

First Record of *Discosporangium mesarthrocarpum* (Meneghini) Hauck (Phaeophyceae, Ochrophyta) from the Ogasawara Islands, Japan

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Abstract A brown alga, *Discosporangium mesarthrocarpum* (Meneghini) Hauck (Discosporangiales, Phaeophyceae, Ochrophyta) was collected from the deep water off Chichi-jima Island, Ogasawara Islands, Japan. This is the first record of the species and order from East Asia or North-western Pacific Ocean. This alga differs from all other brown algae in having uniseriate filaments formed by apical growth and unique disc-shaped plurilocular sporangia without a stalk cell. These morphological features characterize the order Discosporangiales, which is considered as the most primitive in the all brown algal orders.

Key words: brown algae, Discosporangiales, *Discosporangium mesarthrocarpum*, Japan, Ogasawara Islands, Phaeophyceae.

Introduction

Discosporangium mesarthrocarpum (Meneghini) Hauck (Discosporangiales, Phaeophyceae, Ochrophyta) is a small brown alga having unique morphological features: uniseriate filamentous thalli with apical growth cells and disc-shaped plurilocular sporangia without a stalk cell, which characterize the previously monotypic genus *Discosporangium*.

The systematic position of the species had been controversial for a long time since the original description because of its primitive and strange morphology. Kjellman (1891) treated *Discosporangium* as a member of Choristocarpaceae with also monotypic genus *Choristocarpus* because of their similarity in vegetative morphology of the filaments with apical cells. In contrast, Schmidt (1937) established the new family Discosporangiaceae and the new order Discosporangiales for the species in regarding the unique reproductive organs as the important character, while Fritsch (1945) incorporated the

Choristocarpaceae in Sphacelariales without *Discosporangium*. Nevertheless, many authors also placed both *Discosporangium* and *Choristocarpus* under Sphacelariales because they could not admit Discosporangiales in the previous classification system of brown algae (e.g., Womersley, 1987; Prud'homme van Reine, 1993; Abbott and Huisman, 2004). However, using molecular analysis in a recent study, Kawai *et al.* (2007) clarified the position of *D. mesarthrocarpum* and reinstated the family Discosporangiaceae and the order Discosporangiales, which is considered to be phylogenetically sister to all other brown algae.

Discosporangium mesarthrocarpum has very few records outside of the Mediterranean Sea and Womersley (1987) only recorded this species in the Pacific in the last century. Thus there was a hypothesis that Australian algae are derived from the North Atlantic by recent introduction (Prud'homme van Reine, 1993). However, a recent molecular phylogenetic analysis of *D. mesarthrocarpum* by Kawai *et al.* (2007) sug-

gested that the alga of *Discosporangium* in Australia can be a distinct species, which has a reasonable difference in its *rbcL* sequence from the *D. mesarthrocarpum*. Moreover, the second species of *Discosporangium*, *D. pulvillocarpum* was described by Kraft (2009) based on the molecular implications of Kawai *et al.* (2007) and morphological differences from the type species, *D. mesarthrocarpum* in plastids and reproductive organs, for the algae from Lord Howe Island, Australia. On the other hand, Abbott and Huisman (2003) reported *D. mesarthrocarpum* from Hawaiian Islands.

In this study, to confirm the identity of the present brown alga from the Ogasawara Islands, I made anatomical observations on the materials using a microscope.

Materials and Methods

The brown algal material referable to the genus *Discosporangium* was collected from the deep water (46.2–50.8 m in depth) off Chichijima Island in the Ogasawara archipelago (= Bonin Islands), Japan by dredge using the research vessel, the *Koyo* (87 tonnage), operated by the Ogasawara Fisheries Center, Tokyo Metropolitan. For preservation, the material was dried on sheets of paper or fixed in 10% Formalin-seawater. Anatomical observations were made on the material using a microscope. Voucher specimens were deposited in the algal herbarium of the National Museum of Nature and Science (TNS).

Descriptions

Discosporangiales O. C. Schmidt, 1937

Discosporangiaceae O. C. Schmidt, 1937

Discosporangium mesarthrocarpum (Meneghini) Hauck

in L. Rabenhorst, Kryptogamen-flora, ed. 2, vol. 2, 525, f. 236 (1885).

Basionym: *Callithamnion mesarthrocarpum* Meneghini, Giornale Botanico Italiano 1: 288 (1844) [Type locality: Dalmatia, Adriatic Sea,

Mediterranean (Guiry and Guiry, 2012)].

[Figs. 1–18]

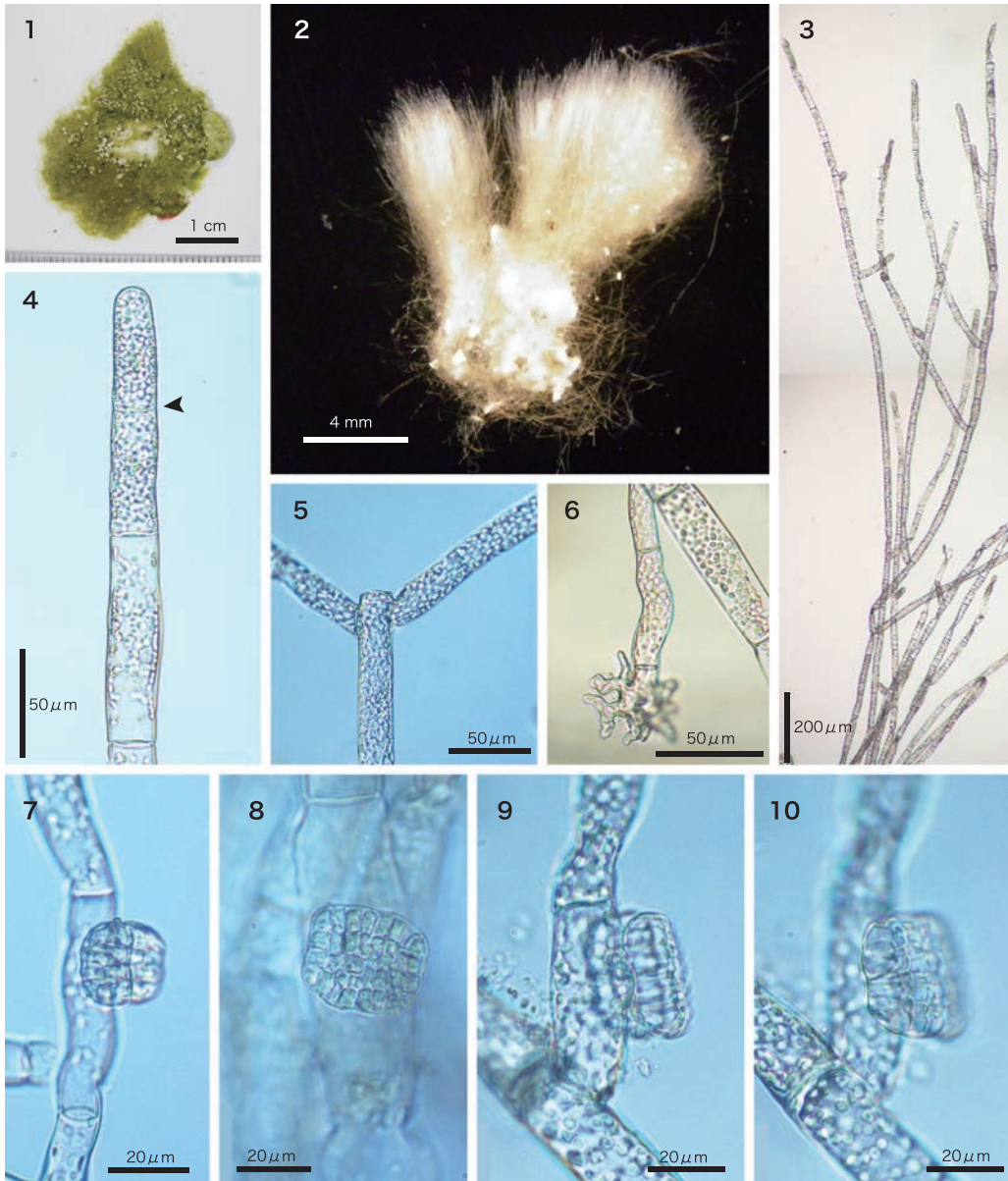
Plants light to golden brown in color, epilithic, attached to rocks or entangled with grains of dead coral by basal cell with rhizoidal appendages (Figs. 1, 2). Thalli erect and densely tufted, composed of branched filaments, up to 1.5 cm in height. Erect filaments uniseriate, irregularly, radially and laterally branched (Figs. 3, 11). Vegetative cells of erect filaments cylindrical, 18–30 μm in diameter, 80–195 μm in length. Growth by cell divisions in a prominent apical cell on each filament (Fig. 4, arrowhead). Apical cells cylindrical, 14–28 μm in diameter, 47–138 μm in length, with rounded ends (Fig. 4). Lateral branches usually initiated singly per cell at various angles, though laterals occasionally initiated oppositely from terminal cell of wounded filaments (Fig. 5). Haptera digitate (Figs. 6, 17, 18). Plastids numerous per cell in both erect filaments and haptera, disc-shaped, circle to ellipsoidal, 3–5 μm in diameter.

Plurilocular sporangia sessile, monolayered, various in form with maturation (Figs. 7–10, 12–16). Young plurilocular sporangia spherical to rounded (Figs. 7, 12). Mature or empty plurilocular sporangia disk-shaped, quadrate or square in surface view (Fig. 8), up to 40 μm in length, up to 35 μm in width, up to 16 μm in thickness, bending outward convexly on the center (Figs. 9, 10), usually composed of eight locules in length, eight locules in width (Fig. 16).

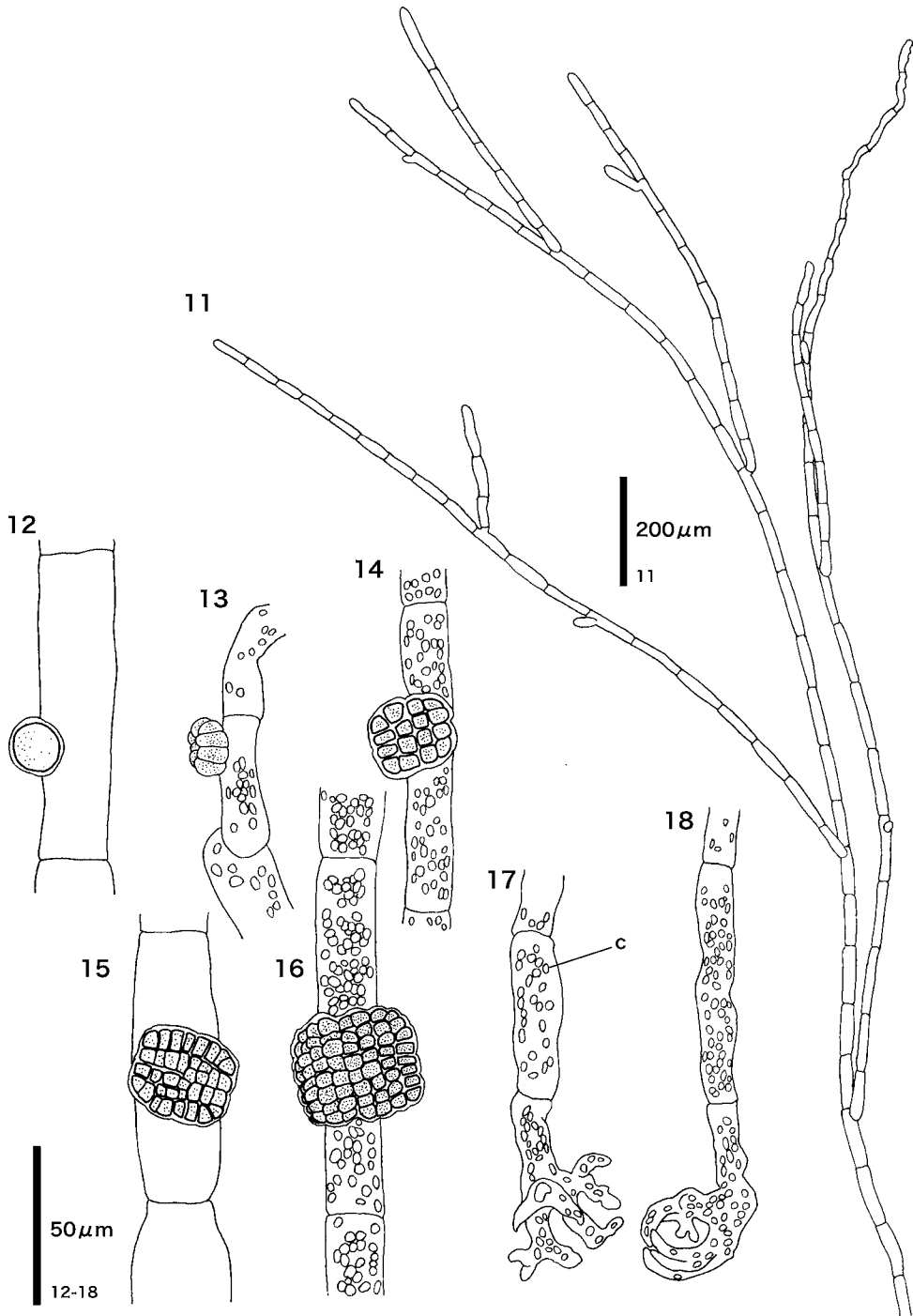
Specimens examined: Subtidal from 46.2 m to 50.8 m in depth, off Chichijima Island, Ogasawara Islands, Japan (27°07'08–15"N, 142°10'42–44"E), 8 July 2010, leg. T. Kitayama (TNS-AL 176344, 176345).

Japanese name: Tama-kushige (nom. nov.).

Distribution: *Mediterranean Sea*: Croatia (type locality), Italy, Morocco, Spain (Ribera *et al.*, 1992), France (Coppejans, 1979; Ribera *et al.*, 1992), Greece (Tsirika and Haritonidis, 2005; Kawai *et al.*, 2007), Malta (Cormaci *et al.*, 1997); *Atlantic Ocean*: Bermuda (Schneider and Searles, 1998), Canary Islands (Haroun *et al.*, 1993), Madeira (Neto *et al.*, 2001); *Pacific*



Figs. 1–10. *Discosporangium mesarthrocarpum* from Ogasawara Islands, Japan. 1. Habit showing a thallus entangled with coral sands (dried specimen, TNS-AL 176344). 2. Habit showing tufts of erect filaments. 3. Erect filaments with apical cells and laterals. 4. Apical cell showing a newly formed cell wall (arrowhead). 5. Opposite pair of laterals just on the terminal of a broken erect filament. 6. Holdfast with a digitate hapteron. 7. Immature plurilocular sporangium with eight cells. 8. Surface view of mature plurilocular sporangium with mostly 32 cells. 9, 10. Side views of identical empty plurilocular sporangium with mostly 64 locules, showing outward bending of this sporangium in the different focuses.



Figs. 11–18. *Discosporangium mesarthrocarpum* from Ogasawara Islands, Japan. 11. Erect filaments. 12–16. Various stages of plurilocular sporangia. 12. Initial stage of plurilocular sporangium with a single cell. 13. Side view of a primordial plurilocular sporangium with eight cells. 14. Surface view of a primordial plurilocular sporangium with sixteen cells. 15. Surface view of a mostly mature plurilocular sporangium with 36 cells. 16. Surface view of a mature plurilocular sporangium with 64 cells. 17, 18. Haptera showing digitate ends containing many chloroplasts (c).

Ocean: South Australia (Womersley, 1987), Hawaii (Abbott and Huisman, 2003, 2004), Japan (Ogasawara Islands, the present study).

Discussion

The present brown algal materials from the Ogasawara Islands, Japan are in morphological agreement with descriptions or figures of Mediterranean algae of *Discosporangium mesarthrocarpum* by Hauck (1885), Coppejans (1983), Kawai *et al.* (2007) in both vegetative and reproductive morphology. This is the first record of the species from East Asia and the northwestern Pacific Ocean.

Finding this alga from the northwestern Pacific suggests that this species has a wide distribution in both the Atlantic and Pacific, though Prud'homme van Reine (1993) suggested that this species is endemic to the Mediterranean and introduced recently from the North Atlantic Ocean because of rare records outside of the Mediterranean Sea. Kawai *et al.* (2007) denied the hypothesis inferring from the genetic divergence between Greek algae and Australian algae. In general, it seems that artificial transportation is not easy for deep marine algae like this species, whose habitat is probably 20–50 m in depth.

When Kraft (2009) described *D. pulvillocarpum*, he considered the South Australian plants of *D. mesarthrocarpum* illustrated by Womersley (1987) as the possibly identical taxon with his new species. According to Kraft (2009), vegetative cells of *D. pulvillocarpum* has many bacilliform plastids, while the plastids of Mediterranean plants of *D. mesarthrocarpum* cultured by Kawai *et al.* (2007) and illustrated by Coppejans (1983) are discoid or ellipsoidal in shape. On the other hand, the plants of "*D. mesarthrocarpum*" from the Hawaiian Islands recorded by Abbott and Huisman have "disc-shaped to elongate" plastids, which are bacilliform judging from the photograph (Abbott and Huisman, 2003, f. 20; Abbott and Huisman, 2004, f. 71). In the present Ogasawara plants, plastids are discoid and similar to the ones observed so far in Mediterranean

plants.

As for reproductive structures, Kraft (2009) showed morphology of plurilocular sporangia in his new species, which was described as different from ones of type species, though the present author could not find any definite difference in the organs between the Japanese plants and *D. pulvillocarpum*. Only outward bend of mature plurilocular sporangia (Figs. 9, 10) is possible to be a morphological difference, which is known in *D. mesarthrocarpum* (Hauck, 1885, f. 236, c), but the feature is unclear in the original description of *D. pulvillocarpum* (Kraft, 2009). In this paper, therefore, the present alga is treated tentatively as *D. mesarthrocarpum* inferring from differences in shape of plastids. To clarify the relationship among the populations of *Discosporangium* inside the Pacific, a molecular analysis of the plants from the Ogasawara Islands is required.

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