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Congracilaria babae gen. et sp. nov. (Gracilariaceae), an Adelphoparasite Growing on *Gracilaria salicornia* of Japan*

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Abstract

A red alga, *Congracilaria babae* was found parasitic on *Gracilaria salicornia* from Okinoerabu Island, Kagoshima Pref., southern Japan, and is described as a new species in a new genus of Gracilariaceae. The new species is characterized by having no rhizoids and by having vegetative structure and reproductive organs closely related to those of the host plant. Bisporangia are the suggested asexual reproductive organs instead of tetrasporangia.

Many accounts on parasitic red algae have been published over more than 100 years. Recently Goff (1982) summarized them and listed 101 species in 57 genera. More species continue to be added (Yoneshigue and Oliveira, 1984 ; Bula-Meyer, 1985).

The parasitic species are divided broadly into two categories, adelphoparasites and alloparasites, on the basis of the degree of the taxonomic affinity with their hosts. Adelphoparasites are very closely related to their hosts, and about 80% of all parasites are assigned to this group (Goff, 1982). Of all these adelphoparasites, only six species and one variety have been reported in Gracilariaceae until now (Table 1). In this paper, a new adelphoparasitic red alga which grows on *Gracilaria salicornia* (C. Agardh) Dawson is described.

Materials and methods

The specimens of the new species were collected in tide pools at the two sites on Okinoerabu Island, southern Japan, and were immediately fixed with ca 10% formalin-seawater and preserved in it.

Sections for microscopic observation were made with a freezing microtome, and the squash method was also employed for the observation of carpogonial branches and early developmental stages of cystocarps. The materials sectioned or squashed were stained with dilute methylene blue or aniline blue (less than 1%) for tissue observation and with Wittmann's solution (Wittmann, 1965) for nuclei, and mounted in glycerine to which phenol had been added.

The dried and liquid-preserved specimens have been deposited in the herbarium of the Laboratory of Marine Botany, Faculty of Fisheries, Hokkaido University,

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Table 1. Relationships between reported parasites in Gracilariaceae and their hosts

parasite	host	references
Gracilariophila oryzoides Setchell and Wilson	*Gracilaria pacifica* (cf. Abbott, 1985) (Wilson, as *Gracilaria confervoides*)	Wilson, 1910
	Gracilaria textorii var. *cunninghamii* (cf. Dawson, 1949, 1961) (Wilson, as *Gracilaria multipartita*)	
	Gracilaria lemaneiformis (cf. Abbott, 1983) (Dawson, as *Gracilariopsis sjoestedtii*)	Dawson, 1949
	Gracilaria papenfussii (cf. Abbott, 1983) (Dawson, as *Gracilaria andersonii*)	
Gracilariophila gardneri Setchell	*Gracilaria textorii* var. *cunninghamii* (cf. Dawson, 1961) (Setchell, as *Gracilaria cunninghamii*)	Setchell, 1923
	Gracilaria crispata	Dawson, 1949
Gracilariophila deformans Weber van Bosse	*Gracilaria salicornia* (Weber van Bosse, as *Corallopsis salicornia*)	Weber van Bosse, 1928
	Gracilaria crassa	Chang and Xia, 1978
Gracilariophila sibogae Weber van Bosse	*Gracilaria salicornia*	Weber van Bosse, 1928
Gracilariophila infidelis (W. van B.) Weber van Bosse	*Gracilaria salicornia* (Weber van Bosse, as *Corallopsis salicornia*)	Weber van Bosse, 1928
	Gracilaria crassa	Chang and Xia, 1978
Gracilariophila setchellii Weber van Bosse	*Gracilaria salicornia* (Weber van Bosse, as *Corallopsis salicornia*)	Weber van Bosse, 1928
	Gracilaria crassa	Chang and Xia, 1978
Gracilariophila setchellii var. *aggregata* Weber van Bosse	*Gracilaria minor* (cf. Durairatnam, 1961) (Weber van Bosse, as *Corallopsis salicornia* var. *minor*)	Weber van Bosse, 1928

Hakodate (HAK).

Observations

On the thallus of *Gracilaria salicornia* from Okinoerabu Island, southern Japan, where high seawater temperatures (21–28°C) occur, many small parasites resembling tubercles were observed. At the beginning of growth, the parasite can be recognized as a mere swelling on various places of the host plant, and upon maturing, it becomes spherical (Fig. 2) and then usually develops into a mushroom-shaped structure with a short stipe (Figs. 3, 4).

The surface of the part corresponding to the cap of the mushroom is scarcely lobed, but smooth or slightly undulate. The parasite is up to 3 mm high from the interface with the host to the top, and up to 4.5 (−5) mm wide at the cap. The stipe is up to 1 mm high, and up to 1.2 mm diam. The color is almost the same as that of the host, yellowish to purplish brown, or a little lighter.

Structurally the frond is composed of a cortical layer (Fig. 5) of 1 row (rarely

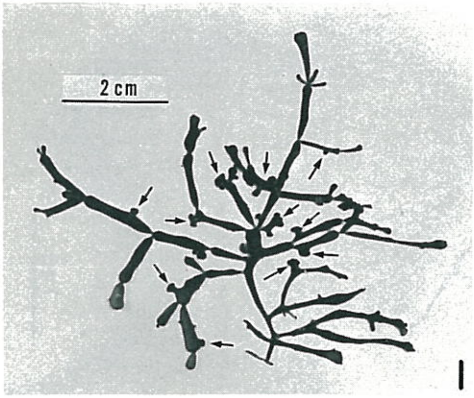


Fig. 1. Holotype specimen (Y3021 in HAK) of *Congracilaria babae* (arrows) on *Gracilaria salicornia*.

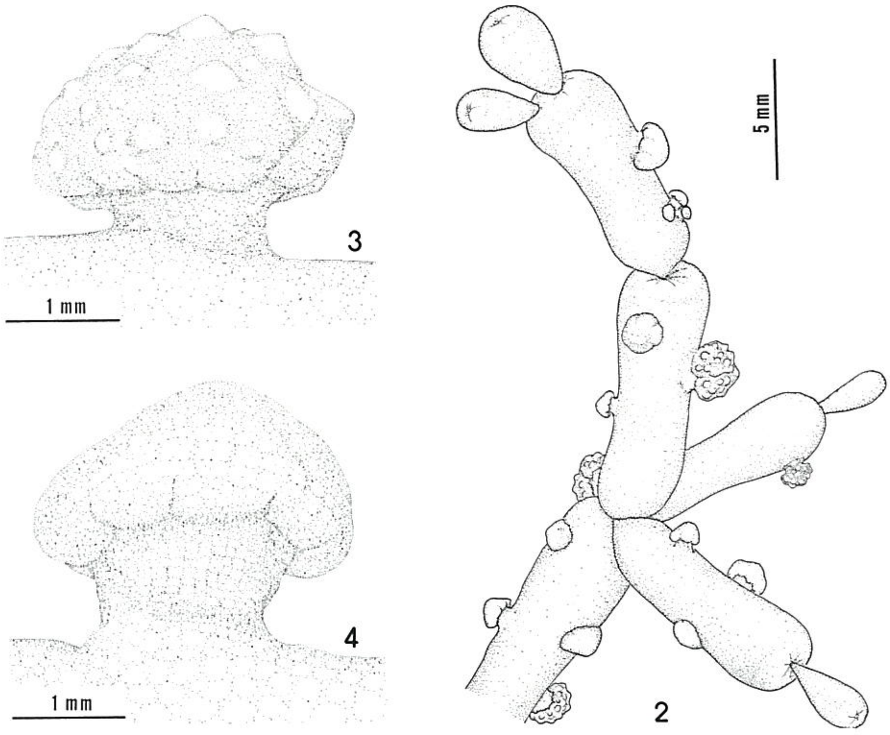
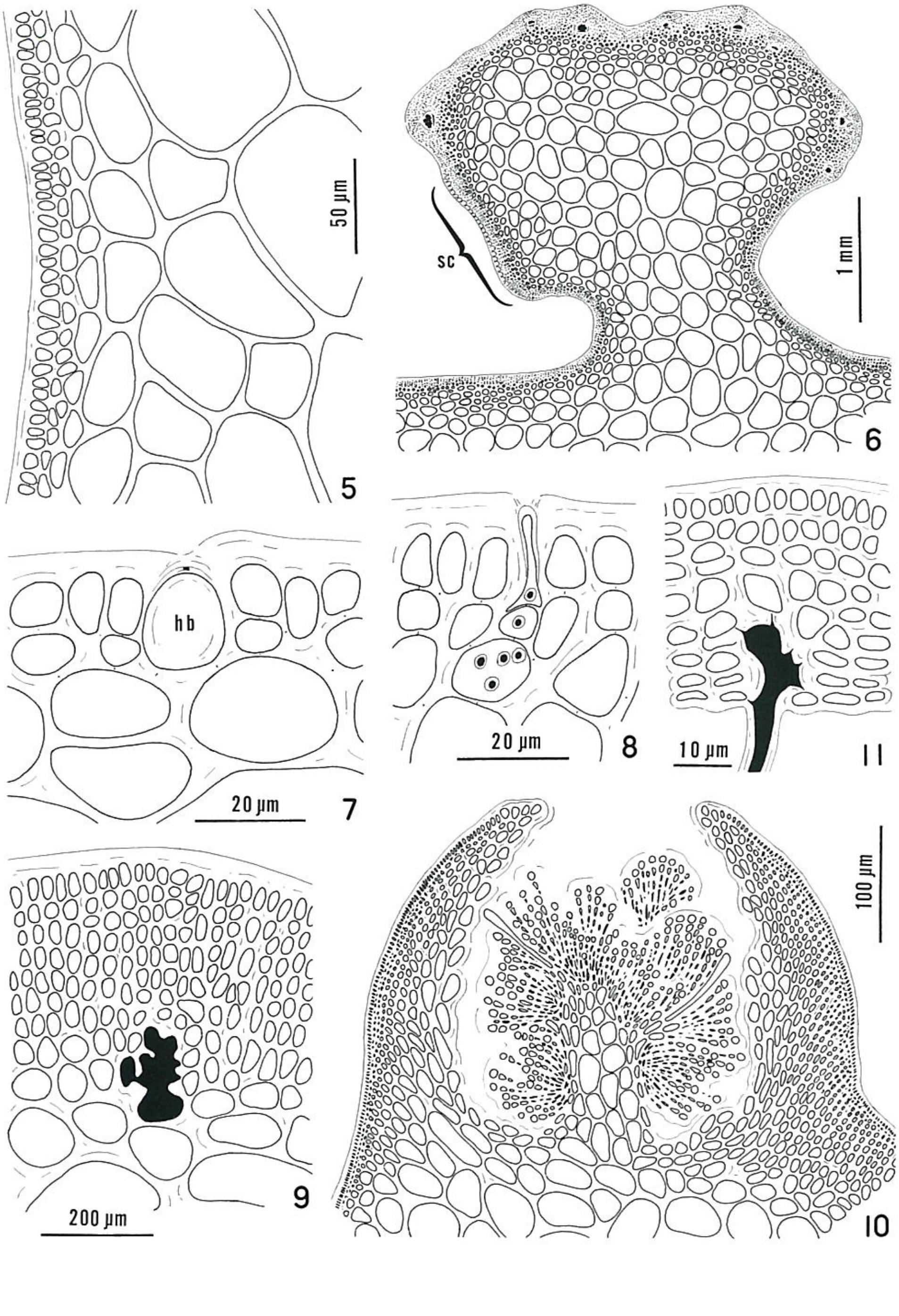


Fig. 2. Habit of *Congracilaria babae*, growing on various places of the host plant, *Gracilaria salicornia*. Fig. 3. A cystocarpic frond with young cystocarps. Fig. 4. A bisporangial frond, showing mushroom shape with smooth surface.



2 rows) of densely protoplasmic cells. The outermost cells are 7.2–9.6 (−11.2) μm high, 5.6–9.6 (−10.4) μm wide, with primary pit connections only.

Inward of the cortex, there is a layer of 2 or 3 rows of cells that are smaller and less protoplasmic than the cortical cells and more or less compressed parallel to the frond surface (Fig. 5). Cells increase in size toward the center, reaching 400-560 μm diam. (Figs. 5, 6) with the medullary cells poorly protoplasmic. Transition in cell size from cortex to medulla is abrupt. Few hair basal cells (Fig. 7) are present, 17-24 μm high, 16-18 μm wide.

No rhizoids penetrate the tissue of the host and there are no special cells which might work for attaching to the host. Only pit connections were observed to connect host vegetative cells. Therefore, the tissues of the two plants appear to be continuous, the chief distinction being the frequency of hair basal cells, which are abundant in the host but rare in the parasite. The parasite does not induce any morphological response in the host, such as bending.

Carpogonial branches, consisting of two cells (Fig. 8), are numerous, borne all over the cap. After presumed fertilization, the cells around each carpogonial branch unite and develop into a large fusion cell (Fig. 9). This cell serves as the starting point of placental tissue which produces gonimoblasts on its periphery. Cystocarps (Fig. 10) are dome-shaped, 400-540 μm high, 600-700 μm wide, and each has a single ostiole at its top. When crowded close together, two young cystocarps sometimes come to unite with age, giving the appearance of one cystocarp with two ostioles. A large number of cystocarps arise in a single frond ; a frond with more than 100 cystocarps was observed.

In the central part of the cystocarp, the placental tissue is composed of large cells, 24-58 μm long, 20-50 μm wide. On these cells, gonimoblasts and only a few absorbing filaments (Fig. 10) are produced. Gonimoblast filaments are composed of a row of elongate cells, with cells close to its tip developing into carposporangia. Some absorbing filaments reach the pericarp and connect with pericarp cells (Fig. 11) through pit connections.

Cystocarps almost always coexist with spermatangia on the same frond, and in addition to that, very rarely with a few bisporangia. Thus it is possible for three phases of reproductive organs to appear in a single frond.

A spermatangial mother cell primordium is converted from an outermost cell of the cortical layer. The primordium forms a branch system of mother cells by dividing repeatedly, resulting in the formation of a oval conceptacle. Spermatangia are produced on a branched system, each mother cell dividing once or twice, and finally spermatangia cover the entire inner surface (Fig. 12) of the conceptacles. Conceptacles are 46-50 (−60) μm deep, up to 40 μm wide, embedded in a sorus, and are usually isolated from each other by vegetative cells, but are sometimes confluent and thus wider. The development of spermatangia is equivalent to that of Verrucosa-type of the genus *Gracilaria* (Yamamoto, 1978).

Bisporangia appear superficially (Figs. 14, 15) in any area of the cap that has neither spermatangia nor cystocarps, but are rarely accompanied by a few cystocarps

Fig. 5. A sectional view of sterile portion of cystocarpic frond. Fig. 6. A sectional view of a frond in which cystocarps and spermatangial conceptacles (sc) coexist. Fig. 7. A sectional view of sterile portion, showing a hair basal cell (hb). Fig. 8. A carpogonial branch, consisting of two cells. Fig. 9. A sectional view of a young cystocarp, showing a fusion cell. Fig. 10. A sectional view of a mature cystocarp. Fig. 11. A sectional view of the tip of an absorbing filament communicating with pericarp cells through pit connections.

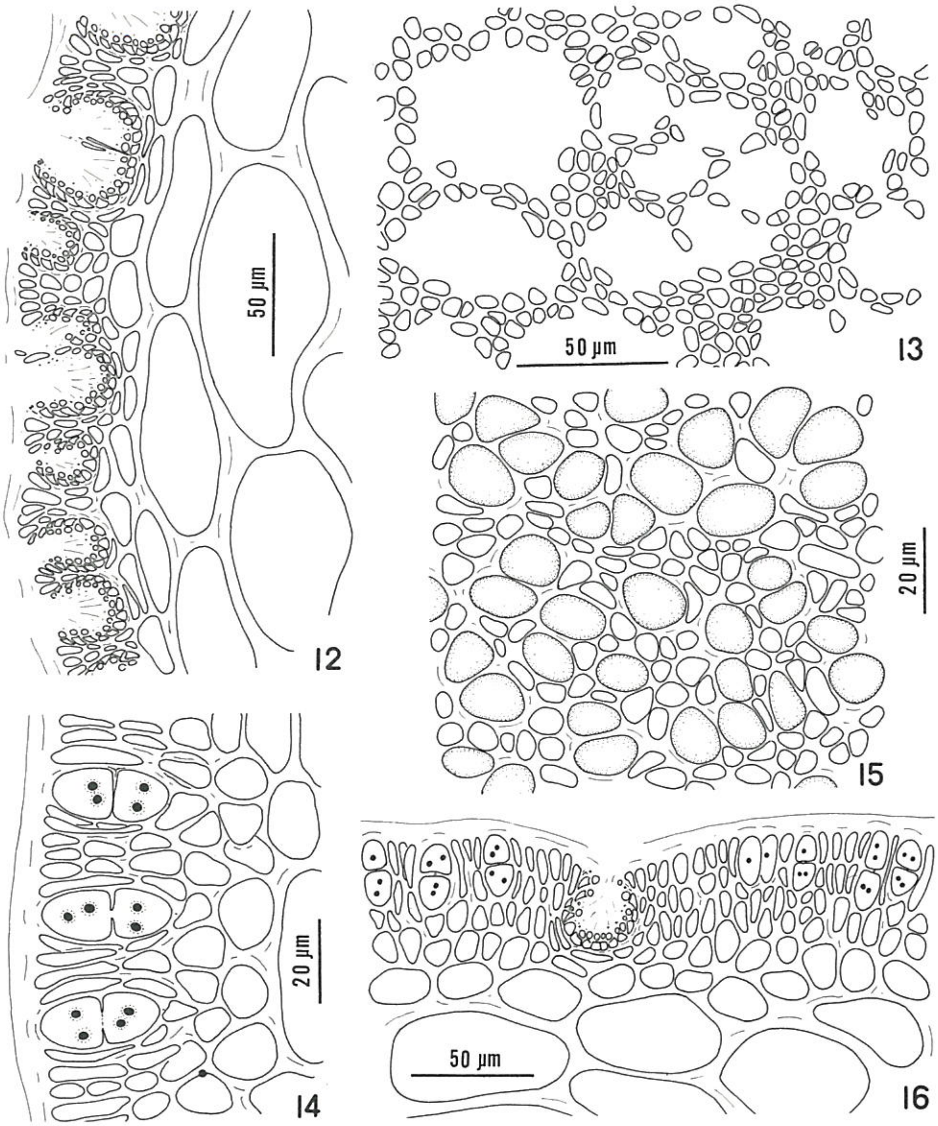


Fig. 12. A sectional view of mature spermatangial conceptacles, showing confluence with neighboring ones. Fig. 13. Surface view of mature spermatangial frond. Fig. 14. A sectional view of bisporangial frond, showing transversely divided sporangia in which each spore has two nuclei. Fig. 15. Surface view of bisporangial frond. Fig. 16. A sectional view of bisporangia, showing coexistence with a spermatangial conceptacle.

or spermatanigial conceptacles (Fig. 16). Sporangia are produced very close together, 38-50 μm high, 18-20 μm wide, surrounded by rows of elongated vegetative cells, their color is yellowish brown.

In the present materials, the sporangia are always divided transversely to produce bispores, each with two nuclei. Tetrasporangia were never observed.

Congracilaria gen. nov.

Parasitica in *Gracilaria* specie, inconspicue differens in pulvinum ad frondes fungiformes, affixa sine rhizoideis, coloris ochraceo-brunnei similaris ei hospitis plantae. Cortex uni-bicellularis, medulla cellularum sphaericarum; transitio abrupta. Pilus cellularum basalium adest. Rami carpogoniales bicellulares, cystocarpia procurrentia filis absorbentibus ad pericarpium. Spermatangia portata in conceptaculis ovalibus. Sporangia in forma bisporarum, utrarumque duobus nucleis.

Species typica: *Congracilaria babae*

Parasitic on *Gracilaria* species, inconspicuously differentiated into cushion- to mushroom-shaped fronds, attached without rhizoids, of yellowish brown color similar to that of host plant. Cortex comprising 1 or 2 layers of cells, medulla of spherical cells; transition abrupt. Hair basal cells present. Carpogonial branches two-celled, cystocarps projecting, with absorbing filaments extending to pericarp. Spermatangia borne in oval conceptacles. Sporangia forming bispores, each with 2 nuclei.

Type species: *Congracilaria babae.*

Congracilaria babae Yamamoto sp. nov.

Frondes parasiticae in partibus variis *Gracilariae salicorniae*, fungiformes, usque ad 3 mm altae, usque ad 4.5 (−5) mm latae, pagina rasili vel paulo undulata. Cellulae corticales dense protoplasmicae, cellulae medullosae augentes ad centrum, extendentes 400-560 μm diametro. Pilus cellularum basalium rarius adest. Cystocarpia tholiformia 400-540 μm alta, 600-700 μm lata, filis absorbentibus. Spermatangia portata in integra pagina interiore conceptaculorum, aggregatorum in soris. Conceptacula spermatangi 46-50 (−60) μm profunda, usque ad 40 μm lata, interdum confluentia, plerumque esse cum cystocarpiis, rarenter sporangiis. Sporangia in forma bisporarum, utrarumque duobus nucleis, dispersa superficialiter super integra fronde, plerumque segregata frondibus spermatangi et cystocarpi.

Fronds parasitic on various parts of *Gracilaria salicornia*, mushroom-shaped, up to 3 mm high, up to 4.5 (−5) mm wide, surface smooth or a little undulate. Cortical cells densely protoplasmic, medullary cells becoming large toward center, reaching 400-560 μm diameter. Hair basal cells infrequently present. Cystocarps dome-shaped, 400-540 μm high, 600-700 μm wide, having absorbing filaments. Spermatangia borne on entire inner surface of conceptacles, the conceptacles grouped in sori. Spermatangial conceptacles 46-50 (−60) μm deep, up to 40 μm wide, sometimes confluent, very often coexisting with cystocarps, rarely with sporangia. Sporangia forming bispores, each with 2 nuclei, scattered superficially over the entire frond, usually separated from spermatangial and cystocarpic fronds.

Habitat: This species grows on various parts of the thallus of *Gracilaria salicornia* (tetrasporophyte) in shallow tide pools.

Specimens examined: Nishibaru in Okinoerabu Island of Kagoshima Pref. (C*, S, B, Aug. 16, 1985, M. Baba); Furusato in Okinoerabu Island of Kagoshima Pref.

* C: cystocarpic plant; S: spermatangial plant; B: bisporangial plant

(C, S, Mar. 27, 1981, M. Baba; C, S, B, Aug. 18, 1985, M. Baba).
Type locality: Nishibaru in Okinoerabu Island.
Holotype: Y3021 in HAK (Nishibaru, Aug. 16, 1985). Isotypes and other materials also in HAK.
Japanese name: Fushikure-take.

Discussion

The vegetative and reproductive features of *Congracilaria babae* almost coincide with those of the genus *Gracilaria*. However, this species is separated from *Gracilaria* on the basis of its parasitic nature.

Of the parasitic species related to *Gracilaria*, *Gracilariophila oryzoides* Setchell and Wilson (Wilson, 1910) was the first to be reported and was followed by *G. gardneri* Setchell (Setchell, 1923); Dawson, 1949). *Gracilariophila*, as defined by its type species, is mainly characterized by 1) the presence of penetrating rhizoids, 2) the lack of color, and 3) the superficial production of spermatangia (table 2).

Congracilaria is similar to *Gracilariophila* in comprising very small plants growing on the frond of *Gracilaria*. The presence or absence of rhizoids appears to be the most important point in distinguishing these genera of parasites. *G. oryzoides* is essentially non-pigmented (Abbott and Hollenberg, 1976) as compared to the yellowish brown of the new species. The absence of rhizoids in *Congracilaria* suggests that this genus is a hemiparasite rather than a parasite.

The difference in the patterns of spermatangial production also seems important, the sorus of oval conceptacles in *Congracilaria* contrasting with the superficial layer in *Gracilariophila*. Finally, the sporangia of *Congracilaria* form bispores rather than tetraspores as in *Gracilariophila*. The differences between the two genera are summarized in Table 2.

Weber van Bosse (1928) described four species and one variety of *Gracilariophila*, and put them in Section Arhiza which she established for the species without rhizoids. Subsequently, Chang and Xia (1978) recognized three of Weber van Bosse's species in the Chinese algal flora, although in their material spermatangia were produced in conceptacles.

Congracilaria babae is closely related to the four species of Weber van Bosse, although the pattern of spermatangial production is different (Table 2). It seems even more closely related to the species which Chang and Xia identified with those of Weber van Bosse, having similar cystocarps and spermatangial pattern and being pigmented (Table 2). If the absence of rhizoids can be confirmed in the Chinese material, those species would need to be reconsidered as possible members of *Congracilaria*, since the only generic difference remaining would be the presence of bisporangia in *Congracilaria*.

The taxonomic significance of bisporangia vis-a-vis tetrasporangia is subject to varying interpretation. Bisporangia are found in various families of red algae (Guiry, 1978). They are characteristic of certain species, but occur only in certain populations of other normally tetrasporangial species. The role of bispores in the life history has been revealed through the culture studies of *Gardneriella tuberifera* (Goff, 1981) and *Gelidium pristoides* (Carter, 1985). In *Gardneriella tuberifera*, bispores contain two heterotypic nuclei and thus develop into monoecious plants.

Table 2. Comparison of the features of the two genera, *Gracilariophila* and *Congracilaria*

	rhizoid	spermatangial pattern	asexual reproductive organ	color	monoecious or dioecious
Gracilariophila Setchell and Wilson (in Wilson, 1910)	present	superficial	tetrasporangium	white	dioecious
Gracilariophila of Weber van Bosse, 1928	absent	superficial	tetrasporangium	?	monoecious or dioecious ?
Gracilariophila of Chang and Xia, 1978	?	oval conceptacle	tetrasporangium	same as host	monoecious or dioecious ?
Congracilaria Yamamoto	absent	oval conceptacle	bisporangium	same as host	monoecious

Congracilaria agrees with this pattern of development in being almost always monoecious.

Finally, it may be pointed out that four genera of adelphoparasites of Gracilariaceae may ultimately be recognized : 1) *Gracilariophila* Setchell and Wilson, 2) *Congracilaria* Yamamoto, 3) *Gracilariophila* sensu Weber van Bosse (1928), and 4) *Gracilariophila* sensu Chang and Xia (1978).

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