

# *Cryptocoryne* hybrids (Araceae) 3: Hybrids between *Cryptocoryne cordata* and *Cryptocoryne nurii* from southern Peninsular Malaysia

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## ABSTRACT

*Cryptocoryne* is a genus of 64 current species with nine indigenous species recognized from Peninsular Malaysia as well as six interspecific hybrids. Natural hybrids within *Cryptocoryne* have been reported from Sri Lanka, Thailand, Lao P. D. R., Peninsular Malaysia, Singapore, Sumatera, Sarawak, and Kalimantan. Here we examine hybrid populations from southern Peninsular Malaysia. All hybrids were sterile but propagate vegetatively. Populations vary in morphological appearance of leaves and spathe limbs. Analyzing the different

populations found in southern Peninsular Malaysia and comparing these with artificially produced hybrids show that the here-presented populations represent *C. ×decus-silvae*, hybrids between *C. cordata* var. *cordata* and *C. nurii* var. *nurii*.

## KEY WORDS

Aroids, natural and artificial hybrids, vegetative reproduction, chromosome numbers, Southern Peninsular Malaysia, *Cryptocoryne cordata* var. *cordata* × *C. nurii* var. *nurii*, *C. ×decus-silvae*.

## INTRODUCTION

At present 64 species, 19 additional varieties and 14 interspecific hybrids of *Cryptocoryne* are recognized (Bastmeijer 2020; Jacobsen et al. 2020; Wongso et al. 2017, 2019, 2020). *Cryptocoryne* are distributed throughout Southeast Asia, with nine indigenous species recognized from Peninsular Malaysia, viz. *C. affinis* Hook.f., *C. ciliata* (Roxb.) Schott, *C. elliptica* Hook.f., *C. cordata* Griff. var. *cordata*, *C. griffithii* Schott, *C. longicauda* Engl., *C. minima* Ridl., *C. nurii* Furt. var. *nurii*, *C. nurii* Furt. var. *raubensis* Ganapathy & Siow, and *C. schulzei* De Wit (Othman et al. 2009; Bastmeijer 2020), as well as five interspecific hybrid combinations which will be outlined below.

In southern Peninsular Malaysia (Johor, Malacca, and Pahang) it is not uncommon to find more than one species of *Cryptocoryne* sharing the same stream or river system. Suitable species combinations coexist, resulting in conditions for hybridization. Natural *Cryptocoryne* hybrids have been reported from Sri Lanka (Jacobsen 1981, 1987; Jacobsen & Ørgaard 2019), Thailand and Lao P. D. R. (Jacobsen 1980; Jacobsen et al. 2016), Peninsular Malaysia (Othman et al. 2009; Rosazlina 2016; Komala 2019), Singapore (Bastmeijer & Kiew 2001), Sumatera (Wongso et al. 2019), Sarawak (Ipor et al. 2015), and Kalimantan (Jacobsen et al. 2002; Bastmeijer et al. 2013), with an overview presented by Jacobsen et al. (2016).

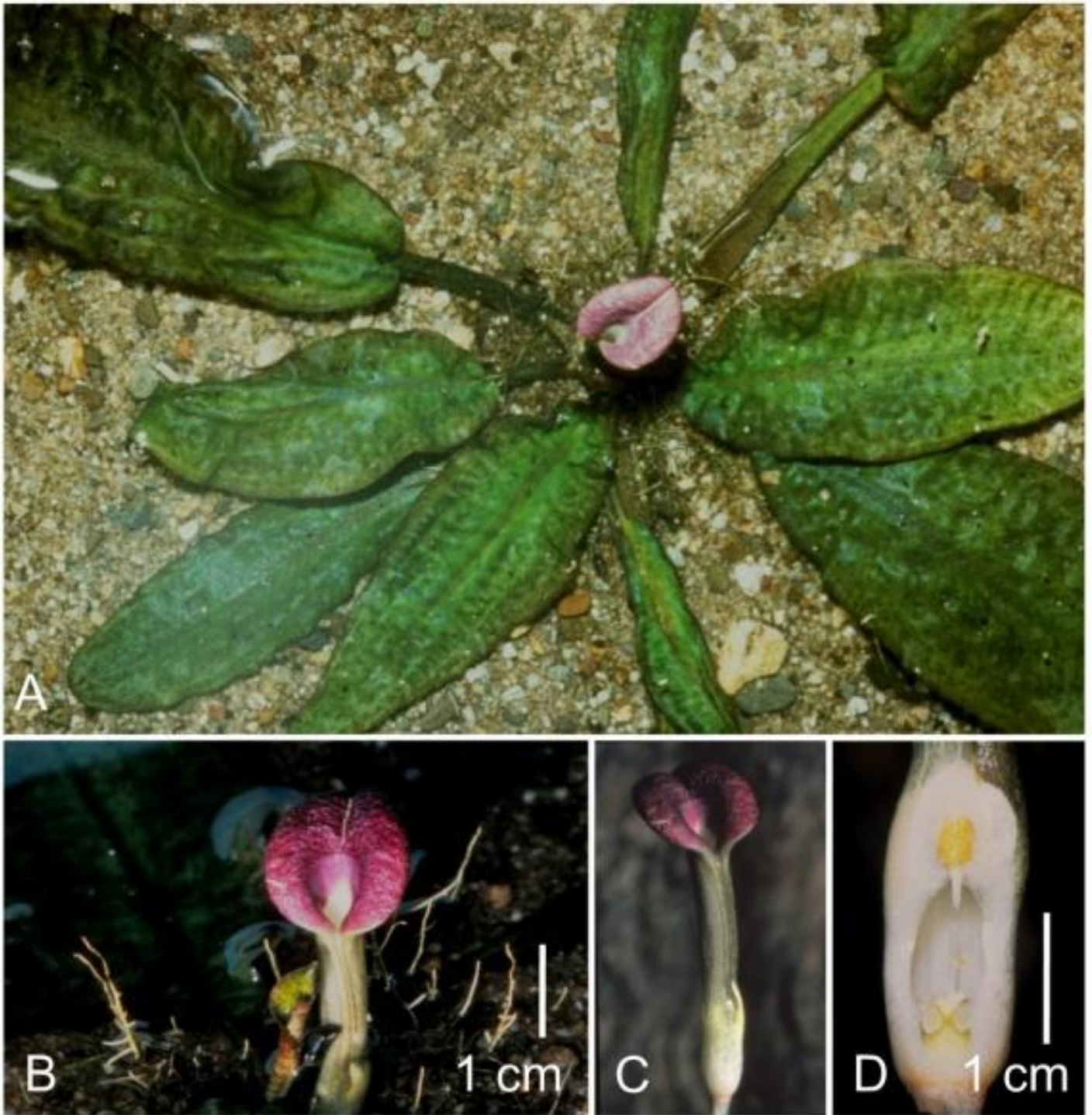
Several *Cryptocoryne* hybrids and hybrid complexes are recognized from the peninsula and Singapore:

*Cryptocoryne* × *purpurea* Ridley nothovar. *purpurea*, has parentage of *C. cordata* var. *cordata* and *C. griffithii* (Othman et al, 2009; Rosazlina, 2016) [nothovar. *borneoensis* N. Jacobsen et al. described from southern Kalimantan with the parentage *C. cordata* Griffith var. *grabowskii* (Engler) N. Jacobsen and *C. griffithii* (Jacobsen et al. 2002)]. Note: nothovar., hybrid variety.

*Cryptocoryne* × *timahensis* Bastmeijer has recently been suggested to be a hybrid between *C. nurii* var. *nurii* and *C. schulzei* by Jacobsen et al. (2016, 2019a) based on hybridization experiments which is now supported by molecular studies (Komala 2019). It was originally assumed to be a hybrid between *C. cordata* var. *cordata* and *C. nurii* var. *nurii* (Bastmeijer & Kiew 2001).

*Cryptocoryne* × *zukaii* Rataj was initially described from cultivated material of undocumented origin (with the trade label “Penang 3”). Recent experiments are consistent with it being a hybrid between *C. cordata* var. *cordata* and *C. minima* (Jacobsen et al. 2016, 2019a; Komala 2019).

*Cryptocoryne* × *griffithioides* N. Jacobsen and *C. ×schulzeioides* N. Jacobsen are hybrids between *C. griffithii* and *C. nurii* var. *nurii*, and *C. griffithii* and *C. schulzei*, respectively, sampled from secondary habitats in Johor (Jacobsen et al. 2020).



**Figure 1.** *Cryptocoryne*  $\times$  *decus-silvae* De Wit; cultivated type specimen (from an area around Chaah, Johor). **A.** Plant grown in a tank in shallow water seen from above; **B.** close up of spathe limb showing the rough surface and smooth tube opening; **C.** The whole spathe showing the kettle, tube, and limb; **D.** Cut open kettle showing the female flowers, the sterile interstice (broken) and the male flowers (yellow). Photographs by H. C. D. de Wit.



**Figure 2.** *Cryptocoryne*  $\times$  *jacobsenii* De Wit; cultivated type specimen from an unknown locality in Malaysia. **A.** Plant grown emergent in a pot seen from above; **B.** Spathe limb showing the rough surface, an indication of a low collar and the red spotted tube opening; **C.** Cut open kettle showing female flowers, sterile spadix part, male flowers and flap partly covering the male flowers, and the inner kettle wall with small red spots in the upper part. Photographs by N. Jacobsen.

*Cryptocoryne decus-silvae* De Wit and *C. jacobsenii* De Wit have been described from cultivated material from Johor; the latter assumed to come from southern Peninsula Malaysia. Their identity and identification have caused considerable uncertainties and problems over the years and are our focus here.

Over the years we have obtained a number of new *Cryptocoryne* accessions from southern Peninsular Malaysia that morphologically did not match any of the known species or hybrids from the region.

Many interspecific plant hybrids are male and/or female sterile. If presented with a deviant looking plant, a first check is to examine the pollen fertility/stainability. This can easily be done by staining with “cotton blue” (see, e.g., Wongso et al. 2019). The plants subjected to this study all showed a very low pollen fertility, suggesting hybrid origin.

## MATERIAL AND METHODS

Much of the material was sampled in their natural habitats by the authors, and all available material has been cultivated in the



**Figure 3.** *Cryptocoryne* – NJ 2997, ‘Planteimporten’, 1978; cultivated specimen from an unknown locality in Malaysia. **A.** Plant grown emergent in a pot seen from above; **B.** Spathe limb showing the rough surface, an indication of a thin low collar and the red spotted tube opening; **C.** Cut open kettle showing female flowers, sterile spadix part, male flowers, the white appendix and flap in an upright position closing the exit into the tube. Photographs by N. Jacobsen.

greenhouses of the School of Biological Sciences, Universiti of Malaysia, Penang, and of the Department of Plant and Environmental Sciences, University of Copenhagen. Herbarium specimens are placed at C while the herbarium at USM, Penang keeps some of the specimens. Data on the material are provided under each heading.

Colours of the surface of the spathe limb are described as red, brown, yellow etc. However, when inspecting the limb through a hand lens or a stereo microscope, it becomes clear that what seems to be solid colours are in fact composed of numerous tiny variously coloured cells/spots on a cream-yellowish base, and it is the density

of the spots which determines the overall macroscopic colour perception as solid or spotted. Moreover, colours change over days, as they fade, so when comparing pictured spathes, they should be of the same age.

In the designation of the artificial hybrids the female plant is mentioned first. In the natural hybrids the parents are listed in alphabetical order.

## RESULTS

### *Cryptocoryne decus-silvae* De Wit – Figure 1

Het Aquarium 46(7): 177. Type: Schulze legit 6.4.71 s.n., *De Wit 12.698* legit in *calidario vadensi* 28.8.71 (WAG, now in L).

Described by de Wit (1976) based on material supposedly collected by J. Schulze in Peninsular Malaysia on 6 April 1971. Correspondence between Schulze and de Wit (1971) showed that the material in question (plant no. 2) was sent to de Wit in Wageningen by Schulze, labeled “Schulze s.n. 6.4.1971”, without locality specifications. The letter correspondence and data on Schulze’s herbarium specimens show that Schulze was not in any way near Peninsular Malaysia at that time. However, he had received a shipment of plants from Peninsular Malaysia, and the plant in question (plant no. 2 which is one of three plants sent to de Wit) came from an area around Chaah in the north-western part of Johor. This plant was cultivated in Wageningen by de Wit and flowered on 28.8.1971. This is the type specimen of *C. decus-silvae* De Wit.

**Characteristic** for this type specimen are the long, slightly bullate leaves (10–20 × c. 6 cm), and the spathe with the recurved pink limb with a somewhat rough surface. The even pink colour persists into the rather narrow throat which has a slight demarcation of a collar.

Cultivation experiences from Copenhagen greenhouses demonstrate that plants in cultivation grown under suboptimal conditions are generally smaller

than plants from nature; in case of *C. decus-silvae* the grown plants develop leaves appressed to the soil surface and the spathe is short (c. 5 cm long). Under natural growing conditions it is expected that the leaves and spathes could be longer.

### ***Cryptocoryne jacobsenii* De Wit – Figure 2**

Het Aquarium 46 (7): 177. Type: *N. Jacobsen 2864* culta H.B.H. 24.12.1974 e Singapore (WAG, now in L).

Also described by de Wit (1976) in the same article and on the same page as *C. decus-silvae*. The type material was based on the specimen *N. Jacobsen 2864*, cultivated in Copenhagen, when flowered on the 24.12.1974. This accession was received from the Danish aquarium plant nursery ‘Tropica’ in a shipment from Singapore on 28.9.1973. The shipment contained *C. “minima”* (maybe *C. schulzei*), *C. nurii* var. *nurii*, *C. sp.* (NJ 2864), *C. “bullosa”* (verified as *C. affinis*), and *C. affinis*. The species composition of the lot suggest that the plants originated from Peninsular Malaysia, but this is not certain as ‘Tropica’ received plants from many parts of SE Asia via Singapore in that period.

Based on surveys of the *Cryptocoryne* of Sumatera Jacobsen & Bogner (1987) suggested that *C. jacobsenii* originated from Sumatera rather than from Peninsular Malaysia (see also Othman et al. 2009). However, as seen in our conclusions below,

we are now of the opinion, that it is of peninsular origin.

**Characteristic** of the type specimen of *C. jacobsenii* are the elongate ovate leaves with dark markings, and the spathe with the recurved limb of an evenly shining bright red colour on a rough surface. The colouration transforms into spotted in the upper part of the somewhat narrow throat with a clear demarcation of a collar-like structure raised above the limb surface.

The cultivated type specimen did not look like a plant grown under natural conditions: small and short leaves, and a short spathe. Under natural conditions, we expect that the leaves could be twice the size, with the spathe longer and the limb broader. Chromosome number:  $2n = 34$  (Jacobsen 1977).

### ***Cryptocoryne* – NJ 2997 – Figure 3**

The material was imported by the Danish aquarium shop ‘Planteimporten’ from Singapore; it probably originated from Peninsular Malaysia. It was taken into cultivation as accession NJ 2997 in 1978.

**Characteristic** for the cultivated plant was the ovate leaf lamina with darker brownish line markings. The spathe limb bright red, the surface distinctly rough, a collar is indicated but not prominently raised and the tube opening is marked with small red spots. Chromosome number:  $2n = 34$  (Arends et al. 1982).

### ***Cryptocoryne* – T 81 – Figure 4**

The accession NJ 3131 was obtained 28 November 1979, from Robert A. Gasser’s nursery in Florida and was labeled “T 81”.

The origin is unknown, but probably from southern Peninsular Malaysia. Gasser’s picture of the spathe had irregular whitish margins of the limb (as if it had been helped in opening), resembling that of some accessions from Kulai, Pantl and Chaah.

**Characteristic** for NJ 3181 [= T 81] is the broad, red spathe limb with a rough surface, and a rather narrow, yellowish-red spotted tube opening. Leaf blades ovate. Chromosome number:  $2n = 34$ . (Arends et al. 1982; as *C. jacobsenii*).

### ***Cryptocoryne* – Kulai – Figure 5**

Johor. Behind Chinese cemetery, 6 km stone E of Kulai towards Kota Tinggi. 13 February 2001, NJM 01–04.

This accession came from a ditch in an oil palm plantation behind a water plant nursery northeast of Kulai. People from the nearby plant nursery said that it was deliberately planted in the ditch (together with at least two other *Cryptocoryne* species). The plants from the ditch had brownish broadly ovate leaves, while when transferred into cultivation the new leaves were cordate, green with brownish markings.



**Figure 4.** *Cryptocoryne* – T-81; cultivated by R. Gasser, Florida. Spathe limb (cut open) showing the rough limb surface, indication of collar, and tube opening yellow with spots. Photograph by R. A. Gasser.





**Figure 5.** *Cryptocoryne* – NJM 04–4, Kulai, Johor; **A.** Plants submerged in a small ditch in an oil palm plantation; **B.** Plants taken out from the A site; **C.** Spathes from cultivated plants showing the rough limb surface, an indication of a low collar, and the yellow tube opening with a few red spots. Photographs by N. Jacobsen.



**Figure 6.** *Cryptocoryne* – B 1142, Kota Tinggi; **A.** Plants cultivated submerged in a tank; **B – C.** Spathes from cultivated plants showing the very rough limb surface, an indication of a low collar, and the yellow tube opening with a small red spots; **D.** Cut open kettle showing female flowers, sterile spadix part, male flowers, the sterile, purplish appendix and the flap in an upright position closing the exit into the tube. Photographs by N. Jacobsen.



**Figure 7.** *Cryptocoryne* – IBI 05–15; Sungai Bebar; Pahang. **A.** Cultivated, submerged specimen; **B – C.** Spathes at different ages. Photographs by N. Jacobsen.

**Characteristic** are the broadly ovate to cordate, green leaves with brownish markings, the spathe up to 15 cm long, with a recurved limb of a light brown to reddish brown colour on a slightly rough surface. The upper part of the narrow throat is spotted on a brown-yellow base with a clear demarcation of a collar-zone not raised above the limb surface. Chromosome number:  $2n = 34$ , reported here for *NJM 01–04*.

### ***Cryptocoryne* – Kota Tinggi – Figure 6**

Johor. On the road from Kota Tinggi to Mersing. 13 December 2005, *Ng 0512–1* [(= *B 1142*); Ganapathy & Siow s.n. (= *NJ 3512*); from the same locality].

The accession came from a ditch running next to a sandy stream in an old oil palm plantation a little north of Kota Tinggi. Several populations of *C. cordata* var. *cordata* were observed in ditches a few meters away joining the same stream. The original population may have survived forest cutting and managed to recolonize the stream and ditch in the plantation, which provided some shade, or it could have recolonized from stands further upstream in the Pantii Forest.

**Characteristic** are up to 30 cm long leaves, with a broadly ovate-cordate, dark brownish leaf blade with darker markings. When transferred into cultivation new leaves had the same shape and colours. The

spathe up to 20 cm long; the spathe limb recurved, deep red brown with a very rough surface presenting some irregularly transverse ridge-like structures; the opening of the throat has a raised, dark yellow inward bending collar structure. Chromosome number:  $2n = 34$ , reported here for *B 1142*.

### ***Cryptocoryne* – Sungai Bebar – Figure 7**

Pahang, Sg. Bebar. May 2005, *IBI 05–15*.

The accession came from a stream tributary to the Sungai Bebar, in central eastern Pahang. It differs from the other accessions presented here in the structure and colour of the limb and the collar-zone. It was first thought to belong to *C. ×purpurea* nothovar. *purpurea*. However, a cordate-leaved *C. nurii* var. *nurii* (*B 1285*) from this area has been included in an artificial hybrid, *CyCy 804* (see below), as the male parent, and the resulting hybrid resembles the Sungai Bebar plant in colour and spathe limb surface structure.

The morphological differences between the Sg. Bebar and the Johor plants are possibly due to different genotypes of the parents. In the case of *IBI 05–15* the cordate-leaved *C. nurii* var. *nurii* occurring north of the Endau Rompin National Park could be one parent. *C. cordata* var. *cordata* has also been documented from Sg. Bebar (Ganapathy & Siow s.n. = *NJ 3447*).

**Characteristic** are the up to more than 25 cm long leaves, with a broadly ovate-cordate brownish leaf blade with markings, and sometimes noticeable veins. The spathe up to more than 10 cm long; the spathe limb bent backwards with a distinctly rough surface of an evenly dull yellow colour, the opening of the throat with a conspicuous, somewhat broad collar-zone structure, with the yellow colour continuing into the throat. Chromosome number:  $2n = 34$ , reported here for *IBI 05–15*.

***Cryptocoryne* – Panti Bird Sanctuary – Figures 8, 9, 10, 11**

Johor, Ulu Sg. Sedeli Besar subdistr., Panti Bird Sanctuary. 4 March 2011, *NJM 11–24, –25, –27, –32, –34* [= *RR 11/9–1 to –8*].

These accessions were found in streamlets and pools between roots in the eastern Panti forest region in a secondary forest. At one site at Panti, *C. cordata* var. *cordata* was found close to the hybrid populations.

When found in the forest, the leaves varied in colour from brownish to green with markings; in cultivation these colours are maintained to some extent, but generally the shape became broader towards a cordate shape.

**Characteristic** are the up to 20 cm long leaves, narrowly to more broadly ovate, brown to greenish with  $\pm$  brownish

markings to brownish with markings, and leaf margins sometimes slightly undulate. The spathe generally less than 15 cm long; the spathe limb recurved with an irregularly rough surface with an evenly reddish or brownish colour, the opening of the throat with a clear demarcation of a sometimes raised collar structure with an abrupt transition to a darker yellow colour with many small fine spots into the throat.

***Cryptocoryne* – Labis (N of Chaah) – Figure 12**

Johor, Bekok to Labis, stream along the road in rain forest. 16 August 2014. Ganapathy & Siow s.n. [= *NJM 14–24 = TT(J) 14–25 RT\_Johor*].

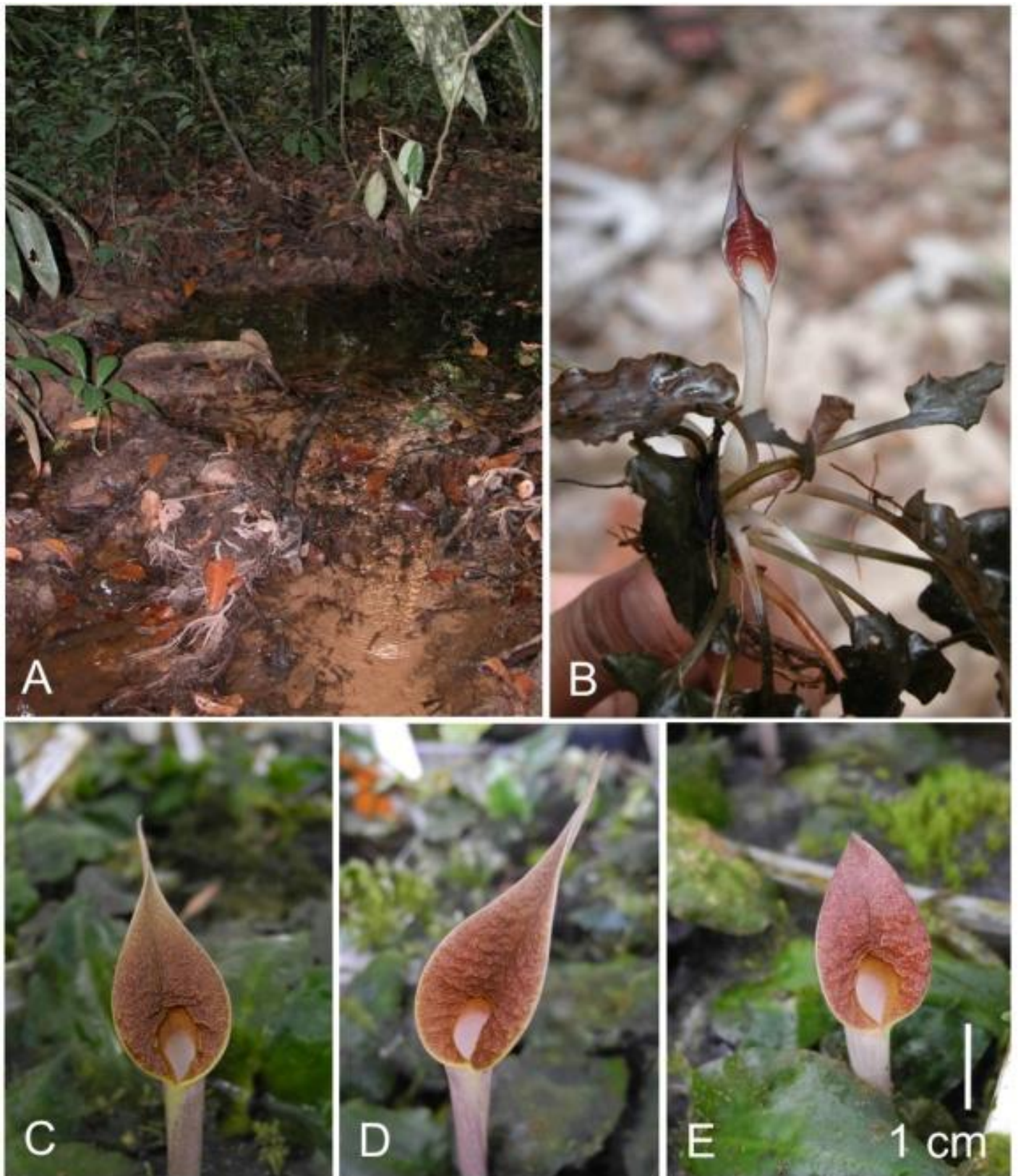
This accession came from a stream in a forest east of Labis (north of Chaah). It resembles the Kulai plant to such an extent that it is difficult to distinguish the two. It may be that the Kulai accession was transplanted from the Labis–Chaah region.

Schulze's original information on the type of *C. decus-silvae* from the Chaah region initiated our search in this region, however most of the area around Chaah is presently occupied by oil palm plantations.

Zhou Hang (2004) reported a *Cryptocoryne* locality between Chaah and Labis, but we have not been able to locate the locality indicated.



**Figure 8.** *Cryptocoryne* – Panti Bird Sanctuary, Johor. **A – C**, NJM 11–24, **D – E**, NJM 11–25. **A – C.** Cultivated plants showing different spathe limb colours from what was collected as one sample of different ages; **D – E.** Cultivated plant in a 1-liter tank and showing the rough spathe limb. Photographs by N. Jacobsen.

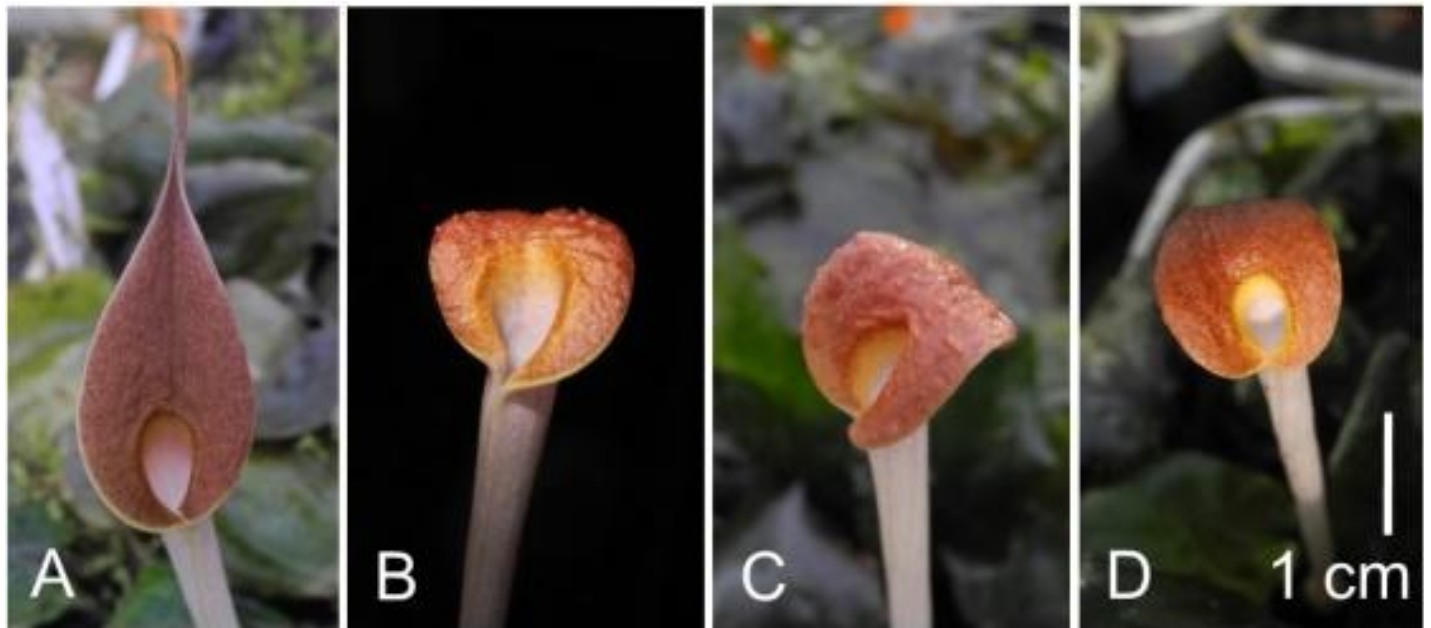


**Figure 9.** *Cryptocoryne* – NJM 11–27, Panti Bird Sanctuary, Johor. **A.** Habitat with small streamlets reticulate trickling through the forest floor; **B.** Sample from A with a spathe limb cut open; **C – E.** Spathe limbs from B showing different shapes (and ages) from one plant. Photographs by N. Jacobsen.



**Figure 10.** *Cryptocoryne* – NJM 11–32, Panti Bird Sanctuary, Johor. **A.** Habitat in a small forest pool with streamlets trickling through; **B – E.** Spathe limbs from A showing different shapes and ages. Photographs by N. Jacobsen.





**Figure 11.** *Cryptocoryne* – NJM 11–34; Panty Bird Sanctuary, Johor. **A – E.** Spathe limbs showing different shapes and ages. Photographs by N. Jacobsen.



**Figure 12.** *Cryptocoryne* – *Ganapathy & Siow s.n.* [= NJM 14–24 = TT(J) 14–25 RT\_Johor], Labis (N of Chaah), Johor. **A – B.** Plants in situ, B with a young spathe; **C.** Plant extracted (B) and spathe carefully cut open; **D.** Cultivated plant showing fully developed spathe limb with a rough surface, a narrow, yellowish, red spotted tube opening. Photographs by J. Siow.

In 2015 a sample KT(J)15–13 was obtained from the area along the Bekok – Labis road, close to the above-mentioned site. It turned out to be *C. ×purpurea* nothovar. *purpurea* (Komala, 2019).

**Characteristic** are the up to 30 cm long leaves, with a broadly ovate, brownish leaf blade with darker markings. The spathe up to 15 cm long; the spathe limb recurved with a rough surface of an evenly red-brownish colour, the opening of the throat had a clear demarcation of a collar structure, not raised above the surface, and an abrupt transition of colour to a darker yellow with many tiny spots in the throat. When the plants are transferred to cultivation new leaves become cordate, green with brownish markings.

### ***Cryptocoryne* – Yellow Ring –Figure 13, 14**

Pahang, S of Tasek Chini, north of Bukit Ibam, Pahang. Stream by bridge. 26 April 2010. K. Nakamoto KN.005 [(= B 1400), Ganapathy & Siow s.n. (= NJ 3486)]. Ganapathy & Siow s.n. is from the same locality.

Nakamoto (2012) was the first to locate this plant in 2010 and to present photos of it. The same locality was reported by Wang (2010). An article on introduction and cultivation is provided by Reitel (2011).

**Characteristic** are the more than 25 (–40) cm long leaves, with a broadly ovate,

green or brownish, cordate leaf blade with darker markings and sometimes conspicuous veins and the lower surface with a purple tinge. The spathe up to 20 cm long; the spathe limb recurved with a distinctly rough surface with irregular ridge-like structures of an evenly yellow colour, the somewhat narrow opening of the throat with a conspicuous, collar structure raised above the surface, and the yellow colour continuing into the throat. Chromosome number:  $2n = 34$ , reported here for B 1400.

### **Artificial hybrids – Figure 15**

As it was realized that a number of *Cryptocoryne* were of hybrid origin, and not the least in Peninsular Malaysia, *C. ×purpurea* nothovar. *purpurea* being among the first to be recognized as such, it was straightforward to start a hybridization program (Jacobsen et al. 2019a) to elucidate the possibilities, and in the present context, the four combinations listed below were obtained.

**CyCy 804:** *C. cordata* var. *cordata* × *C. nurii* var. *nurii*

IBI 05–20, Pasir Gajah, Terengganu, Malaysia × B 1285 (cordate leaved genotype), Nakamoto MRO–01, Rompin, Pahang, Malaysia.

The male parent was a cordate-leaved *C. nurii* var. *nurii* type from the Rompin area, which was reflected in the hybrid offspring; the leaves were more cordate than in similar

hybrids including the narrow-leaved *C. nurii* var. *nurii* from Johor. The spathe was deformed upon opening, but it was possible to see the light brown colour of the limb. The surface was a bit rough with a broad collar zone and a yellowish throat colour. The spathe limb resembled those of Sg. Bebar plants more than those from Pant.

**CyCy 846:** *C. cordata* var. *cordata* × *C. nurii* var. *nurii* (lanceolate leaved genotype)

IBI 05–21, Kuala Berang, Terengganu, Malaysia × B 802, Sg. Kahang, Johor, Malaysia.

The male parent was a lanceolate-leaved *C. nurii* var. *nurii* type from Johor, which was reflected in the hybrid offspring. The hybrid siblings varied in spathe limb colour, from orange to light brown to yellow (rough with many tiny spots), much like the variation and appearance found in the Pant populations. The collar zone was narrower than in *C. cordata* var. *cordata*, but broader than in *C. nurii* var. *nurii*.

**CyCy 847:** *C. nurii* var. *nurii* (lanceolate leaved genotype) × *C. cordata* var. *cordata*

B 802, Sg. Kahang, Johor, Malaysia × NJT 02–21, S of Narathiwat, Thailand.

This combination is almost the reciprocal of CyCy 846 including the same *C. nurii* accession but as female parent. The spathe of limb varies in colour from light brownish to pure reddish, with the collar zone ±

developed, but always with tiny spots in the throat. Spathe limb colours vary more than in CyCy 846, perhaps due to a higher number of hybrid siblings. It is to be noted that the colours of the spathe limb generally are brighter on the opening day, then fading the following days.

**CyCy 952:** *C. cordata* var. *cordata* × *C. nurii* var. *nurii*

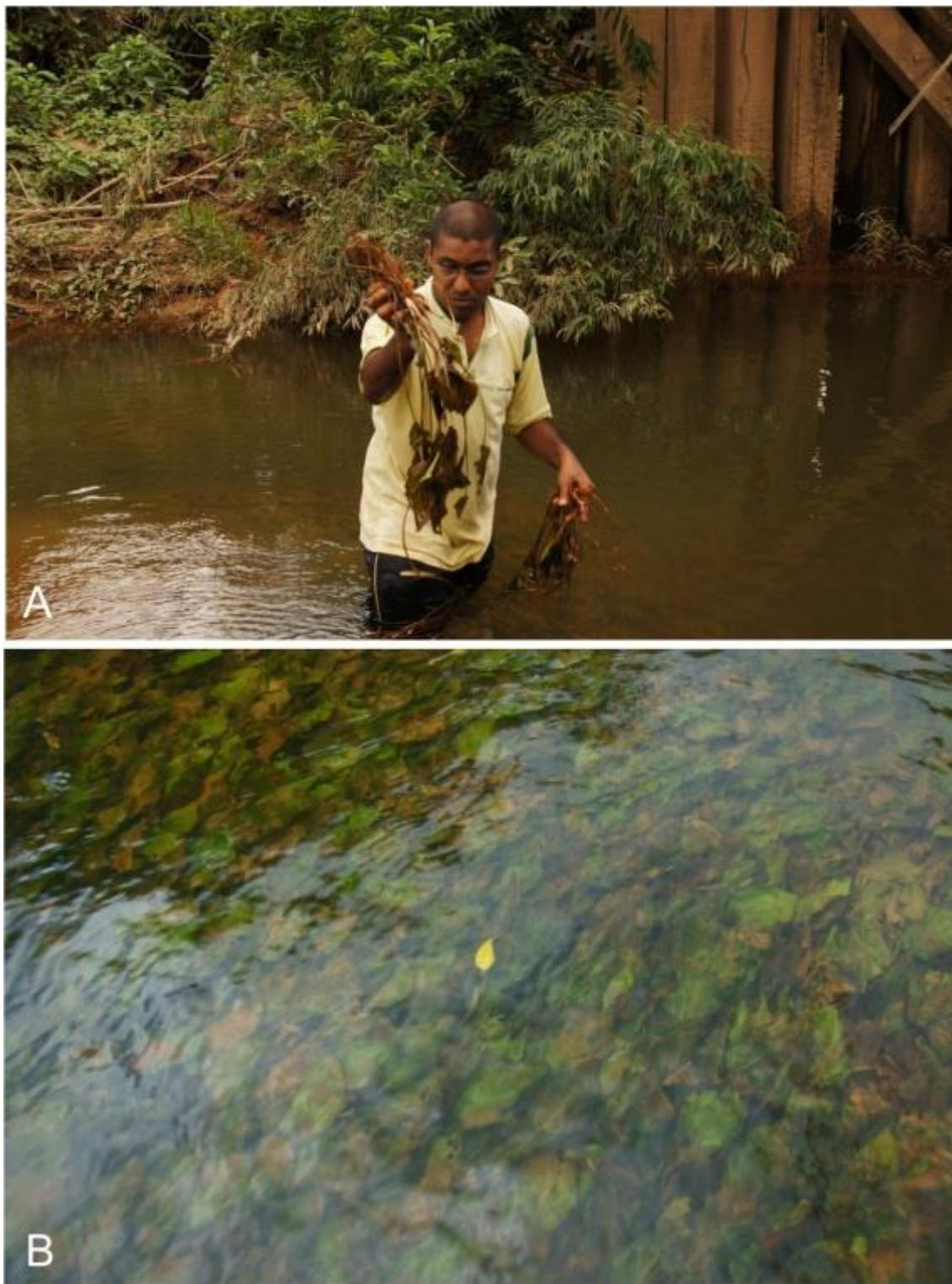
B 859, SW s.n., N of Sg. Kolok, Thailand × B 802, Sg. Kahang, Johor, Malaysia.

Similar combination as the above CyCy 846, except that the female parent came from just north and south of the Malaysia – Thailand border, respectively. The variations of the spathe limb structure of the two were similar.

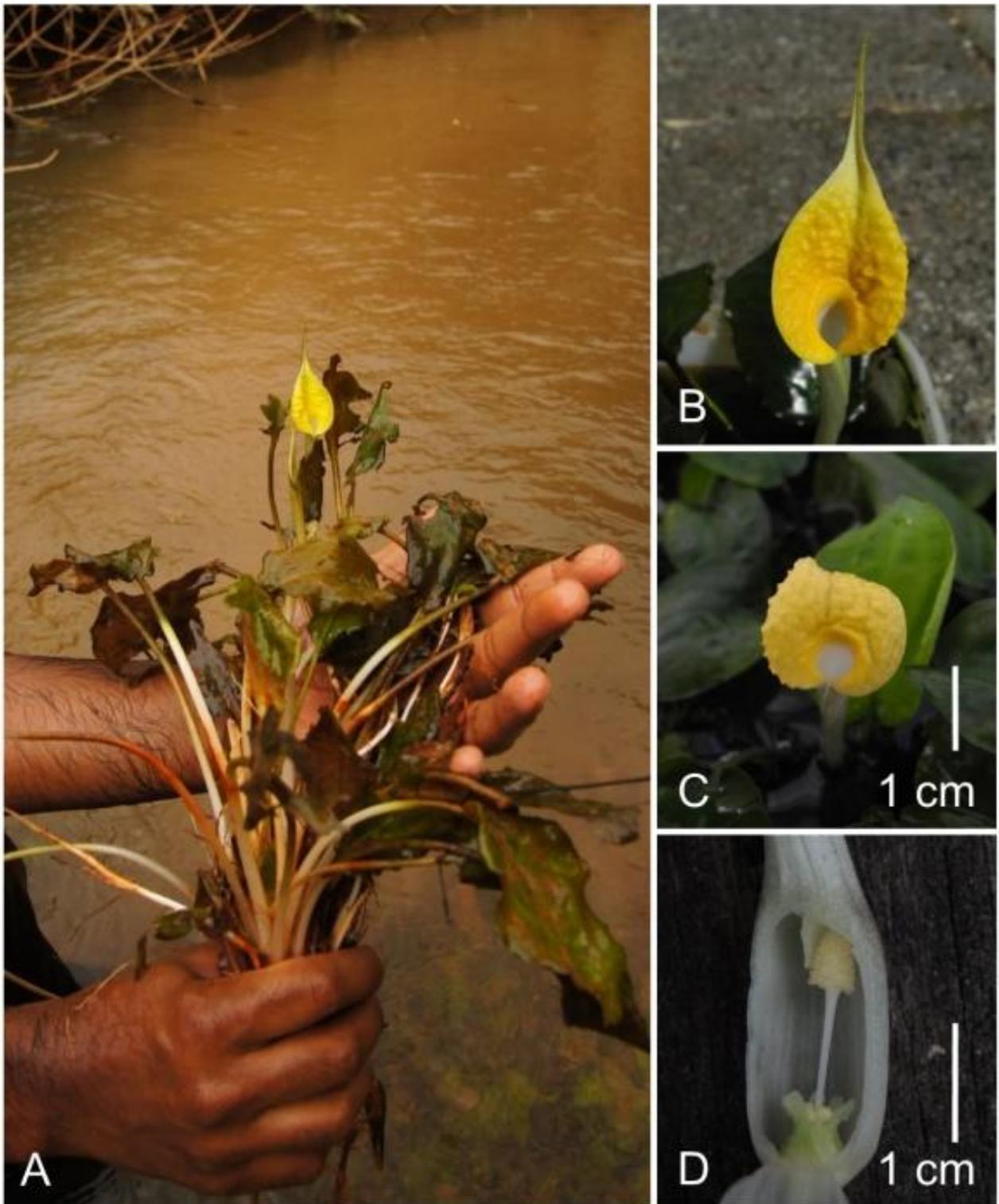
### Molecular study

A molecular study of *Cryptocoryne* from the Malesian region (Komala 2019) included one sample of *C. × decus-silvae* (labelled as *C. × jacobsenii*, KT(J) 14–25 R1\_Johor (= NJ 14–24) [another sample labeled *C. × decus-silvae*, NJ 3447, later turned out to be *C. cordata* var. *cordata*]. The phylogenetic analysis using Neighbor Joining, Maximum Parsimony and Bayesian Inference approach show that:

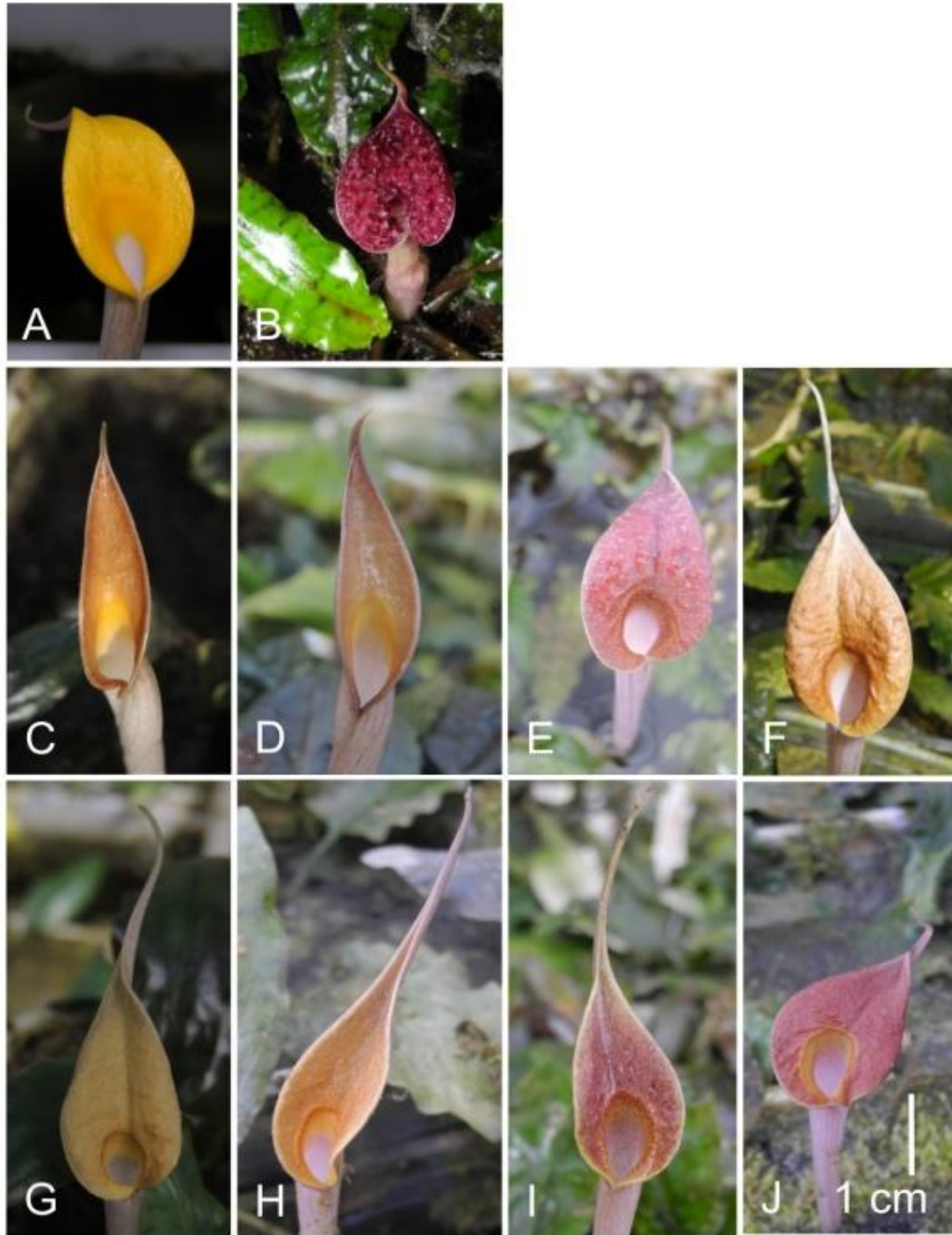
1) Analysis of the Internal Transcribed Spacer (ITS) of nuclear ribosomal DNA sequences placed the one sample of *C. × decus-silvae* together with *C. cordata* var. *cordata*, *C. nurii* var. *nurii* and *C. schulzei* (and



**Figure 13.** *Cryptocoryne* – Yellow Ring; S of Tasek Chini, north of Bukit Ibam, Pahang; Ganapathy & Siow s.n. (= NJ 3486). **A.** H. B. Ganapathy extracting whole plants from the sampled site; **B.** Stand of large, submerged plants in the middle of the stream showing one yellow spathe limb. Photographs by J. Siow.



**Figure 14.** *Cryptocoryne* – Yellow Ring; S of Tasek Chini, north of Bukit Ibam, Pahang. **A.** Whole extracted plant from the sampled site, *Ganapathy & Siow s.n.* (= NJ 3486); **B – D.** *K. Nakamoto KN.005* [= B 1400]. Spathe limbs from cultivated plants showing the rough limb surface and the tube opening with the pronounced raised collar; **D.** Cut open kettle showing receptive female flowers, light yellow olfactory bodies, sterile spadix part, male flowers and partly cut off flap beside the male flowers, and the white inner kettle wall. Photographs: A by J. Siow, B – D by N. Jacobsen.



**Figure 15.** Artificial hybrids. **A – B:** Parents of CyCy 847 (I & J): *C. nurii* var. *nurii* and *C. cordata* var. *cordata*; **C – D:** CyCy 804. *C. cordata* var. *cordata* × *C. nurii* var. *nurii* (cordate leaved genotype): IBI 05–20, Pasir Gajah, Terengganu, Malaysia × B 1285, Nakamoto MRO–01, Rompin, Pahang, Malaysia; **E – F:** CyCy 846. *C. cordata* var. *cordata* × *C. nurii* var. *nurii* (lanceolate leaved genotype): IBI 05–21, Kuala Berang, Terengganu, Malaysia × B 802, Sg. Kahang, Johor, Malaysia; **G – H:** CyCy 952. *C. cordata* var. *cordata* × *C. nurii* var. *nurii*: B 859, SW s.n., N of Sg. Kolok, Thailand × B 802, Sg. Kahang, Johor, Malaysia; **I – J:** CyCy 847. *C. nurii* var. *nurii* (lanceolate leaved genotype) × *C. cordata* var. *cordata*: B 802, Sg. Kahang, Johor, Malaysia × NJT 02–21, S of Narathiwat, Thailand. Photographs by N. Jacobsen.

others), but more importantly, the ITS sequences of *C. ×decus-silvae* has very high sequence similarity to *C. nurii* var. *nurii* (Bayesian inference) compared to other species in Clade A.

2) Analysis of the matK-trnK gene of chloroplast DNA sequences, also placed the sample of *C. ×decus-silvae* together with *C. cordata* var. *cordata* and *C. nurii* var. *nurii*.

3) Analysis of the rbcL gene of chloroplast DNA sequences also placed the sample of *C. ×decus-silvae* together with *C. cordata* var. *cordata* and *C. nurii* var. *nurii* and other species; however, this analysis was rather unresolved due to very low sequence mutation rate.

In conclusion the molecular study placed the one sample of *C. ×decus-silvae* together with *C. cordata* var. *cordata* and *C. nurii* var. *nurii* but was unable to resolve the parental relations further.

## DISCUSSION

The taxonomically described *Cryptocoryne* taxa in question were originally described in 1976 as new species, viz. *C. decus-silvae* and *C. jacobsenii*. Since then it has not been possible to find exactly similar plants in nature in the Johor region, nor are we aware of any that have been traded commercially. Over the years many localities in Johor have been searched without success. There are, however, still many streams and rivers unexplored. We have checked the Chaah

lead for *C. decus-silvae*, and we succeeded in finding a population E of Labis (**Figure 11**) which resembled the Kulai plant (**Figure 5**), and it is not possible to distinguish the two on morphological grounds. In later years some plants from southern Peninsular Malaysia resembling them have been found in nature.

The natural and artificial hybrids described in the present paper were all pollen sterile and morphologically intermediate between the expected parents. The variation found is assumed to be ascribed to differences in genotypes among the parents involved; the segregation found in the artificial hybrid offspring is a result of heterozygosity in the parent plants. The hybrid CyCy 804 has a cordate-leaved *C. nurii* var. *nurii* as one parent while CyCy 846 and 847 have a narrow leaved *C. nurii* var. *nurii* as one parent; and the latter combinations (CyCy 846 and 847) were almost each other's reciprocal combinations, as the *C. cordata* var. *cordata* parents came from SE Thailand (NJT 02–21, Narathiwat), and NE Peninsular Malaysia (IBI 05–21, Kuala Berang, Terengganu), respectively. In CyCy 804 the *C. cordata* var. *cordata* (IBI 05–20) also came from Terengganu. The yellow spathe limb in “Yellow Ring”, is outstanding in colour as the spathe limb is of a reddish colour in the other naturally occurring hybrids.

A previously published artificial hybrid combination: *C. cordata* Griff. var. *siamensis* N. Jacobsen & D. Sookchaloem (yellow spathe limb) × *C. fusca* De Wit (brown-



purple spathe limb) [CyCy 392: NJT 02–5 ( $2n = 102$ ) × B 1079 ( $2n = 34$ )], resulted in offspring showing two different colour forms of the limb: one intermediate in colour, and one pure yellow; they were almost identical morphologically in other characters (Jacobsen et al. 2019c).

Similarly, another combination: *C. fusca* De Wit (brown spathe limb) × *C. yujii* Bastmeijer (white spathe limb) [CyCy 354: KB04–04 ( $2n = 34$ ) × Mie 11/4 ( $2n = 34$ )], resulted in two different hybrid colour forms of the limb: one light brown in colour, and one pure white, in other characters they were ± identical (Jacobsen et al. 2019b).

The yellow spathe limb in the above mentioned *C. cordata* var. *siamensis* – *C. fusca* hybrid, and the white spathe limb in *C. fusca* – *C. yujii* combinations provide an explanation for the occurrence of “Yellow Ring”.

The above-mentioned accessions are all referred to *C. cordata* var. *cordata* – *C. nurii* var. *nurii* hybrids. As the parents are diploid with a chromosome number of  $2n = 34$ , the hybrids also were diploid. All the hybrids were sterile, i.e. with a pollen fertility of zero or close to zero. The leaf shape varied, some had cordate leaves (*C. cordata*) while others had narrowly ovate to almost lanceolate leaves (*C. nurii*), depending on the genotype of the parents. The spathe length was variable but intermediate, between the long-tubed *C. cordata* and the short-tubed *C.*

*nurii*. The colours of the spathe limb varied from deep purple pink to deep reddish (*C. nurii*) to yellowish (*C. cordata*); in one case the limb was completely yellow (“Yellow Ring”). The distinct branched protuberances found in *C. nurii* were not prominent in the hybrids. The artificially produced hybrids were quite similar to the naturally occurring hybrids, but the much rougher limb surfaces were not found in any of the artificially produced hybrids. The collar of the hybrids was ± developed (*C. nurii*) or just present as an indication of a collar zone (*C. cordata*). The characteristic pink-red coloration of the limb pictured for the type specimen of *C. ×decus-silvae*, was not found in any plants from nature. Our interpretation is that it is consistent with the variation found in the accessions presented here, as with the deep red and rough spathe limb of the type of *C. jacobsenii*. The clear yellow colour of the limb found in “Yellow Ring”, was at first surprising, but when similar colours of spathe limbs showed up in the artificially produced hybrids it was obvious, that it was just an occasionally occurring hybrid segregation.

## CONCLUSIONS

We conclude from the morphological variation in the artificial hybrids that the naturally occurring hybrids are the result of multiple hybridization events between different genotypes of *C. cordata* var. *cordata* and *C. nurii* var. *nurii*. The genotype variation of parents can explain the differences observed in both natural and artificial hybrids. Similar scenarios are

observed from the hybrid *C. ×purpurea* Ridley nothovar. *purpurea* the parentage here being *C. cordata* var. *cordata* and *C. griffithii* (Jacobsen et al. 2016; Othman et al. 2009; Rosazlina 2016).

It would of course have been convenient had it been possible to recover identical phenotype matches for *C. decus-silvae* and *C. jacobsenii* in nature. The deforestation in Johor over the last 50 years means that, it is likely that their habitats have been destroyed, and it may not be possible to recover them, but the chance is that the populations still may exist in a yet uninvestigated relict locality.

The type material of *C. decus-silvae* and *C. jacobsenii* is not in cultivation any longer, so it has not been possible to study live material again and make comparisons to our new material.

In relation to the nomenclature, *C. decus-silvae* and *C. jacobsenii* were published together in the same article and on the same page by de Wit (1976). As they both represent hybrids between *C. cordata* var. *cordata* and *C. nurii* var. *nurii*, one of the names has to be chosen as the valid one.

The evidence that the type material of *C. decus-silvae* was collected somewhere in the Chaah-Labis region is convincing. There is a small chance that *C. jacobsenii* originated from Sumatera, so we choose *C. decus-silvae* as the legitimate name for the hybrid combination *C. cordata* var. *cordata* × *C. nurii*

var. *nurii*. If *C. jacobsenii* was chosen, and it later on showed that it did originate from Sumatera as a hybrid between other parents, it would require a return to the name of the Johor plants. This hypothetical situation can be avoided when choosing *C. decus-silvae* as the legitimate name.

On basis of the hybrid experiments and the analysis of the naturally occurring hybrids, we consider the accessions included here to be naturally occurring *Cryptocoryne* hybrids between *C. cordata* var. *cordata* and *C. nurii* var. *nurii* from the southern part of Peninsular Malaysia: T-81, Kulai, Kota Tinggi, Panti B. S., Labis, Sg. Bebar and “Yellow Ring”, as belonging to *C. ×decus-silvae*.

***Cryptocoryne ×decus-silvae* De Wit,**  
Het Aquarium 46(7): 177.

Type: Schulze legit 6.4.71 s.n., *De Wit* 12.698 legit in calidario vadensi 28.8.71 (WAG, now in L).

Synonym: *Cryptocoryne jacobsenii* De Wit,  
Het Aquarium 46(7): 177.

Type: *N. Jacobsen* 2864, culta H.B.H. 24.12.1974 e Singapore (WAG, now in L, isotype C).

*Leaves* cordate to elongate-ovate, base cordate, upper surface green to dark green with purplish markings to brown and brown mottled, smooth to somewhat bullate, lower surface somewhat light green to dark with

purple markings or purplish, blade 7–20 cm long, 2–6 cm broad; petiole 4–10 cm long. *Spathes* 5–15 cm long, outside shaded olive green to purplish, tube inside white; kettle 1.5–2 cm long sometimes with small purple spots in the upper part, limb up to 4 cm long, ovate to broadly ovate, recurved, sometimes with a furrow along the middle, surface rugose to irregularly rough or with transversal ridge-like structures, brownish to bright red to red purple, collar zone or a non-prominent collar present, neither broad (like in *C. cordata*) nor narrow (like in *C. nurii*), of the same colour as the limb or with spots fading into the tube. *Spadix*: Female flowers 6–7, greenish in the upper part, stigmas ovate to irregularly rounded. Olfactory bodies yellow to cream-coloured, rounded to irregular. Male flowers 40–50. *Infructescence* unknown. *Chromosome number*  $2n = 34$  (Arends et al. 1982) and the here reported.

*Distribution* – Peninsular Malaysia, Johor and Pahang.

*Notes* - To distinguish among the hybrids from the different localities this may be done by adding the trade name or locality name, like e.g. *C. ×decus-silvae* De Wit – “Yellow Ring” or “Kota Tinggi”.

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