout, subterranean stolons. Leaves usually less than 10 together in a rosette, 20–25(–30) cm long, blade erect-spreadling from an upright petiole, dark green, lighter green abaxially, narrowly ovate, 2–3 × 5–10 cm, thick, softly spongy, smooth, margin entire, smooth or with fine crenulations. Cataphylls whitish brownish, c. 3 cm long, 2-keeled, usually reaching soil surface. Peduncles 1 or 2, to 8 cm long. Spathe c. 6 cm long, whitish outside in proximal

Fig. 7. Cryptocoryne erwinii – A: whole flowering plant showing habit; B: two spathes seen from back (older) and front (younger); C: opened kettle of younger spathe with lighter yellow male and female flowers; D: chromosomes showing 2n = 26. – Photographs: A–C by S. Wongso; D by K. R. Munk.

Fig. 8. Cryptocoryne isae, habitat at type locality with completely emergent plants on forest floor between other herbs and dead leaves. – Photograph: 19 August 2015 by S. Wongso.
part, distal ½ purplish; kettle ovate-cylindric, slightly constricted below level of male flowers, to 2.5 cm long, white inside, flap light yellow; tube c. 1 cm long, white inside; limb forward obliquely twisted, to 3 cm long, purple with an indistinct, darker collar, rather smooth, red colour continuing a few mm into tube. Spadix to 3 cm long, usually with 5 whitish female flowers with broadly ellipsoid to emarginate stigmas with a slight purplish tinge along stigmatic margins; olfactory bodies yellow, rounded; male flowers 30–40, yellowish. Syncarp ovoid with persistent stigmas. Seeds with germinating embryo emerging c. ⅓ from distal end with c. 5 plumulary processes.

Chromosome number — $2n = 10$, reported here for SW 1561.

Distribution — Probably endemic to W Kalimantan, Schwaner mountains, Sekadau Regency, S of Sekadau, where it has been observed in one locality besides the type locality.

Ecology — The plants that provided the type specimens were found among other herbs emerging from low-lying forest floor in the upper, drier areas near a stream with a loamy, muddy substrate; the long petiole may be an adaptation to tree leaf accumulation rather than to deep water or substrate sedimentation. The short spathe on a short peduncle situated between the proximal parts of the petioles indicates that plants are always emergent during the flowering season at this site.

A second known locality is reported SW of the type locality. This locality has a higher water level; the peduncle is longer (more than 6 cm). Unfortunately, this site will be opened for agriculture soon. The type locality was also somewhat disturbed, with only secondary forest present. Altitude 125 m.

Eponymy — Named after Isa Bin Ipor, of UNIMAS, who has studied the Cryptocoryne species of Sarawak for many years and more recently has joined explorations for species in Kalimantan.

Remarks — Chromosome number $2n = 10$. This surprisingly low number is new in Cryptocoryne. Comparable low chromosome numbers have recently been recorded in the SE Asian Araceae genus Typhonium (Wang & al. 2002; Dao & al. 2007; Sousa & al. 2014).

Cryptocoryne regina Wongso & Ipor, sp. nov. – Fig. 11–13. Holotype: Indonesia, W Kalimantan, Müller mountains, Kapuas Hulu Regency, S of Temuyuk, 20 Aug 2015, S. Wongso & I. B. Ipor SW 1563 (BO; isotypes: C, L).

Diagnosis — Cryptocoryne regina resembles C. auriculata in having leaves with a green to pinkish marbled, triangular-ovate, somewhat spongy blade, but the spathe limb differs in being obliquely twisted, whitish to purple, with an indistinct, lighter collar zone. Its chromosome number is $2n = 28$, a number that has previously been reported for the C. beckettii Thwaites ex Trimen group from Sri Lanka.

Description — Amphibious herbs, variable in height, 6–10(–15) cm tall depending on locality. Rhizome thick, stout, notched, with long, subterranean stolons. Leaves up to 8 together in a rosette, erect-spreading from up-
right petioles, 10–23 cm long (longer in more submerged plants), blade dark green to lighter brownish (reddish) opalescent, with darker green markings, lighter green abaxially, ovate to narrowly ovate, 2.5–3.5 × 8–12 cm, somewhat thick and softly spongy, smooth. *Cataphylls* whitish to greenish distally, c. 3 cm long, 2-keeled, usually situated below soil surface. *Peduncle* 1–3 cm long. *Spathe* 6–11 cm long, whitish outside in proximal part, above kettle becoming silvery to purplish; *kettle* ovate-cylindric, 2–3.5 cm long, white inside, *flap* light yellow; *tube* 1–2 cm long, white inside; *limb* upright or backward bent to forward obliquely twisted, 2–3 cm long, smooth adaxially, silvery white to reddish or with a reddish margin, collar zone distinct, silvery white to white or with a reddish tinge. *Spadix* to 3.5 cm long, with 5–7 greenish *female flowers* with broadly ellipsoid to emarginate stigmas; *olfactory bodies* whitish, irregularly rounded; *male flowers* 40–70, yellowish. *Syncarp* not observed.

**Chromosome number** — 2n = 28, reported here for SW 1563; and additional collections SW 1562 and SW 1573.

**Distribution** — Endemic to W Kalimantan, Müller mountains, Kapuas Hulu Regency, S of Temuyuk.

**Ecology** — Streams and rivers, where it may occupy sandbanks in smaller streams or river banks in larger streams or rivers. It tends to be found in sites near or just above the lower water level, in which it is able to maintain itself tightly woven in between tree roots. Water parameters at the type locality: pH 6.6, conductivity 37 μS/cm, temperature 26 °C. The substrate is a sand and loam mix and the habitat resembles that of *Cryptocoryne auriculata* from Sarawak.

At a second locality (SW 1562), a little further toward the west, the water parameters were: pH 6.3, conductivity 44 μS/cm, temperature 25 °C. The plants at the second locality were growing on a sandbank in the middle of a smaller stream and the plants and inflorescences were slightly larger than at the type locality, and the leaves were completely green.

More than ten localities have been recorded, so the distribution of this species comprises more diverse habitat conditions. For example, it is also found on the banks of larger rivers with strong current and fluctuating water level (SW 1563). Altitude range 50–75 m.

**Etymology** — The specific epithet *regina*, which is Latin, meaning queen, refers to the commercial trade name ‘Silver Queen’, a plant with a bright silvery spathe limb.

**Remarks** — Chromosome number 2n = 28, a number previously reported for the *Cryptocoryne beckettii* group from Sri Lanka (Arends & al. 1982; Jacobsen 1977), but this number has most likely evolved twice, and does not indicate close relationship.

Variation in leaf-size and colour is found at different localities; at present it is not known to what extent this variation is genetically based.

*Cryptocoryne sahalii* Wongso & Ipor, **sp. nov.** — Fig. 14–16. Holotype: Indonesia, C Kalimantan, Müller mountains, Gunung Mas Regency, NW of Kuala Kurun, 4 Apr 2015. S. Wongso & J. B. Ipor SW 1509, cultivated as B 1631, 24 Sep 2017 (BO).

**Diagnosis** — *Cryptocoryne sahalii* resembles *C. grifithii*, but has many more (20–30 vs 10) green to purple, rounded, cordate leaves in a rosette; the limb of the spathe is purple (to yellowish), upright to recurved in the distal
part (C. griffithii is strongly recurved) with a relatively narrow opening with a thin collar rim; the surface of the limb has many small, round-ed protuberances (C. griffithii has a rather thick collar and larger, prominent, rounded protuberances). Its chromosome number of \(2n = 22\) has previously been reported for C. ciliata.

**Description** — Amphibious herbs, 6–10(–15) cm tall. *Rhizome* thick, stout, notched, with long, subterranean stolons. *Leaves* up to 20–30 together in a rosette, spreading horizontally on water and mud surface, 10–15 cm long; *blade* dark green to lighter brownish (reddish), lighter green abaxially, ovate to narrowly ovate, 2.5–3.5 × 6–8 cm, smooth. *Cataphylls* whitish to greenish distally, c. 3 cm long, 2-keeled. *Peduncle* 1–3 cm long. *Spathe* 4–6 cm long, outside purplish or green leopard-spotted in distal part, whitish in proximal part; *kettle* ovate-cylindric, 1.5–2 cm long, white inside, *flap* light yellow; *tube* c. 2 cm long, white inside; *limb* upright or backward bent, 2–3 cm long, adaxial surface with many small, rounded protuberances, purple-red (to yellowish), with a relatively narrow, often vertically situated opening with a thin collar rim, throat dark purple continuing a few mm into tube. *Spadix* to 2 cm long, with usually 5 or 6 whitish to greenish *female flowers* with short, broadly ellipsoid to emarginate stigmas; *olfactory bodies* yellow, rounded; *male flowers* 20–30, yellowish. *Syncarp* ovoid, pointed, with persistent stigmas. *Seeds* rough with ridges; embryo germinating with 3 plumu-

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Fig. 12. *Cryptocoryne regina* – A: habit of plant showing marbled leaf blades; B: spathe with upright limb; C: spathe from cultivated specimen; D: habit of plants, with spathes; E: two spathes with kettles cut open; F: seed showing embryo emerging from distal end of seed and two plumular processes; G: chromosomes showing \(2n = 28\) (SW 1563). – Photographs: A, B, 20 August 2015 by S. Wongso; C by J. D. Bastmeijer; D–F by S. Wongso; G by K. R. Munk.

Fig. 13. *Cryptocoryne regina* – A: artificially opened kettle of spathe showing female flowers at base, naked spadix axis, and male flowers at apex; B: female flowers with receptive stigmas; C: male flowers halfway hidden behind flap. – Photographs: J. D. Bastmeijer.
lary processes, protruding radicle first from distal end of seed.

**Chromosome number** — $2n = 22$, reported here for SW 1509 and an additional collection SW 1628.

**Distribution** — Known from the Müller mountains, C Kalimantan, S part of Gunung Mas Regency, NW of Kuala Kurun, and from W Kalimantan, in the N Müller mountains, Kapuas Hulu Regency, SW of Temuyuk (SW 1628).

**Ecology** — Submerged to emergent plants in small and slow-flowing streams in a clay-sand substrate (together with Cryptocoryne striolata and Barclaya rotundifolia M. Hotta). Water parameters at the type locality: pH 6.2, conductivity 30 μS/cm, temperature 26 °C. At Kapuas Hulu Regency (SW 1628), the plants were submerged to emergent near or just above the lower water level and rooted in between the fine tree roots at the banks of smaller rivers. Altitude range 75–225 m.

**Eponymy** — Named after Abdul Sahal, who discovered the type population with his trained eye for plants.

**Remarks** — Cryptocoryne sahalii resembles *C. griffithii* (Othman & al. 2009): the

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**Fig. 14.** Cryptocoryne sahalii, habitat at type locality with leaf rosettes just submerged. – Photograph: 4 April 2015 by S. Wongso.

**Fig. 15.** Cryptocoryne sahalii – A: artificially opened kettle of spathe showing female flowers at base, naked spadix axis, and male flowers at apex; B: female flowers with outward bent stigmas; C: male flowers showing droplets of pollen on apex of horn. – Photographs: J. D. Bastmeijer.

**Fig. 16.** Cryptocoryne sahalii – A: flowering cultivated plant with purple spathe limb; B: flowering cultivated plant with yellow spathe limb and opened syncarp with seeds; C: germinating seed showing three plumulary processes that have emerged through distal end of the seed; primary root has not yet begun developing; D: chromosomes showing $2n = 22$ (SW 1509). – Photographs: A by J. D. Bastmeijer; B by H. Budianto; C by S. Wongso; D by K. R. Munk.
rosette has 20–30 leaves in *C. sahalii* (vs up to c. 10 in *C. griffithii*); yellowish spathes have been observed twice in *C. sahalii* (vs never in *C. griffithii*); the spathe limb is ± upright and slightly recurved in the distal part in *C. sahalii* (vs strongly recurved in *C. griffithii*); the outside of the unopened spathe limb is purplish sometimes green leop­ard-spotted in *C. sahalii* (vs uniformly green to purplish in *C. griffithii*); the surface of the spathe limb is dark purple in *C. sahalii* (vs often reddish in *C. griffithii*); the spathe limb has small, more distantly distributed protuberances or larger, irregular protuberances in *C. sahalii* (vs uniformly rounded protuberances rather closely distributed and not irregular in *C. griffithii*); the collar opening is ± vertical in *C. sahalii* (vs ± horizontal in *C. griffithii*); the collar rim is rather thinner in *C. sahalii* than in *C. griffithii*; the chromosome number is $2n = 22$ in *C. sahalii* (vs $2n = 34$ in *C. griffithii*).

The second known accession from the N Müller mountains, Kapuas Hulu Regency, SW of Temuyuk, SW 1628, differs from the type gathering by having the spathe limb with more distinct protuberances and the unopened limb of the spathe is not leopard-spotted on the outside.

The chromosome number $2n = 22$ has previously been reported for *Cryptocoryne ciliata*, but most likely does not reflect any closer relationship with *C. sahalii*.

**Cryptocoryne yujii var. hendrikii** Wongso, var. nov. – Fig. 17–19.

Holotype: Indonesia, W Kalimantan, Schwaner mountains, Sekadau Regency, SW of Sekadau, 1 Apr 2016, S. Wongso SW 1601 (BO; isotypes: C, L).

**Diagnosis** — *Cryptocoryne yujii* var. *hendrikii* often has more than 25 spreading leaves to 15 cm long, with a green to purplish green, cordate blade; the spathe is white, c. 8 cm long; the limb has a rough surface and is upright with a long tail and a black-purple collar, thereby resembling *C. yujii* var. *yujii* from Sarawak; it differs, however, in the many-leaved rosette of > 10 and often > 25 leaves (vs 5–8 in *C. yujii* var. *yujii*) with the blade to 4 × 8 cm (vs to 7 × 10 cm in *C. yujii* var. *yujii*).

**Description** — Amphibious herbs c. 10 cm tall. *Rhizome* thick, stout, notched, with rath­er short, stout, subterranean stolons. *Leaves* often more than 25 together in a rosette, 10–15 cm long; blade green to purplish green when sun-exposed, cordate, 2–4 × 6–8 cm, smooth. *Cataphylls* whitish, brown­ish distally, c. 2 cm long, 2-keeled, usually situated below soil surface. *Peduncle* 1–2 cm long. *Spathe* 7–10 cm long, white outside; *kettle* c. 1 cm long, cylindric, white inside, *flap* white; *tube* c. 3 cm long, white inside; *limb* to 4 cm long, distal part a little twisted, white with a rough surface and a blackish purple collar continuing a few mm into tube. *Spadix* c. 1 cm long, with usually 5 whitish *female flowers* with broadly ellipsoid stigmas; *olfactory bodies* light yellow, rounded; *male flowers* 25–40, yellowish with a distinct brownish colour along thecae margins. *Syncarp* whitish brownish, ovoid, pointed, stigmas persistent. *Seeds* yellowish brownish, somewhat rough, germinating with 2 plumulary process, protruding radicle first from distal end of seed.

**Chromosome number** — $2n = 34$, reported here for SW 1601.

**Distribution** — Probably endemic to W Kalimantan, Schwaner mountains, where it is known from three lo­calities.
Ecology — Small, muddy streams and creeks with slow-running water seeping over the surface of the clayey-sandy soil, with the leaves spreading over the surface. Water parameters: pH 6.4, conductivity 30 μS/cm, temperature 26 °C. Altitude range 50 – 100 m.

Eponymy — Named after Hendrik, who has assisted in discovering several new Cryptocoryne species during field trips in Kalimantan.

Remarks — Cryptocoryne yujii var. hendrikii and var. yujii differ in leaf number and size and spathe length: leaves > 10, often > 25 together, 2–4 × 6–7 cm and spathe 7–10 cm long in var. hendrikii vs. leaves 5–8 together, 3–7 × 6–10 cm and spathe 15–20 cm long in var. yujii, which is strictly correlated to habitat. Cryptocoryne yujii var. hendrikii may be considered an ecotype adapted to small, shallow streams and seeping mudflats, whereas var. yujii is an ecotype adapted to larger streams or rivers with deeper water. The use of varietal rank is in accordance with the varieties of C. crispatula Engl. s.l. as used in the Flora of Thailand (Jacobsen & al. 2012).

The chromosome number $2n = 34$ is found in a number of Cryptocoryne species in the Malesian region (see, e.g., Arends & al. 1982; Bastmeijer 2017), including C. yujii var. yujii.

Conservation status
As most of the presently described new Cryptocoryne are known only from one or a few localities, it is difficult to ascertain their conservation status according to the IUCN (2016), except that they are mostly Data Deficient (DD). In relation to the more than 250 Cryptocoryne localities known from Kalimantan, the records mainly concern C. cordata var. grabowskii, C. fusca and C. striolata; those described here represent just a few, which as far as is known are local endemics to the Schwaner mountains and Müller mountains. More observations are needed in order to outline a conservation assessment.

Cryptocoryne bastmeijeri is currently known from two localities. The habitat is rather inaccessible, which might help to preserve it.

Cryptocoryne erwinii is known only from the type locality. The habitat is rather inaccessible, which might help to preserve it.

Cryptocoryne isae is, in addition to the type locality, known only from one other locality, which is potentially threatened. The habitat of the type locality is rather inaccessible.

Cryptocoryne regina seems rather widespread and not immediately in danger, as it is found at more than ten known localities within an area of 40 × 30 km. In order to sustain this, monitoring is needed to outline a conservation assessment.

Cryptocoryne sahalii is known from the type locality NW of Kuala Kurun, C Kalimantan, and an additional three localities SW of Temuyuk, W Kalimantan; more observations are needed in order to outline a conservation assessment.
Cryptocoryne yujii var. hendrikii is known only from two localities additional to the type locality, but within a restricted area. The habitat is rather inaccessible, which might help to preserve it.

Key to the Cryptocoryne taxa of Borneo

With the new taxa of Cryptocoryne described here and previously, a new key is provided. The characters and measurements are from wild-growing accessions. Deviant specimens are not included in the key. For brevity, the term "limb" refers here to the limb of the spathe.

1. Limb with long cilia at margin ........ C. ciliata
   - Limb without cilia at margin ........... 2

2. Leaf blade ± covered with hairs on abaxial surface and/or along margin ............ 3
   - Leaf blade glabrous ......................... 5

3. Leaf blade lanceolate, ± bullate; spathe 5–7 cm long, very narrow, kettle white inside .......... C. uenoi
   - Leaf blade ovate to shortly lanceolate, not significantly bullate; spathe 7–10(–12) cm long, broad, kettle ± purplish inside, often inflated ........... 4

4. Limb abruptly narrowed into a tail, collar pronounced .......... C. ferruginea var. ferruginea
   - Limb gradually tapering into a tail, collar zone present ...................... C. fusca

5. Tube of spathe > 2× as long as limb ........ 6
   - Tube of spathe ≤ 2× as long as limb .......... 15

6. Limb with reddish or purplish protuberances .......... 7
   - Limb ± smooth, yellow, brown or purple .......... 9

7. Limb c. 1 cm wide, with black-purple, coarse protuberances on a white base, collar purple ........... C. zaidiana
   - Limb c. 0.5 cm wide, with fine protuberances, collar not purple ......................... 8

8. Limb ± recurved, with red protuberances, especially on margin, collar yellow with red spots; leaf blade ovate, occasionally slightly bullate .......... C. pallidinervia
   - Limb ± spirally recurved, with yellow to purple protuberances over whole surface, collar zone present; leaf blade lanceolate, bullate .......... C. keei

9. Limb 0.5–1 cm wide, with a rather long, ± twisted apex ........ 10
   - Limb usually more than 1 cm wide, without a long tail or apex ......................... 11

10. Leaf blade 3–12 cm long, usually flat . . C. striolata
    - Leaf blade 10–30 cm long, noticeably bullate .......... C. hudoroi

11. Limb yellow to brownish, collar zone yellow . . . . 12
    - Limb brownish to purple, collar zone purple or purple spotted .......... 13

12. Limb 1–2 cm wide, tube 5–10(–15) cm long; leaf-marginal plain .......... C. cordata var. grabowskii
    - Limb c. 0.5 cm wide, tube 4–6 cm long; leaf with a distinct, membranous, ciliate margin .......... C. aura

13. Limb brownish purple, collar zone yellow-purple spotted .......... C. spurpurea nothovar. borneoensis
    - Limb purple, collar zone plain purple .......... 14

14. Limb almost smooth, shiny purple, collar zone almost as wide as limb .......... C. sbatangkayanensis
    - Limb rough or with protuberances, dull purple, collar zone c. ½ as wide as limb .......... C. spurpurea nothovar. borneoensis

15. Limb white to silvery, occasionally pinkish, collar white or purple ........... C. yujii var. yujii
    - Limb purple or brownish to yellowish .......... 19

16. Limb (collar zone) white, with a long, thin, purple tail .......... C. erwinii
    - Limb wholly white, silvery or pinkish, short or long, collar white or purple .......... 17

17. Limb > 3 cm long, upright, white, surface with protuberances, collar purple .......... 18
    - Limb ≤ 3 cm long, if longer not upright, collar whitish .......... C. regina

18. Leaves 5–8 together, blade 3–7 × 6–10 cm; spathe 15–20 cm long .......... C. yujii var. yujii
    - Leaves > 10, often > 25 together, blade 2–4 × 6–7 cm; spathe 7–10 cm long .......... C. yujii var. hendrikii

19. Limb taper-pointed or with a long tail ................... 20
    - Limb neither taper-pointed nor with a tail .......... 26

20. Leaves light green, blade vertically oriented, spongy, veins inconspicuous; distal part of limb red-purple, collar zone yellow, spotted red .......... C. lingua
    - Leaves various shades of purplish, blade ± horizontally oriented .......... 21

21. Limb at base usually open circular in view, with a distinct collar, tail 10–15 cm long .......... C. longicauda
    - Limb at base not open circular in view, with or without a distinct collar, tail ≤10 cm long .......... 22

22. Limb purple or yellowish, with ± rough protuberances ......... 23
    - Limb purple to dark purple, ± smooth .......... 25

23. Limb with a long, filiform tail, kettle inflated .......... C. ferruginea var. sekadauensis
    - Limb with a long, but not filiform tail, kettle not flattened .......... 24

24. Limb yellow(ish), throat purplish spotted .......... C. keei
    - Limb purple, throat purple .......... C. uenoi

25. Limb ± upright backward coiled, throat open .......... C. striolata
    - Limb forward obliquely twisted, throat hidden .......... C. ideii

26. Leaf blade conspicuously bullate .......... C. bullosa
    - Leaf blade not conspicuously bullate .......... 27

27. Limb upright or recurved, collar narrow, conspicuous .......... 28
    - Limb ± forward obliquely twisted, if ± upright then collar zone broad .......... 29

28. Limb strongly recurved, with many distinctly regular, round protuberances, collar thick in view, ± horizontal in circular opening .......... C. griffithii
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