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Report

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**Morphology of *Batrachospermum beraense*  
(Batrachospermaceae, Rhodophyta) from a Bornean tropical  
rainforest, Malaysia**

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**Abstract**

*Batrachospermum beraense* Kumano (Batrachospermaceae, Rhodophyta) is reported for the first time from Sabah, North Borneo, Malaysia. *B. beraense* from Sabah is characterized by the following combination of features: (i) olive green to blue-green monoecious or dioecious plants that are 2–7 cm high with a diameter of 300–590  $\mu\text{m}$ , more or less dichotomously branched, and mucilaginous; (ii) laterally branched primary fascicles consisting of 7–18 cell-storeys; cylindrical or ellipsoidal fascicle cells that are 4.6–6.1  $\mu\text{m}$  in diameter and 15–30  $\mu\text{m}$  long with numerous short and long terminal hairs; (iii) spherical spermatangia that are 4–7  $\mu\text{m}$  in diameter and are either terminal or subterminal on fascicles; (iv) straight carpogonium-bearing branches, differentiated from fascicles, that are 72–125  $\mu\text{m}$  long, consisting of 8–14 cells, arising from a pericentral cell; (v) ovoidal and indistinctly stalked trichogyne; (vi) single, axial, and spherical to ellipsoidal carposporophytes that are 63–120  $\mu\text{m}$  in diameter and obovoidal carposporangia that are 7.7–11  $\mu\text{m}$  in diameter and 12–18  $\mu\text{m}$  long.

**Key words:** *Batrachospermum beraense*, biogeographical distribution, Borneo, Rhodophyta, Sabah

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**Introduction**

Museum of Nature and Human Activities, Hyogo exchanged an MOU (a memorandum of understanding) with Universiti Malaysia Sabah on 14 June 1997 (Nakanishi et al., 1999). Based on the MOU, the scientific expedition to the Maliau Basin, Sabah, Malaysia on the island of Borneo, was held in May 1999, and carried out research works on the systematics of insects, plants, and other aquatic organisms.

In this paper, *Batrachospermum beraense* Kumano (Batrachospermaceae, Rhodophyta) is reported from the Maliau Basin in Sabah, North Borneo, Malaysia, comparing with two type specimens of the related species. In Sabah, two taxa of *Batrachospermum* have been reported: an unidentified taxon of

*Batrachospermum* from the Maliau River (Anton et al., 1998) and *Batrachospermum gombakense* Kumano et Ratnasabapathy from the Tabin River (Anton et al., 1999). This study contributes to efforts being made to map the biogeographical distribution of *Batrachospermum* species in South-east Asia.

**Material and methods**

The Maliau Basin is located in the south-central zone of the Malaysian State of Sabah in North Borneo (Fig. 1). The Basin is drained by radiating tributaries of the Maliau River, forming a unique and important catchment for the south-central zone of Sabah (Anton and Alexander, 1998). In 1981, it was gazetted as a conservation area within the Sabah Foundation's long-term Forest Management Plan to remain



**Figure 1.** Location of the Maliau Basin. The locality of *Batrachospermum beraense* in Peninsular Malaysia (Tasek Bera) is also shown.

unlogged for purposes of wildlife conservation, education, and scientific research (Mohamed, 1998). Although scientific expeditions have been conducted several times, details on the fauna and flora of the Basin remain obscure.

In May 1999, a scientific expedition was jointly organized by Universiti Malaysia Sabah and the Sabah Forestry Department. Museum of Nature and Human Activities, Hyogo participated in the expedition based on the MOU. The survey of freshwater algae was conducted in the southern part of the Basin. The specimens were collected from the Mait River (one of tributaries of the Maliau River), which runs through the base-camp area (named as the Agathis Camp) located in the southern margin of the Basin.

The water was clear, with a water temperature of 22.6–23.2 °C, pH of 5.09–5.24, and conductivity of 5.61–5.97 mS/m at a Mait River sampling site on May 29, 1999. Specimens were collected and immediately fixed in 10 % formalin. Fixed materials were subsequently examined using a light microscope in the laboratory.

To verify morphological differences, two specimens closely related to the present species were examined:

- (1) *Batrachospermum beraense* Kumano (1978, f. 2): coll. Fort Iskander, Tasek Bera, Pahang, Malaysia, by S. Kumano 16.iv.1971, Herbarium Kobe University, type specimens. These type specimens were transferred to the Herbarium of National Museum of Nature and Science (TNS) in 2009. One of syntypes (TNS-AL 169174–169176, 169178) was examined.
- (2) *Batrachospermum longiarticulatum* Necchi (1990, f. 29, 39–43): coll. Amazonas, Presidente Figueiredo, Manaus-Caracarai Road (Route BR-174), km 115, Brazil, by O. Necchi Jr., 29.i.1984, Necchi Jr. 98 (SP187156), (SP) Herbario do Estado, “Maria Eneyda P.K. Figalço”, Institute de Botanica, Sao Paulo, Brazil, holotype.

### **Morphological features of *Batrachospermum beraense* from Sabah (Figs.2–11)**

*Batrachospermum beraense* from Sabah is characterized by the following combination of features: Olive green to blue-green monoecious or dioecious plants, 2–7 cm high and 300–590 µm in diameter, abundantly and irregularly branched, and moderately mucilaginous (Fig.2). Ellipsoidal and separated whorls, touching each other and more or less compressed (Fig. 3). Primary fascicles with 2–5 branches, dichotomously branched, consisting of 7–18 cell-storeys; cylindrical or ellipsoidal fascicle cells (Fig. 4), 4.6–6.1 µm in diameter, 15–30 µm long, with numerous short and long terminal hairs (Fig. 5). Well-developed cortical filaments and sparse secondary fascicles (Fig. 6). Spherical spermatangia, 4–7 µm in diameter, terminal or subterminal on primary fascicles (Fig. 4). Straight carpogonium-bearing branches, differentiated from fascicles, 72–125 µm long, consisting of 8–14 cells, arising from periaxial cells. Short and numerous involucrel filaments of carpogonium-bearing branches. Carpogonium, 4.6–6 µm in diameter at the base, 8–10 µm in diameter at the apex, and 19–27 µm long; ovoidal trichogyne, indistinctly stalked (Fig. 7). Carposporophytes, pedunculate, single, dense, and spherical, 63–120 µm in diameter, inserted at the periphery of the whorl (Figs. 8–10). Carposporangia obovoidal, 7.7–11 µm in diameter and 12–18 µm long (Fig. 11).

Specimens: Register no. C1-270499 (Fig. 2), 270498, 270492–270495 in HYO, collected on 29 May 1999 by H. Sato.



**Figure 2.** Bisexual specimen of *Batrachospermum beraense* (C1-270499) from the Mait River, Sabah, Malaysia.

Locality: Mait River, at about 200 m upper reach from the Agathis Camp (4° 42' N, 116° 54' E, ca. 530 m a.s.l.) in Maliau Basin, Sabah, Malaysia.

Habitat and specimens examined: The specimens were attached to submerged rocks or boulders, 10–30 cm below the surface of fast running clear waters of the Mait River. Male, female, and bisexual specimens were examined.

### Morphological comparison with related species

According to Entwisle et al. (2009), the genus *Batrachospermum* consists of nine sections: *Acarposporophytum*, *Aristata*, *Batrachospermum*, *Gonimopropagulum*, *Helminthoidea*, *Macrospora*, *Setacea*, *Turfosa*, and *Virescentia*. Among these sections, the section *Aristata* Skuja (1933) is characterized by elongated and straight carpogonium-bearing branches that are differentiated from the vegetative fascicles, as well as pedunculate and spheric carposporophytes (Starmach, 1977; Sheath et al., 1986; Necchi, 1990; Necchi and Entwisle, 1990; Kumano, 1993, 2002; Entwisle et al., 2009) distant from axial filament (Entwisle et al., 2009).

The key discriminating feature of the section *Aristata* is noted by the presence of straight, differentiated carpogonium-bearing branches with

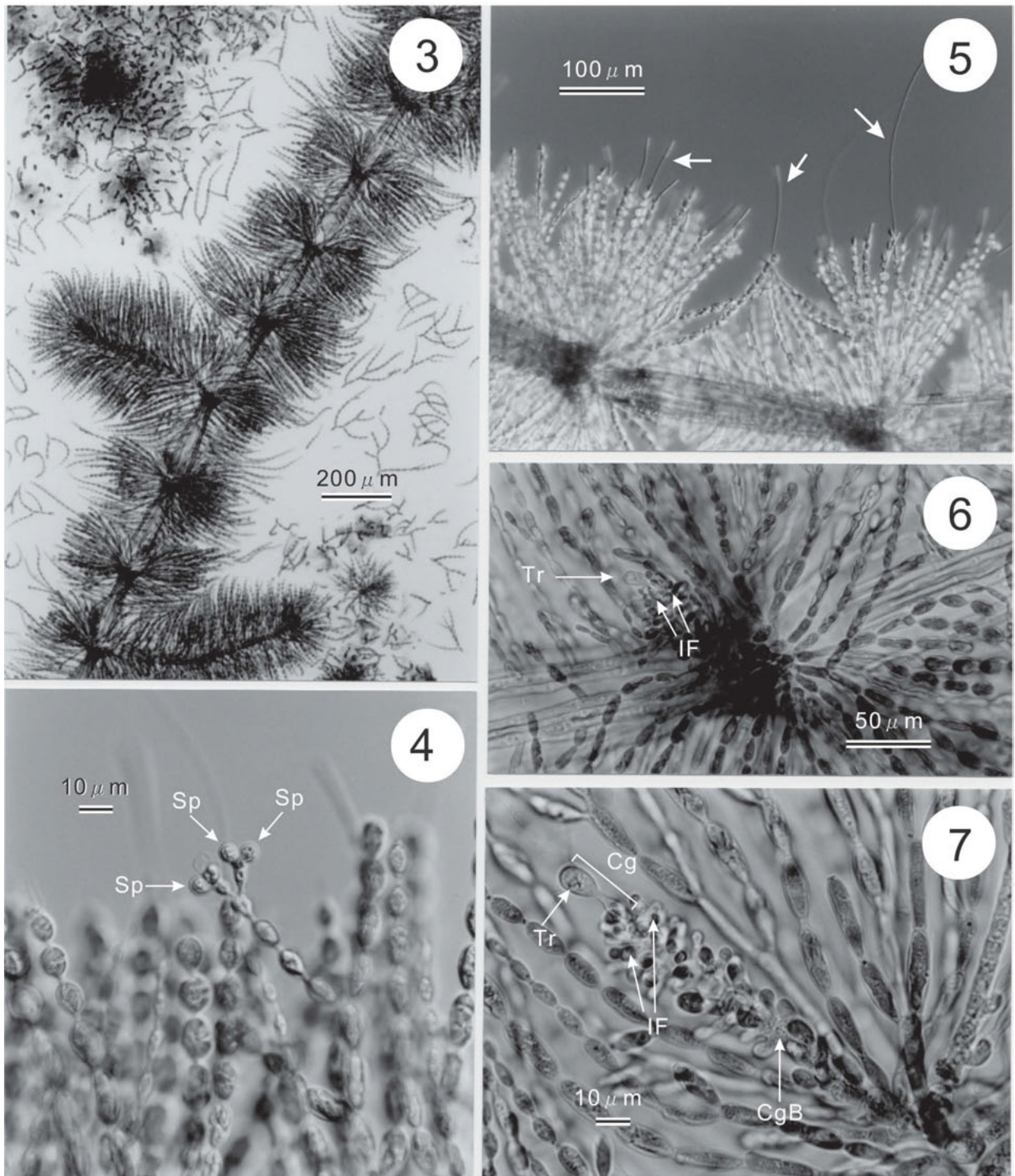
mostly more than 12 cells (Necchi and Entwisle, 1990) and up to 30 cells (Entwisle, et al., 2009). Sheath et al. (1994) recognized three major groupings from the cluster analysis of the morphometric characteristics of the section *Aristata*. The three groups were differentiated by significantly different and non-overlapping dimensions of carposporangia (17.5–36.0 × 21.4–59.2 μm, 5.6–11.1 × 9.5–20.0 μm, and 49.6–90.4 × 98–180 μm for Groups 1, 2, and 3, respectively). Within the section, Group 2 (Sheath et al., 1994) (carpogonium-bearing branches with mostly more than 8 cells), including *B. aristatum*, *B. cayennense*, and *B. longiarticulatum*, fitted well with the description by Necchi and Entwisle (1990) and Entwisle et al. (2009).

*Batrachospermum beraense* from Sabah and its type specimen from Tasek Bera have elongated and straight carpogonium-bearing branches (8–14 cells) (Table 1) differentiated from those of vegetative fascicles, as well as pedunculate and spheric carposporophytes. *B. beraense* can be assigned to Group 2 in Sheath et al. (1994). Within the Group 2, the whorls of *B. aristatum* and *B. cayennense* are obovoid with well-developed secondary fascicles, unlike the barrel-shaped contiguous ones of *B. longiarticulatum* (Necchi, 1990) and the ellipsoidal separated ones of *B. beraense* (Kumano, 1978).

*Batrachospermum beraense* from Sabah and its type specimen are distinguished from *B. longiarticulatum* in terms of the length of both the primary fascicles and carpogonium-bearing branches (Table 1; Figs. 15, 16). *B. beraense* from Sabah is distinguished from its type specimen with respect to whorl size, fascicle cylindrical cells, and carposporangium (Table 1). In addition, the fascicles of *B. beraense* from Sabah have numerous short and long terminal hairs (Fig. 5). The reproductive structures are also characterized by having ovoidal trichogyne that are indistinctly stalked and carpogonium-bearing branches with short and dense involucrel filaments at the distal portion (Figs. 6, 7). These differences may depend on their habitats. The type specimens of *B. beraense* were found in the gentle current waters of the Tasek Bera, whereas *B. beraense* from Sabah is found in the fast running waters of the Mait River.

### Distribution of *Batrachospermum beraense* in Southeast Asia

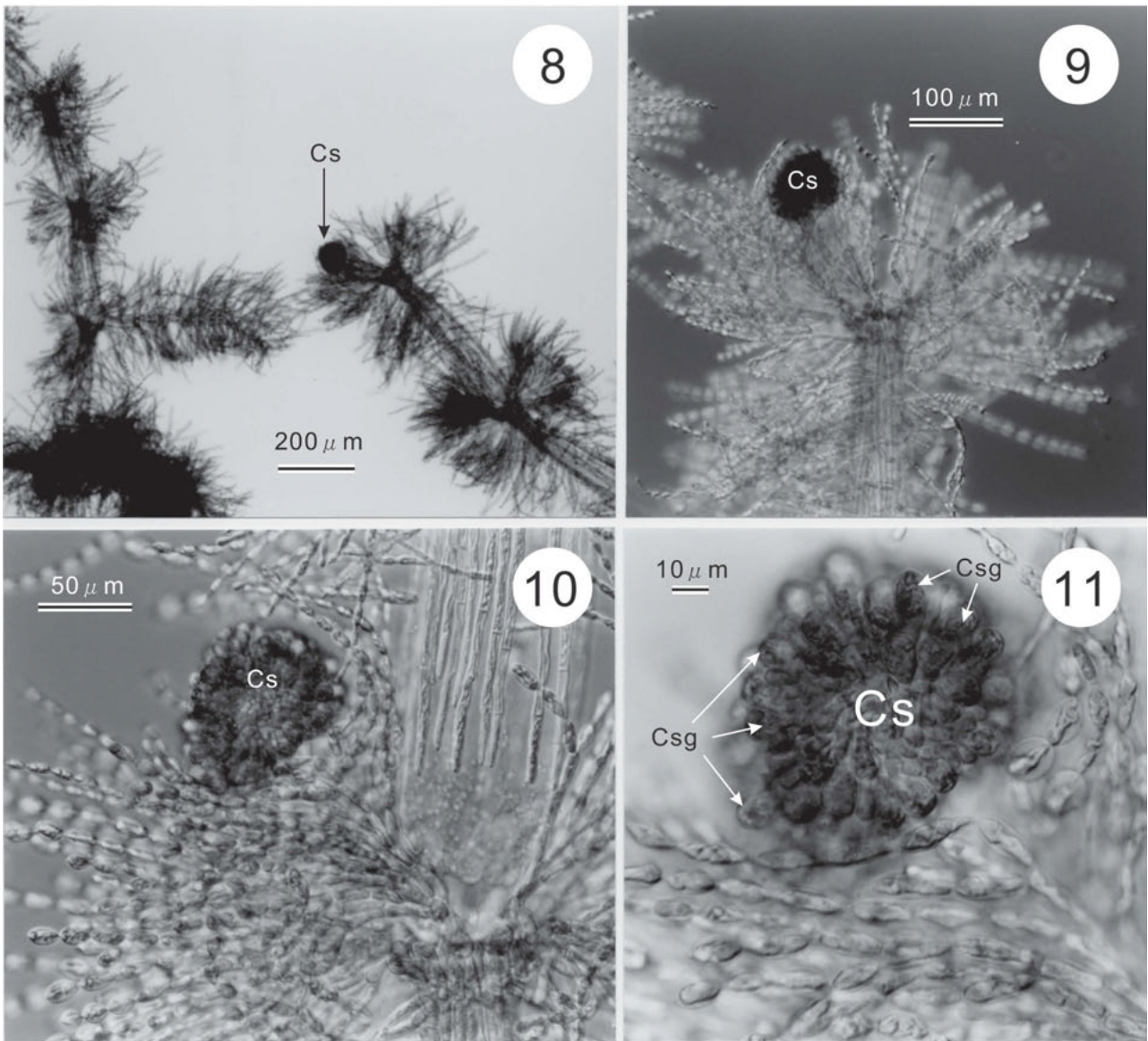
In the present paper, *Batrachospermum beraense* was reported from Sabah in North Borneo,



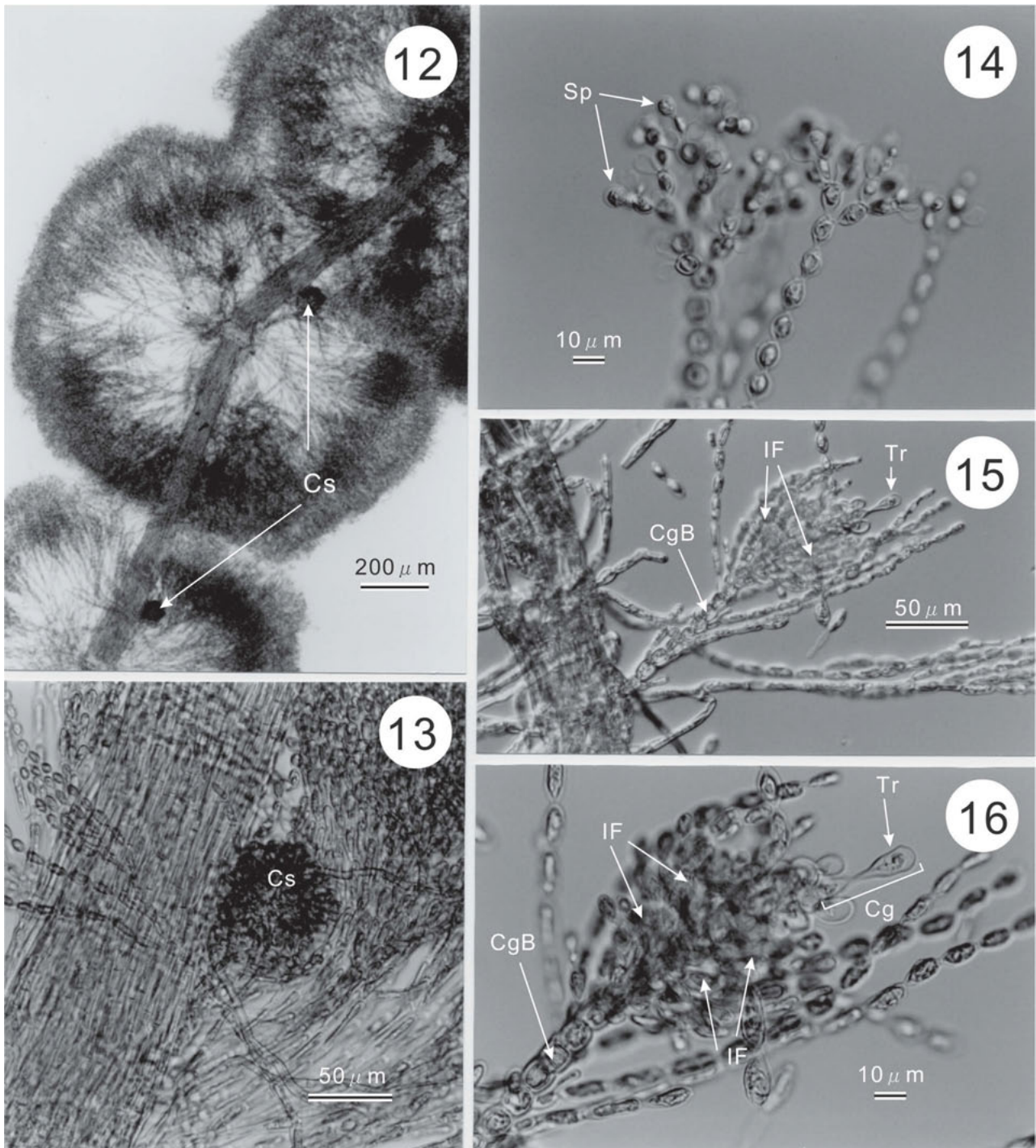
**Figure 3–7.** Morphological observation of *Batrachospermum beraense* from Sabah. 3. Structures of whorls. 4. Spermatangia (Sp) spherical, terminal on primary fascicles. 5. Fascicles with numerous short and long terminal hairs (arrows). 6–7. Carpegonium-bearing branch (CgB) straight, arising from periaxial cells; short and numerous involucre filaments (IF); ovoidal trichogyne (Tr), indistinctly stalked.

**Table 1.** Morphological characteristics of *Batrachospermum beraense*, and *B. longiarticulatum*.

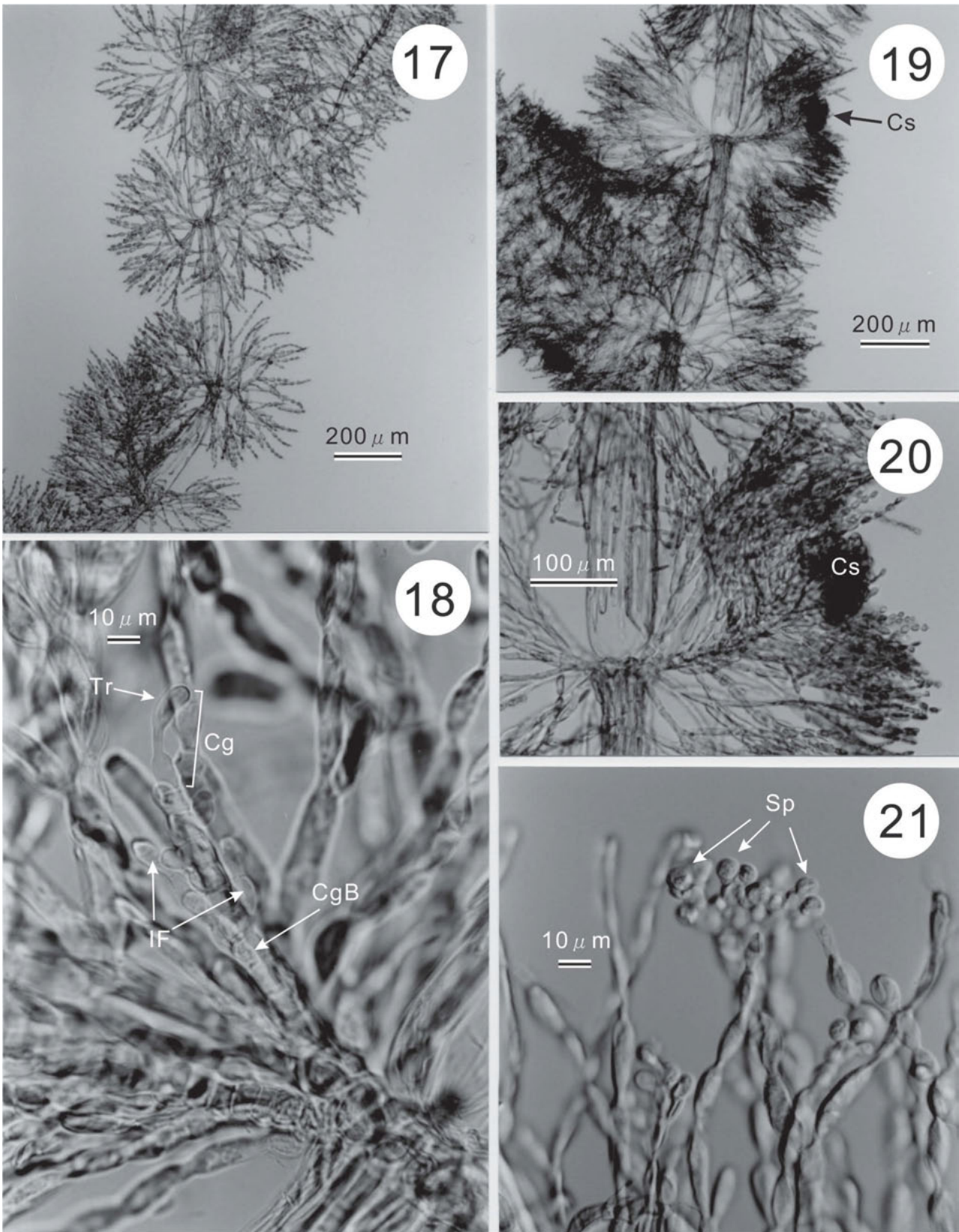
Species	Whorl	Fascicle	Fascicle cylindrical cell		Carpogonium-bearing branch		Carpogonium		Carposporophyte			Carposporangium		Reference
	Diameter (μm)	Cells	Diameter (μm)	Length (μm)	Cells	Length (μm)	Diameter (μm)	Length (μm)	Diameter (μm)	Height (μm)	Cells	Diameter (μm)	Length (μm)	
<i>B. beraense</i> (Sabah, North Borneo)	300-590	7-18	4.6-6.1	15-30	8-14	72-125	4.6-10	19-27	63-120	63-111	2-3	7.7-11	12-18	present study
<i>B. beraense</i> (type specimen)	560-1360	7-12	8-12	39-125	8-12	61-105	6-8	24-30	65-98	48-81	2-3	10-12	18-22	present study
	600-1000	10-13	8-10	50-90	8-11	60-90	5-8	20-27	90-150	---	---	10-12	19-22	Kumano, 1978
<i>B. longiarticulatum</i> (type specimen)	965-1400	19-28	6.2-10	40-70	15-18	180-220	7.3-8.8	22-30	66-130	58-120	2-4	6.5-8.7	12.5-18	present study
	814-1426	19-25	---	---	16-20	---	8.0-10.2	29.2-33.3	74-142	79-137	2-4	6.6-8.7	12.5-17.6	Sheath et al., 1994
	1200-2500	20-32	---	---	12-22	---	7-9	22-32	80-160	---	3-5	6.5-10	13-18	Necchi, 1990



**Figure 8–11.** Reproductive structures of *Batrachospermum beraense* from Sabah. 8–10. Carposporophyte (Cs) spherical, inserted at periphery of whorl. 11. Carposporangia (Csg) obovoidal, terminal on carposporophyte.



**Figure 12–16.** Type specimen of *Batrachospermum longiarticulatum*. 12–13. Structures of whorls showing carposporophyte (Cs); spherical carposporophyte, in the inner whorl. 14. Spermatangia (Sp) spherical, terminal on primary fascicles. 15–16. Carpgonium-bearing branch (CgB) straight, arising from periaxial cells; long and numerous involucral filaments (IF); club-shaped trichogyne (Tr), sessile.



**Figure 17–21.** Type specimen of *Batrachospermum beraense*. 17. Structures of whorls. 18. Straight carposogonium-bearing branch (CgB), arising from periaxial cells; short and long involucre filaments (IF); urn-shaped trichogyne (Tr), stalked. 19–20. Spherical carposporophyte (Cs), inserted at whorl periphery. 21. Spherical spermatangia (Sp), terminal on primary fascicles.

highlighting the biogeographical similarities between Borneo and mainland South-east Asia (Fig. 1).

A continuous land connection between Borneo and mainland South-east Asia existed throughout much of the Cenozoic era. The subsequent formation of the Makassar Straits in the Paleogene Period isolated small land areas in Sulawesi from those in Borneo (Moss and Wilson, 1998). The marked similarities between the flora of Borneo and those of mainland South-east Asia can be accounted for by the existence of this land bridge during the Paleogene and Neogene periods (Moss and Wilson, 1998). As a result of low sea levels during the Quaternary Period, land bridges also connected Borneo with mainland South-east Asia (Williams et al., 1998).

This finding indicates that the species of the genus *Batrachospermum* in Borneo is closely related to those found in mainland South-east Asia. In fact, *B. gombakense* has been reported in both Peninsular Malaysia (Ratnasabapathy and Kumano, 1982) and Sabah (Anton et al., 1999). These results indicate the biogeographical significance of studying the distribution patterns of species of the genus *Batrachospermum* in South-east Asia.

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## マレーシア・ボルネオ島の熱帯雨林で見つかった *Batrachospermum beraense* (淡水産紅藻類カワモズク科) の形態

佐藤 裕 司

淡水産紅藻類カワモズク科の *Batrachospermum beraense* Kumano をマレーシア・サバ州 (ボルネオ島北部) から初め報告する。サバ州に産する *B. beraense* の形態は以下のとおりである。

藻体はオリーブ緑色から青緑色で粘性があり、雌雄同株または異株。長さは 2–7 cm, 径 300–590  $\mu$  m。一次輪生枝は密に分枝し、7–18 個の細胞からなる。細胞は径 4.6–6.1  $\mu$  m, 長さ 15–30  $\mu$  m で、端毛がある。精子嚢は球形、径 4–7  $\mu$  m で輪生枝の先端につく。造果器をつける枝は周細胞から出て、長さ 72–125  $\mu$  m, 8–14 個の細胞からなる。受精毛は卵形、柄は不明瞭。果胞子体は球形から楕円形、径 63–120  $\mu$  m であり、果胞子嚢は倒卵形で径 7.7–11  $\mu$  m, 長さ 12–18  $\mu$  m である。

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