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Taxonomy and distribution of *Sargassum* (Phaeophyceae) in the Gulf of Thailand

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Abstract Ten species of *Sargassum* (Sargassaceae, Phaeophyceae) were found along the Gulf of Thailand. Morphological characteristics of *Sargassum baccularia* (Mertens) C.A. Agardh, *S. binderi* Sonder, *S. cinereum* J.G. Agardh, *S. crassifolium* J.G. Agardh, *S. longifructum* Tseng et Lu, *S. oligocystum* Montagne, *S. polycystum* C.A. Agardh, *S. siliquosum* J.G. Agardh, *S. swartzii* (Turner) C.A. Agardh and one unidentified species were examined and are described in detail. The most common species were *S. polycystum* distributed widely in almost all the study sites, *S. crassifolium* restricted to Prachuap Khirikhan Province, *S. longifructum* restricted to Chumphon Province, *S. siliquosum* restricted to Surat Thani Province and one unidentified species restricted to Songkhla Province. Three species (*S. cinereum*, *S. longifructum* and *S. swartzii*) are new records for the algal flora of Thailand. Five species (*S. baccularia*, *S. cinereum*, *S. longifructum*, *S. polycystum* and the unidentified species) belong to the section Zygothecae (J.G. Agardh) Setchell.

Keywords Phaeophyceae · *Sargassum* · Taxonomy · Distribution · The Gulf of Thailand

Introduction

Sargassum C. Agardh (Sargassaceae, Fucales), a very large brown algal genus with nearly 400 species, is widely distributed in warm and temperate waters, especially in the Indo-west Pacific region and Australia (Tseng et al. 1985). Thailand is a tropical country in south-east Asia with a coastline of approximately 2,650 km, consisting of 1,880 km along the Gulf of Thailand (Pacific Ocean) and 770 km along the Andaman Sea (Indian Ocean); both coasts have a diverse seaweed flora. Thai species of *Sargassum* were first recorded by Reinbold in “Flora of Koh Chang” from the specimens collected by Schmidt (1900–1916) during the Danish Expedition to Siam; *S. polycystum* was reported from Koh Kahdat, Trat Province situated on the east coast of the Gulf of Thailand. Lewmanomont (1988) reported *S. polycystum* from coral reefs along the Gulf of Thailand, and *S. crassifolium* and *S. polycystum* from the Andaman Sea. Egerod (1974) collected *S. grevillei* from Koh Ra, Ranong Province, the Andaman Sea on the Fifth Thai–Danish Expedition of 1966. Nateewathana et al. (1981) and Aungtonya and Liao (2002) compiled and updated the extensive checklist, adding *S. crassifolium*, *S. granuliferum* and *S. siliquosum* from the Reference Collection of the Phuket Marine Biological Center (PMBC). Ajisaka and Lewmanomont (2004) reported *S. stolonifolium* from the Andaman Sea. Noiraksar et al. (2006) collected *S. baccularia*, *S. binderi*, *S. oligocystum* and *S. polycystum* from the east coast of the Gulf of Thailand. While there are numerous reports, there are very few detailed studies of *Sargassum* species in the Gulf of Thailand. The object of the present study is to present detailed descriptions and distribution of *Sargassum* species along the Gulf of Thailand.

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Materials and methods

The specimens were collected from the following nine provinces along the Gulf of Thailand: Chon Buri, Rayong, Chanthaburi, Trat (the east coast); Prachuap Khirikhan, Chumphon, Surat Thani, Nakhon Si Thammarat and Songkhla (the west coast) (Fig. 1) between 2001 and 2006. Whole thalli (with holdfasts) were collected during low tide. Specimens from the deeper areas were collected by SCUBA. Some of the collected specimens were fixed in 4% formaldehyde-seawater, and the remainder was dried on herbarium sheets. Important parts of the thallus were drawn, and sections of receptacles were prepared and stained with 1% aniline blue intensified with 1% HCl and mounted on glass slides using 50% glucose syrup (Karo® Syrup, Corn Products™). Identification of specimens were based on the following taxonomic references: C.A. Agardh (1824); J.G. Agardh (1848, 1889); Reinbold (1913); Grunow (1915); Yamada (1925, 1942); Setchell (1935); Pham (1967); Chou and Chiang (1981); Tseng (1983); Yoshida (1988); Trono (1992, 1997); Tseng and Lu (1992, 1995a, b, 1997); Chiang et al. (1992); Noro et al. (1994); Lewmanomont and Ogawa (1995); Phang et al. (1995); Ajisaka et al. (1995a, b, 1997, 1999) and Ajisaka (2002). The specimens from this study

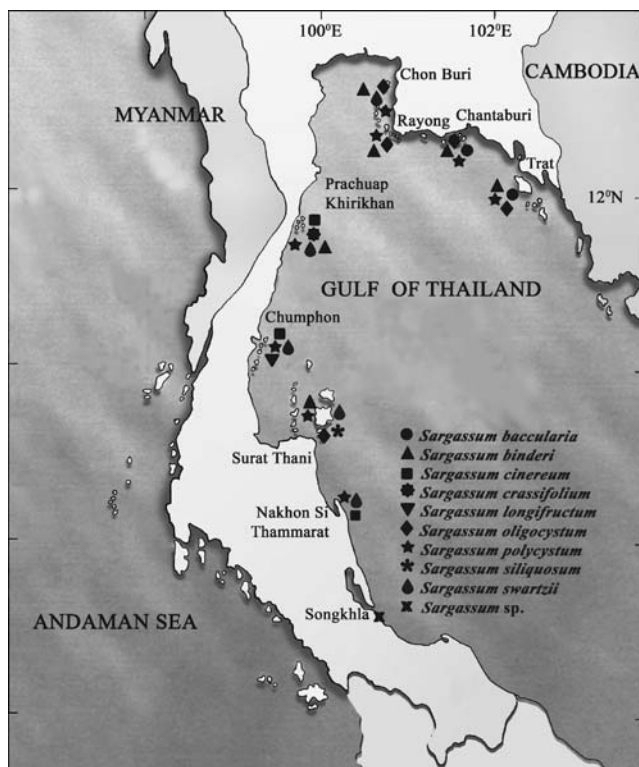


Fig. 1 Study area and distribution of collecting sites for *Sargassum* along the Gulf of Thailand

are deposited at the Bangsaen Institute of Marine Science (BIMS), Burapha University and Kasetsart University Museum of Fisheries (KUMF).

Results

Key to the species of *Sargassum* from the Gulf of Thailand

1. Secondary holdfasts present transformed from stolons; main branches terete, with warts or spines.....*S. polycystum*
1. Secondary holdfasts lacking; main branches terete to flattened, without spines.....2
 2. Primary branches terete; plants dioecious.....3
 2. Primary branches compressed or flattened; plant monoecious.....7
3. Leaves large, up to 5.0–6.5 cm long.....4
3. Leaves small less than 4.5 cm long.....6
 4. Leaves membranous.....*S. cinereum*
 4. Leaves thick, or slightly so.....5
5. Male receptacles short and terete.....*S. siliquosum*
5. Male receptacles long and terete or slightly compressed and sometimes triquetrous at the apices, with dentate margins.....*Sargassum* sp.1
6. Receptacles longer than 20 mm.....*S. longifructum*
6. Receptacles shorter than 20 mm.....*S. baccularia*
7. Receptacles cymosely arranged.....8
7. Receptacles racemosely arranged.....9
 8. Leaves thick, double serrulate at apices.....*S. crassifolium*
 8. Leaves lanceolate to linear lanceolate, margins dentate to slightly entire.....*S. swartzii*
9. Receptacles flattened, often twisted with dentate margins, vesicle stalks flattened.....*S. binderi*
9. Receptacles compressed, not twisted, with apical spines, vesicle stalks terete.....*S. oligocystum*

Description of the species

Sargassum baccularia (Mertens) C.A. Agardh (Fig. 2) Tseng and Lu 1992, p. 16, Fig. 17; Trono 1992, p. 46, Fig. 93; 1997, p. 127; Ajisaka et al. 1999, p. 25, Fig. 2

Holdfast discoid, up to 17 mm in diameter. Stem terete, warty, up to 3 mm in diameter and 1.5 cm long, producing 3–5 spirally arranged primary branches. Primary branches terete, smooth, up to 200 cm long and 2 mm in diameter; leaves large, lanceolate, simple, with asymmetrical bases, up to 45 mm long and 13 mm wide, with rounded to acute

apices, margins dentate with small teeth, midribs distinct near apices, cryptostomata small and scattered to in rows on both sides of the midrib. Secondary branches spirally arranged, terete, smooth, up to 32 cm long and 9 cm in branching interval; leaves lanceolate to linear, simple, with asymmetrical bases, up to 40 mm long and 10 mm wide, with rounded apices, margins dentate with small teeth, midribs distinct near apices, small cryptostomata scattered or in rows on both sides of the midrib (Fig. 2b). Vesicles spherical, sometimes elliptical, up to 4.5 mm long, to 4 mm wide and 3 mm thick, entire at the apices, sometimes mucronate, stalks terete, usually shorter than the vesicles (Fig. 2c).

Plants dioecious. Male receptacles long, terete, up to 10 mm long and 2 mm wide, with smooth surface, simple to

once to twice furcate (Fig. 2d,e). Female receptacles triquetrous, up to 10 mm long and 2 mm wide, with a warty surface, sometimes bearing spines near the apex, simple to furcate (Fig. 2f,g). Male and female receptacles arranged in a raceme, pseudozygocarpic, vesiculate.

Remarks: *Sargassum baccularia* and *S. polycystum* share some morphological characters especially in young plants. We consider that the most important characters to separate the two species are the forms of the vesicles and female receptacles. In *S. baccularia*, the vesicles are spherical to elliptical, and female receptacles are triquetrous, while the vesicles of *S. polycystum* are spherical to obovate, and the female receptacles are terete to slightly compressed.

Fig. 2 *Sargassum baccularia* (Mertens) C.A. Agardh. **a** Habit, **b** leaves, **c** vesicles, **d** male receptacles (arrowhead), **e** transverse section of male receptacle showing male conceptacles (arrowhead), **f** female receptacles (arrowhead), **g** transverse section of female receptacle showing female conceptacles (arrowhead)

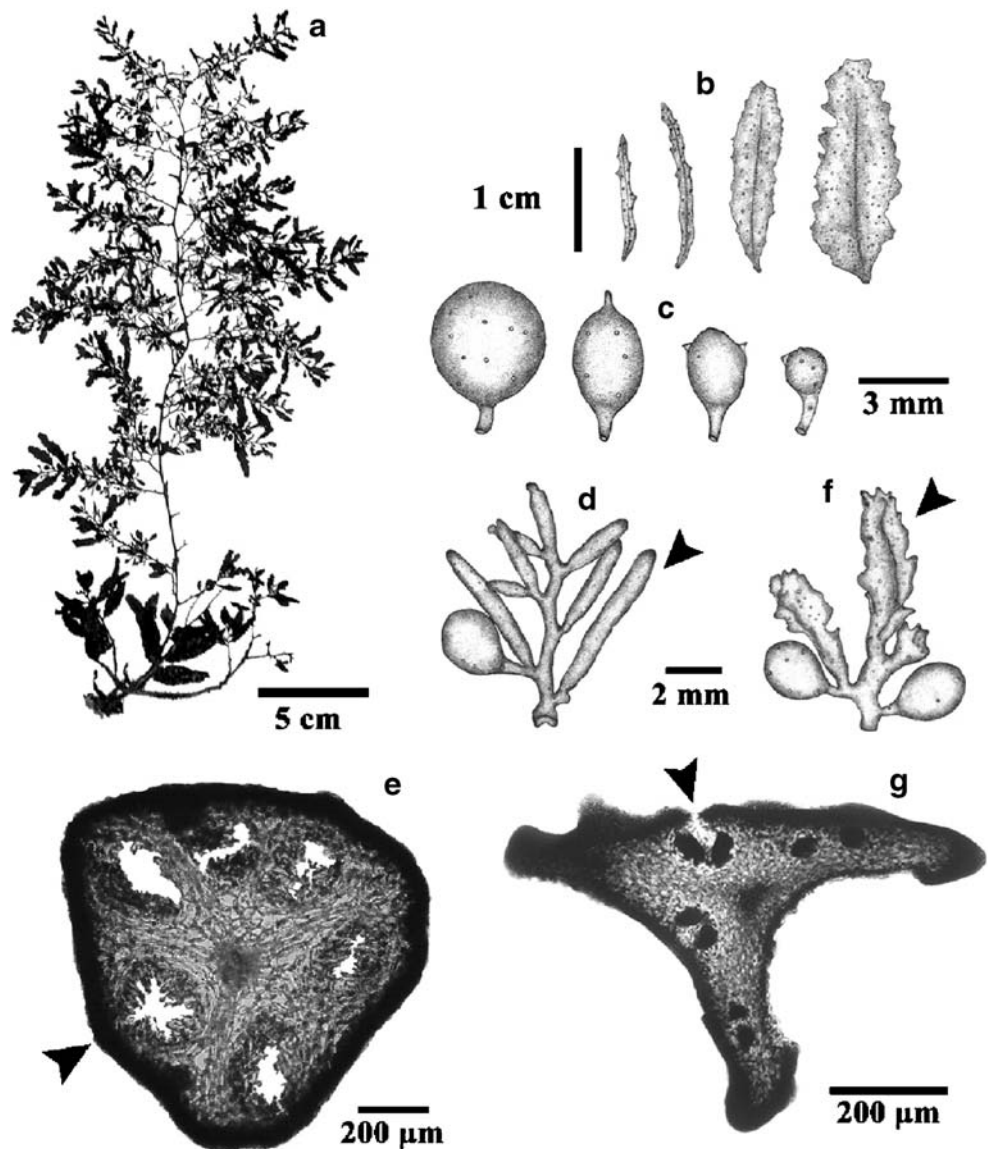
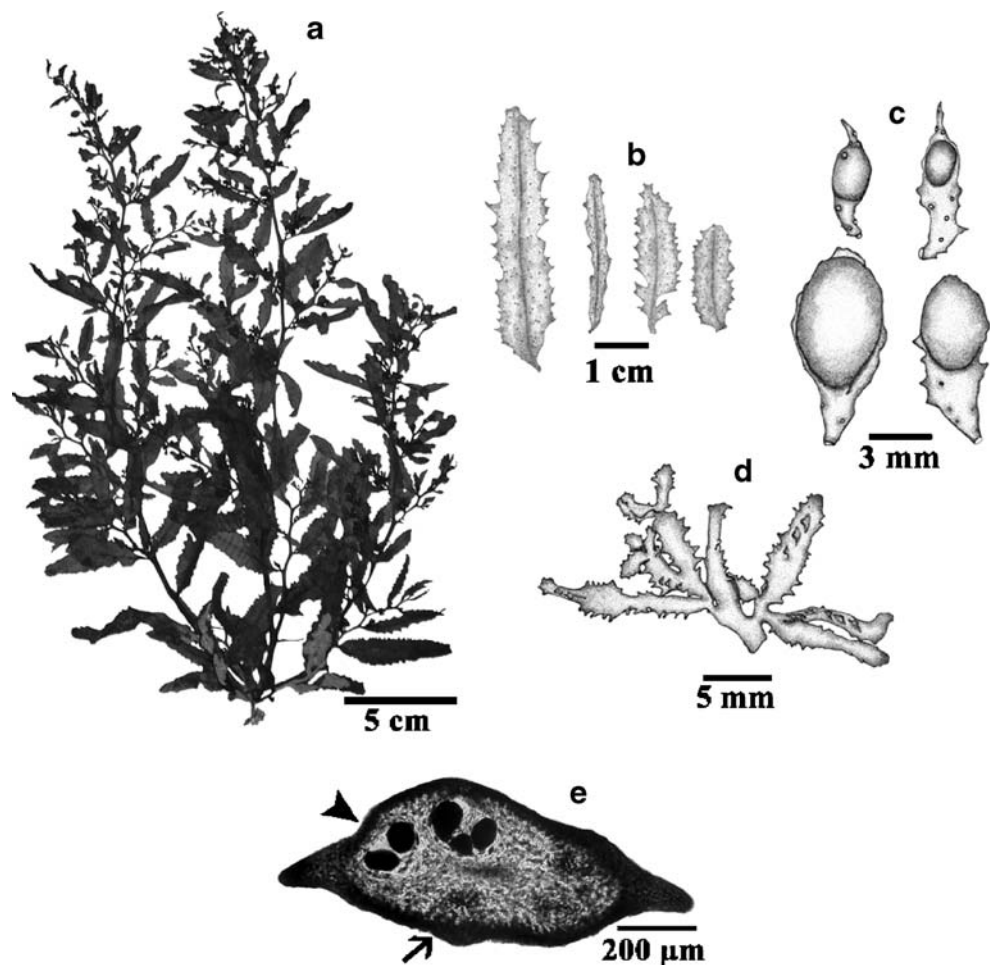


Fig. 3 *Sargassum binderi* Sonder. **a** Habit, **b** leaves, **c** vesicles, **d** androgynous receptacles, **e** transverse section of receptacles showing male conceptacles (arrow) and female conceptacles (arrowhead)



Sargassum binderi Sonder (Fig. 3)

J.G. Agardh 1889, p. 87, Figs. 26–2; Yamada 1925, p. 245; Chou and Chiang 1981, p. 143; Yoshida 1988, p.10; Trono 1992, p. 46, Figs. 1–4, 109; 1997, p. 128, Fig. 86; Tseng and Lu 1995b, p. 96, Fig. 3; Ajisaka et al. 1999, p. 28, Fig. 3

Holdfast discoid, up to 12 mm in diameter. Stem terete, smooth to warty, up to 3 mm in diameter, 1 cm long, producing 6–8 spirally arranged primary branches. Primary branches flattened to compressed, smooth, up to 46 cm long and 5 mm wide; leaves large, lanceolate to slender lanceolate, simple, with asymmetrical bases, up to 77 mm long and 16 mm wide, with rounded to slightly acute apices, margins entire to dentate with small teeth, midribs distinct near apices or vanishing midway, small cryptostomata scattered. Secondary branches distichously arranged, slightly compressed, smooth, up to 40 cm long and 3.8 cm in branching interval; leaves lanceolate to linear, simple with asymmetrical to cuneate bases, up to 64 mm long and 15 mm wide, with rounded to acute apices, margins dentate with sharp teeth, midribs vanishing near apices, small cryptostomata scattered, sometimes arranged in rows on both sides of the midrib (Fig. 3b). Vesicles spherical to

elliptical, up to 10 mm long, to 6 mm wide and 5 mm thick, often mucronate at the apices, sometimes entire, stalks flattened, usually slightly longer than the vesicles (Fig. 3c).

Plants monoecious. Receptacles androgynous, flattened, often twisted, up to 18 mm long and 2 mm wide, sharply dentate at the margin, simple to furcate, racemosely arranged (Fig. 3d,e).

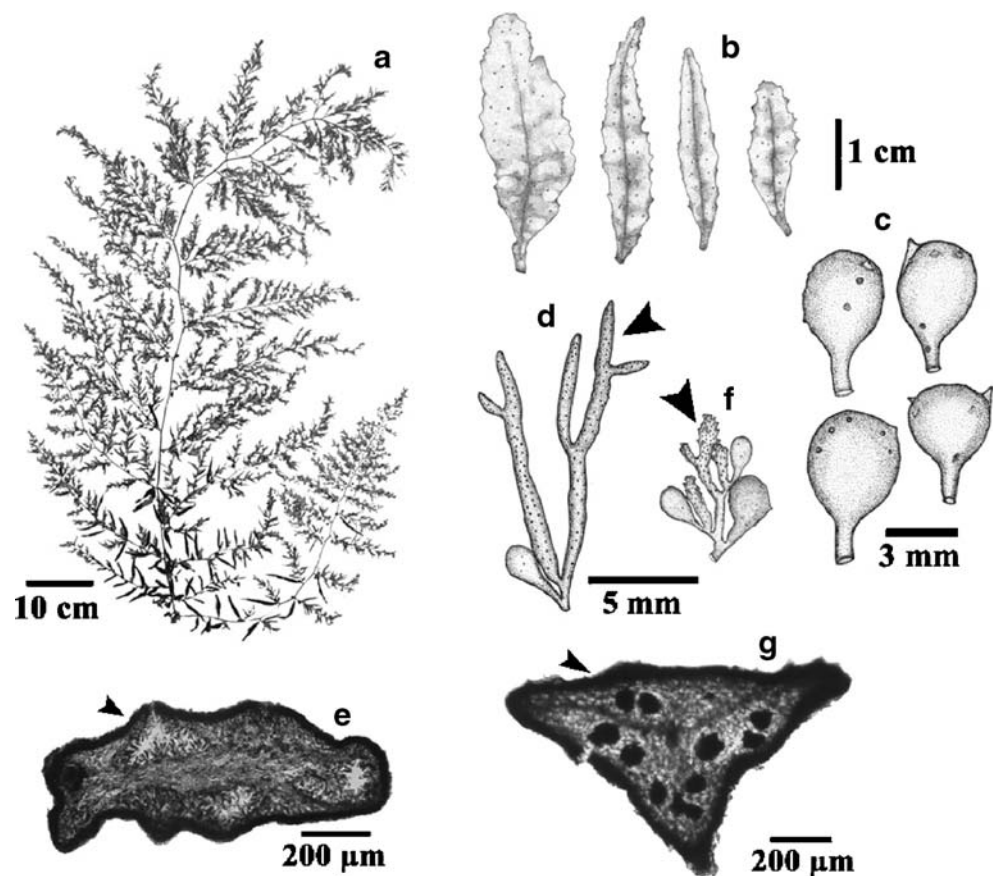
Remarks: *Sargassum binderi* and *S. oligocystum* overlap in many morphological characters, particularly when they are immature. Specimens of *S. binderi* from Thailand are closely related to the specimens from China and Malaysia (Tseng and Lu 1995b; Ajisaka et al. 1999) in the form of their flattened primary branches; spherical to elliptical vesicles which are often mucronate at their apices or sometimes entire, with flattened stalks, and flattened, twisted receptacles, with a sharply dentate margin.

Sargassum cinereum J.G. Agardh (Fig. 4)

Tseng and Lu, 1988, p. 33, Figs. 5, 33; Ajisaka 1999, p. 29, Figs. 3–5, 7

Holdfast discoid, up to 16 mm in diameter. Stem terete, smooth, up to 3 mm in diameter, 10 mm long, producing 4–

Fig. 4 *Sargassum cinereum* J.G. Agardh. **a** Habit, **b** leaves, **c** vesicles, **d** Male receptacles (arrowhead), **e** transverse section of male receptacle showing male conceptacles (arrowhead), **f** female receptacles (arrowhead), **g** transverse section of female receptacle showing female conceptacles (arrowhead)



8 spirally arranged primary branches. Primary branches terete to subterete, smooth, up to 125 cm long and 3 mm in diameter. Leaves membranous, lanceolate to linear lanceolate, simple, with asymmetrical to cuneate bases, up to 65 mm long and 14.7 mm wide, with rounded apices; margins dentate with small teeth, midribs distinct near apices, small cryptostomata scattered to one row or disposed two rows. Secondary branches spirally arranged, terete, smooth, up to 38 cm long and 6 cm in branching interval; leaves lanceolate to linear, simple, with asymmetrical to cuneate bases, up to 48 mm long and 8.9 mm wide, with rounded or sometimes acute apices, margins dentate with small teeth, midribs distinct near apices, small cryptostomata in one row to disposed two rows (Fig. 4b). Vesicles spherical, sometimes obovoid to elliptical, simple, up to 9 mm long, 4.6 mm wide and 4.1 mm thick, entire at the apices, sometimes provided with appendages on one or both sides; stalks terete, sometimes compressed, usually shorter than the vesicles (Fig. 4c).

Plants dioecious. Male receptacles long, terete, up to 18 mm long and 1.1 mm wide, simple to 1–3 times furcate (Fig. 4d,e). Female receptacles normally short compressed and triquetrous, up to 8.3 mm long and 1.5 mm wide, with a warty surface, bearing spines at the apex, simple to once furcate. Male and female receptacles arranged in a raceme, pseudozygocarpic, vesiculate (Fig. 4f,g).

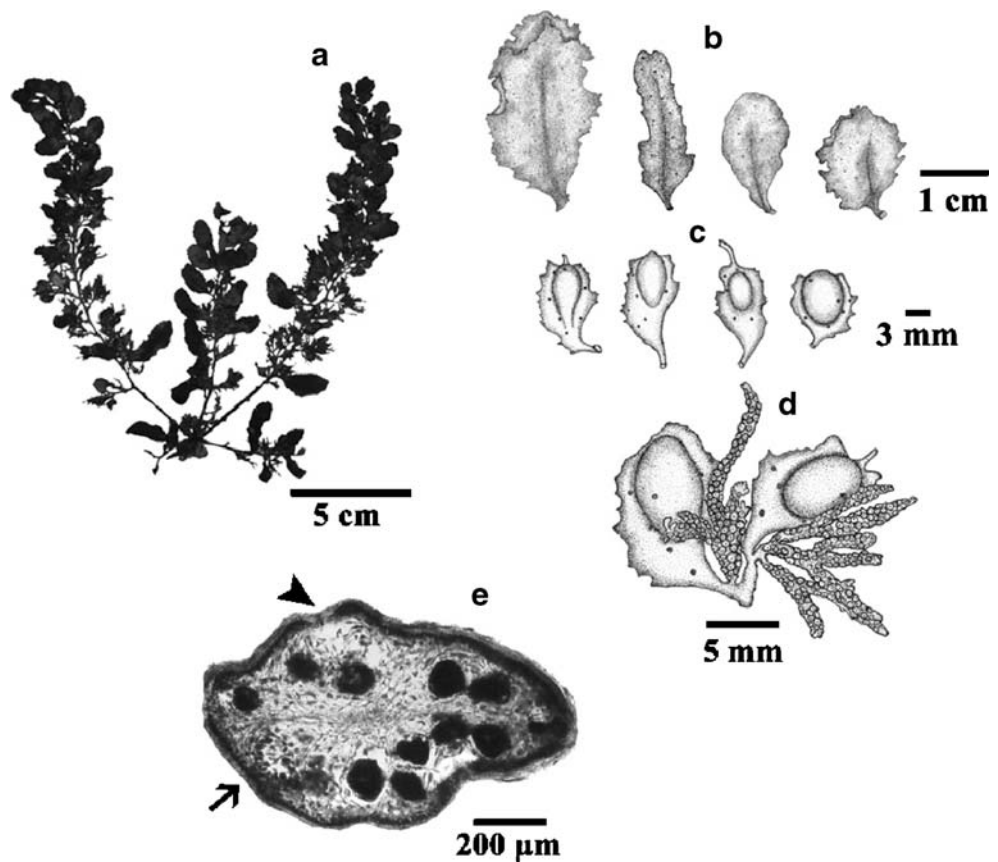
Remark: *Sargassum cinereum* is included in the species group *Cinerea* Setchell in subsection *Pseudozygocarpicae* Setchell (Ajisaka et al. 1995b). Thai specimens of *S. cinereum* closely resemble to the specimens from China (Tseng and Lu 1988) and Malaysia (Ajisaka et al. 1999) in the form of their leaves, which are membranous, lanceolate to linear lanceolate, with asymmetrical to cuneate bases and dentate margins; spherical to elliptical vesicles with entire apices, sometimes provided with an appendage, terete stalks; and female receptacles that are short and triquetrous, with a warty surface and bearing spines at the apex. The morphology of male receptacles of Malaysian specimens resembles Thai specimens in having lengths up to 15–18 mm, but Chinese specimens are only 8–10 mm long. This species is a new record for Thailand.

Sargassum crassifolium J.G. Agardh (Fig. 5)

Trono 1992, p. 50, Figs. 9–11, 112; 1997, p. 131, Figs. 88A–88B; Tseng and Lu, 1997, p. 23, Fig. 14; Ajisaka et al. 1997, p. 34, Fig. 12

Holdfast discoid, up to 17 mm in diameter. Stem terete, smooth, up to 4.6 mm in diameter, 5.3 mm long, producing 4–8 spirally arranged primary branches. Primary branches with slightly compressed in lower parts and slightly terete in upper parts, smooth, up to 29 cm long and 3.8 mm in

Fig. 5 *Sargassum crassifolium* J.G. Agardh. **a** Habit, **b** leaves, **c** vesicles, **d** androgynous receptacles, **e** transverse section of receptacles showing male conceptacles (arrow) and female conceptacles (arrowhead)



diameter. Leaves thick and vertically expanded, large elliptical, elliptical-oval to oblong, simple, with asymmetrical to cuneate bases, up to 32 mm long and 16 mm wide, usually with rounded and double serrulate apices, margins dentate, midribs vanishing midway to distinct near apices, small cryptostomata scattered. Secondary branches alternately arranged, terete, smooth, up to 4.7 cm long and 1.5 cm in branching interval; leaves elliptical-oval, obovate, oblong to lanceolate, simple, with asymmetrical to cuneate bases, up to 19 mm long and 11.3 mm wide, with rounded and double serrulate apices, margins undulate to dentate with small teeth, midribs distinct near apices, small cryptostomata scattered to one row (Fig. 5b). Vesicles spherical, elliptical, ovate to obovoid, simple, up to 8.8 mm long, 7.7 mm wide and 6.4 mm thick, entire or with a pointed end or a short leafy crown at the apices, phyllocysts provided with marginal appendages or wings: stalks with lower part terete and upper part compressed to foliaceous, usually shorter than the vesicles or sometimes longer or equal to the vesicles (Fig. 5c).

Plants monoecious. Receptacles terete in lower part and slightly compressed in upper part, up to 18 mm long and 1.8 mm wide, simple to furcated up to four times, with a warty surface, bearing spines at the apex, arranged in a cymose to compoundly cymose, pseudozygocarpic, vesiculate (Fig. 5d,e).

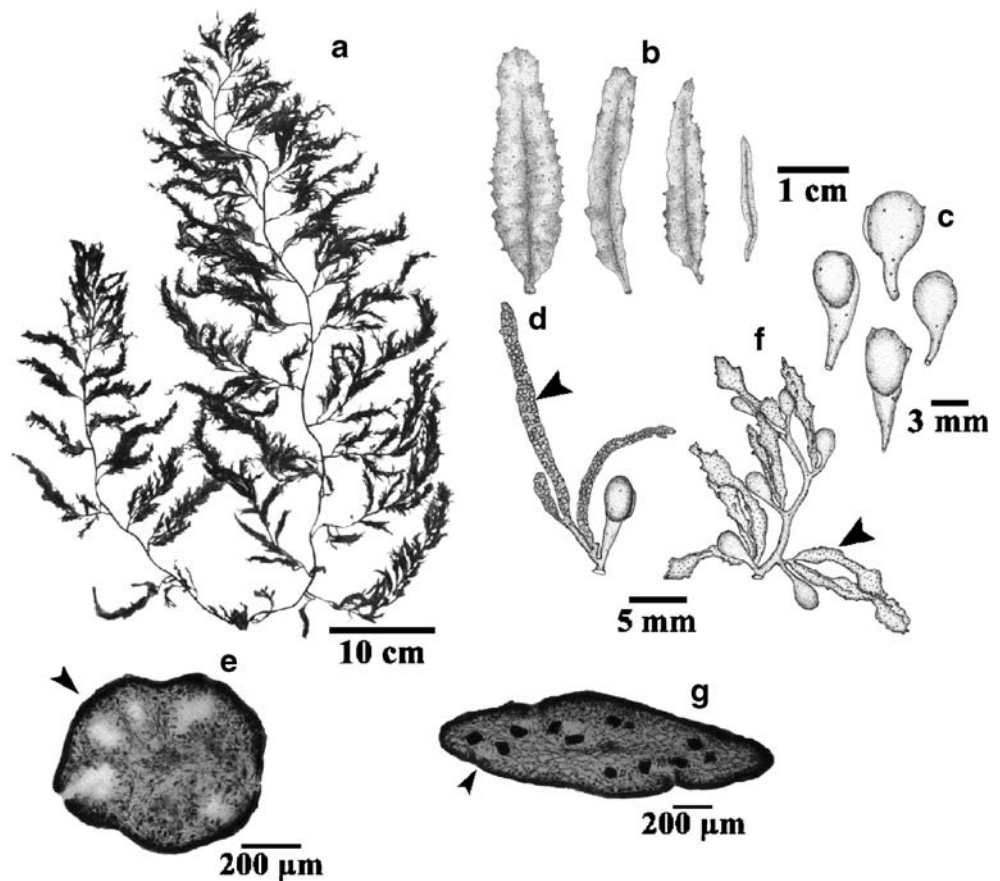
Remarks: *Sargassum crassifolium* has the important distinguishing characters of very thick, vertically expanded, elliptical to oblong hard leaves with blunt apices, sometimes with double serrulate margins; elliptical vesicles, which are entire or with apices pointed or with a short leafy crown leaf, phyllocysts with marginal appendages or wings, stalks with terete lower part and compressed or foliaceous upper part; receptacles with terete lower part and slightly compressed upper part, bearing spines at the apex, arranged in a cymose to compoundly cymose (Trono 1992, 1997; Tseng and Lu 1997; Ajisaka et al. 1997).

Sargassum longifructum Tseng et Lu (Fig. 6)

Tseng and Lu 1988, p. 43, Figs. 10, 25, 26; Ajisaka et al. 1995a, p. 45, Figs. 6–15; Ajisaka et al. 1995b, p. 23, Figs. 11–15

Holdfast discoid, up to 15 mm in diameter. Stem terete, smooth, up to 3.1 mm in diameter, 4.2 mm long, producing 4–9 spirally arranged primary branches. Primary branches terete to subterete, smooth, up to 78 cm long and 3 mm in diameter. Leaves linear-elliptical to linear-lanceolate, simple, with slightly asymmetrical to cuneate bases, up to 32 mm long and 10.9 mm wide, with rounded to acute apices, margins entire to dentate with small teeth, midribs distinct near apices, small cryptostomata scattered. Secondary

Fig. 6 *Sargassum longifructum* Tseng et Lu. **a** Habit, **b** leaves, **c** vesicles, **d** male receptacles (arrowhead), **e** transverse section of male receptacle showing male conceptacles (arrowhead), **f** female receptacles (arrowhead), **g** transverse section of female receptacle showing female conceptacles (arrowhead)



branches spirally arranged, terete, smooth, up to 26 cm long and 5 cm in branching interval; leaves linear-elliptical, linear-lanceolate to linear, simple, with slightly asymmetrical to cuneate bases, up to 31 mm long and 7.6 mm wide, with acute or sometimes rounded apices, margins entire to dentate with small teeth, midribs distinct near apices, small cryptostomata scattered to one row (Fig. 6b). Vesicles slightly spherical, obovoid or elliptical, simple, up to 5.7 mm long, 4.7 mm wide and 3.7 mm thick, entire at the apices, sometimes provided with appendages on one or both sides, stalks terete or sometimes compressed, usually shorter than the vesicles (Fig. 6c).

Plants dioecious. Male receptacles long, terete to slightly compressed and with a few spines at the apex, up to 26 mm long and 1.6 mm wide, simple to forked one to two times (Fig. 6d,e). Female receptacles flattened and sometimes triquetrous, up to 27 mm long and 3.7 mm wide, margins dentate with spines, sometimes twisted, simple to once to twice furcate. Male and female receptacles arranged in a raceme, pseudozygocarpic, vesiculate and leaf (Fig. 6f,g).

Remarks: *Sargassum longifructum* from China, Japan, Vietnam and Thailand display large morphological variations in leaves, vesicles, and receptacles. Leaves varied from elliptical to linear. Vesicles were entire or with winged

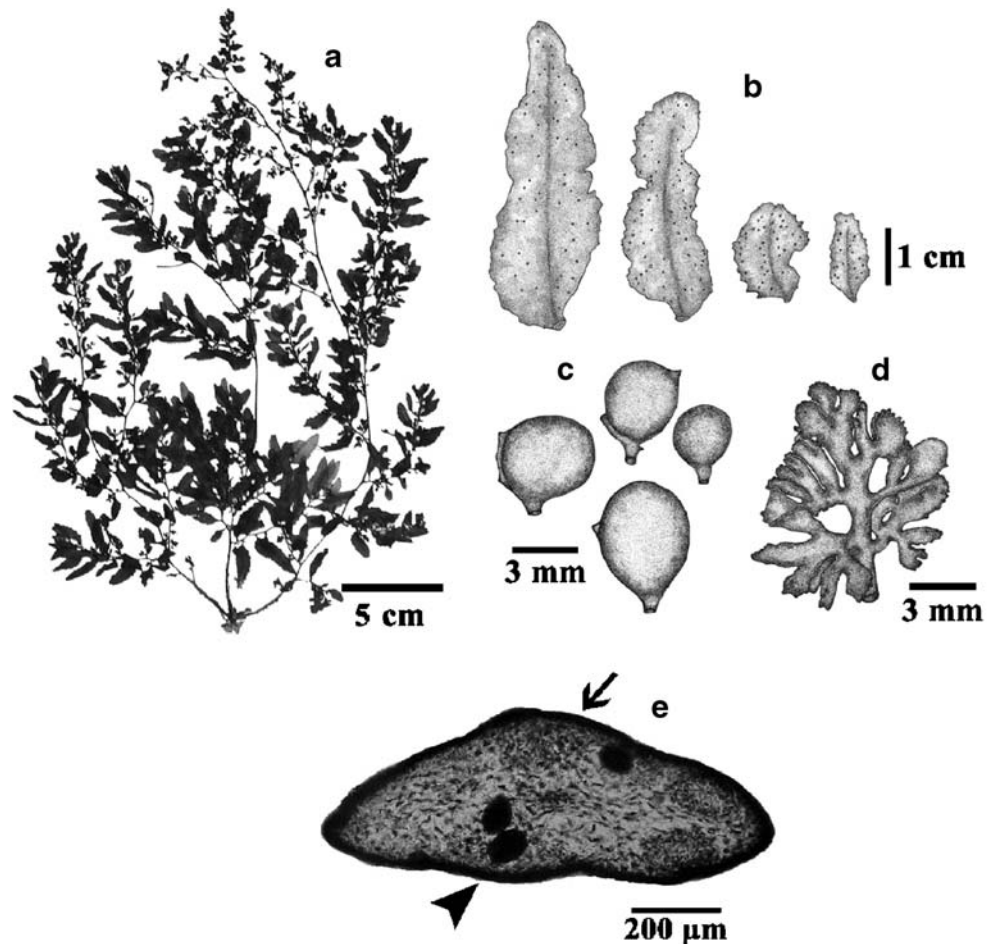
or crowned apices. Male receptacles were terete to compressed, sometimes with spines at the apices. Both male and female receptacles were holozygocarpic or pseudozygocarpic (Tseng and Lu 1988; Ajisaka et al. 1995a, b). This species is difficult to distinguish from *S. cinereum* when the plants are immature, as features of receptacles are important for identification. *Sargassum longifructum* has male receptacles up to 26 mm long and 1.6 mm wide; female receptacles flattened and sometimes triquetrous, up to 27 mm long and 3.7 mm wide. In contrast, *S. cinereum* has male receptacles up to 18 mm long and 1.1 mm wide; female receptacles normally short compressed and triquetrous, up to 8.3 mm long and 1.5 mm wide. This species is a new record for Thailand.

Sargassum oligocystum Montagne (Fig. 7)

Reinhold 1913, p. 156; Grunow 1915, p. 383; Pham 1967, p. 295; Tseng 1983, p. 234, pl. 118, Fig. 1; Noro et al. 1994, p. 27, Fig. 3; Tseng and Lu 1995b, p. 100, Fig. 10; Lewmanomont and Ogawa 1995, p. 83; Ajisaka et al. 1999, p. 34, Fig. 8

Holdfast discoid, up to 12 mm in diameter. Stem terete, smooth, up to 4 mm diameter, 12 mm long, producing 6–8 spirally arranged primary branches. Primary branches

Fig. 7 *Sargassum oligocystum* Montagne. **a** Habit, **b** leaves, **c** vesicles, **d** androgynous receptacles, **e** transverse section of receptacles showing male conceptacles (arrow) and female conceptacles (arrowhead)



flattened to compressed, smooth, up to 49 cm long and 4 mm wide; leaves lanceolate to spatulate, simple, with asymmetrical bases, up to 54 mm long and 18 mm wide, with rounded apices, margins entire to dentate with small teeth, midribs vanishing to distinct near apices, small cryptostomata scattered. Secondary branches distichously arranged, terete to slightly compressed, smooth, up to 19 cm long and 5.3 cm in branching interval; leaves lanceolate to spatulate, simple, with asymmetrical bases, up to 34 mm long and 10 mm wide, with rounded apices, margins entire to dentate with small teeth, midribs vanishing near apices, small cryptostomata scattered (Fig. 7b). Vesicles spherical to elliptical, up to 4 mm long, 4 mm wide and 3 mm thick, entire at the apices, sometimes provided with appendages, stalks terete, usually shorter than the vesicles (Fig. 7c).

Plants monoecious. Receptacles androgynous, slightly compressed, up to 9 mm long and 3 mm wide, warty or with a few marginal spines, simple to furcate two or three times, racemosely arranged, pseudozygocarpic, vesiculate (Fig. 7d,e).

Remarks: *Sargassum oligocystum* from Thailand closely resembles the specimens from Malaysia (Ajisaka et al. 1999) in the form of their compressed primary branches;

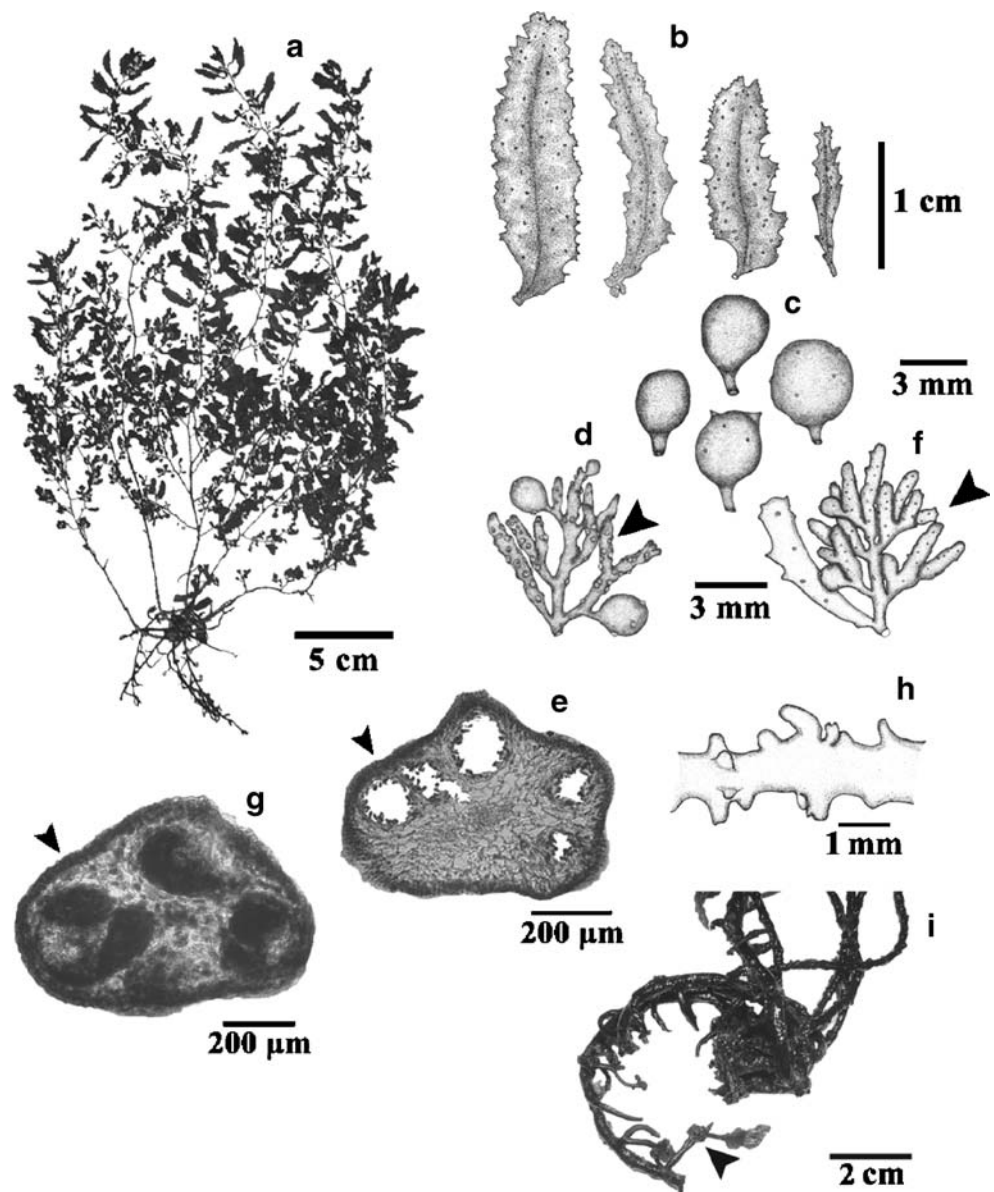
spherical to elliptical vesicles with entire apices, sometimes with small appendages on one side or both sides, terete stalks; slightly compressed receptacles that are warty or have a few spines at the margin. Our specimens differ from those of China (Tseng and Lu 1995b) and the Philippines (Trono 1992; Noro et al. 1994) in having flattened primary branches, and plants are dioecious.

Sargassum polycystum C.A. Agardh (Fig. 8)

Chiang et al. 1992, p. 36, Figs. 1–12; Trono 1992, p. 63; 1997, p. 147, Fig. 96; Ajisaka et al. 1995b, p. 34, Figs. 19–20; Lewmanomont and Ogawa 1995, p. 84; Ajisaka et al. 1999, p. 36, Fig. 6

Holdfast discoid, up to 13 mm in diameter. Stem terete, warty, up to 3 mm in diameter and 4 mm long, bearing up to 5 stolons and 7–9 spirally arranged primary branches. Stolons terete to slightly compressed at their proximal parts, up to 12 cm long and 2 mm wide. Primary branches usually muricate with prolifically branched spines (Fig. 8h), transformed into a stolon and secondary holdfasts (Fig. 8i), up to 200 cm long and 2 mm in diameter; leaves elliptical, lanceolate to linear, simple, with asymmetrical to cuneate

Fig. 8 *Sargassum polycystum* C.A. Agardh. **a** Habit, **b** leaves, **c** vesicles, **d** male receptacles (arrowhead), **e** transverse section of male receptacle showing male conceptacles (arrowhead), **f** female receptacles (arrowhead), **g** transverse section of female receptacle showing female conceptacles (arrowhead), **h** spines on primary branch, **i** secondary holdfast (arrowhead)

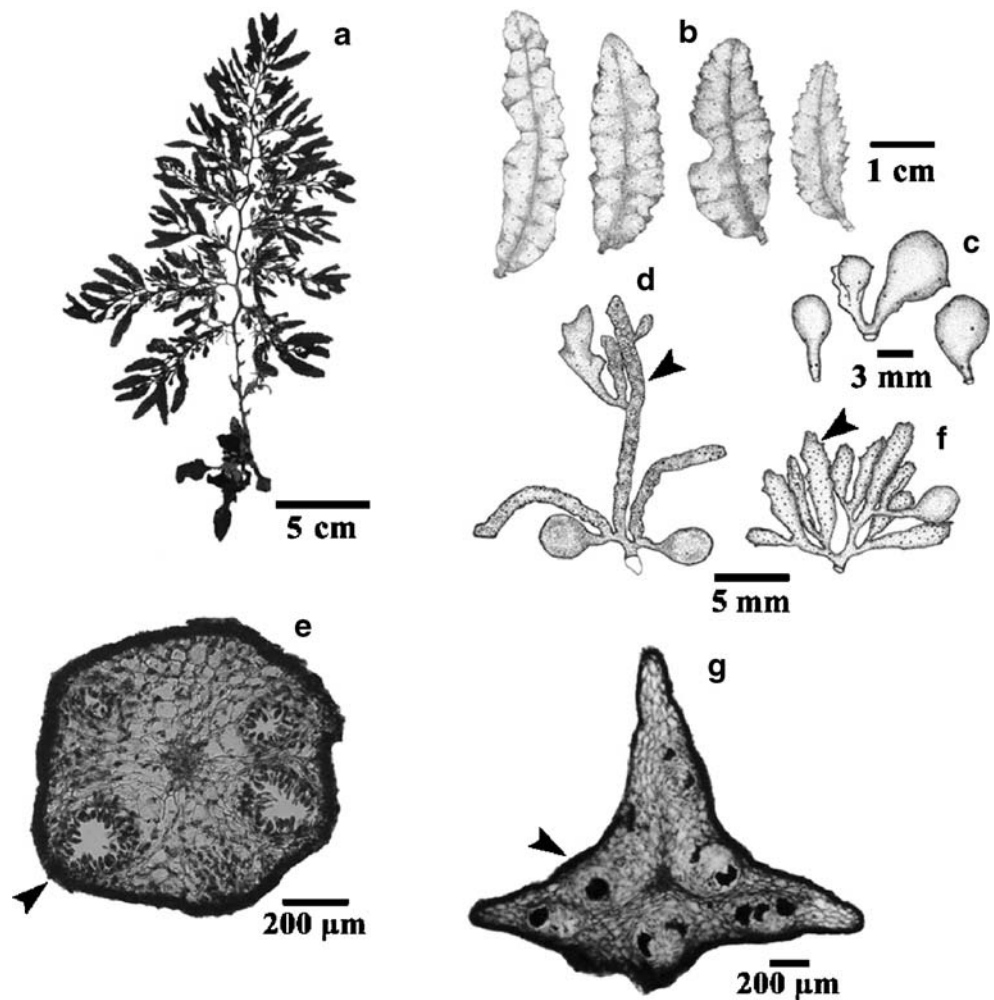


bases, up to 45 mm long and 13 mm wide, with rounded to acute apices, margins dentate with coarse teeth, midribs vanishing to distinct near apices, cryptostomata small and scattered to in rows on both sides of the midrib. Secondary branches spirally arranged, terete, crowded with spines, up to 60 cm long and 16 cm in branching interval; leaves linear-lanceolate to spatulate, simple, asymmetrical with cuneate bases, up to 30 mm long and 7 mm wide, with rounded to acute apices, margins dentate with coarse teeth, midribs vanishing to distinct near apices, small cryptostomata scattered to arranged in rows on both sides of the midrib (Fig. 8b). Vesicles spherical to obovate, to 8 mm long, 6 mm wide and 5 mm thick, entire at the apices or with ear-like wings on both sides of the vesicles, stalks terete, usually shorter than the vesicles (Fig. 8c).

Plants dioecious. Male receptacles long, terete, up to 15 mm long and 1 mm wide, with a warty surface, simple to once furcate (Fig. 8d,e). Female receptacles terete to slightly compressed, up to 4 mm long and 1 mm wide, with a warty surface, simple to once furcate (Fig. 8f,g). Male and female receptacles arranged in a raceme, halozygocarpic and vesiculate.

Remarks: *Sargassum polycystum* is different from *S. baccularia* in having secondary holdfasts transformed from the stolon and heavily muricate on main branches (Chiang et al. 1992; Ajisaka et al. 1995b, 1999). From our observations, some specimens of *S. polycystum* have no secondary holdfasts and some have scattered or absent spines on primary branches, which make them similar to *S. baccularia* when growing together these two species are not easily distinguished.

Fig. 9 *Sargassum siliquosum* J.G. Agardh. **a** Habit, **b** leaves, **c** vesicles, **d** male receptacles (arrowhead), **e** transverse section of male receptacle showing male conceptacles (arrowhead), **f** female receptacles (arrowhead), **g** transverse section of female receptacle showing female conceptacles (arrowhead)



Sargassum siliquosum J.G. Agardh (Fig. 9)

Tseng and Lu 1992, p. 20 Figs. 4, 20; Trono 1992, p. 65 Fig. 97; Phang et al. 1995, p. 55, Figs. 1–8; Trono 1997, p. 149

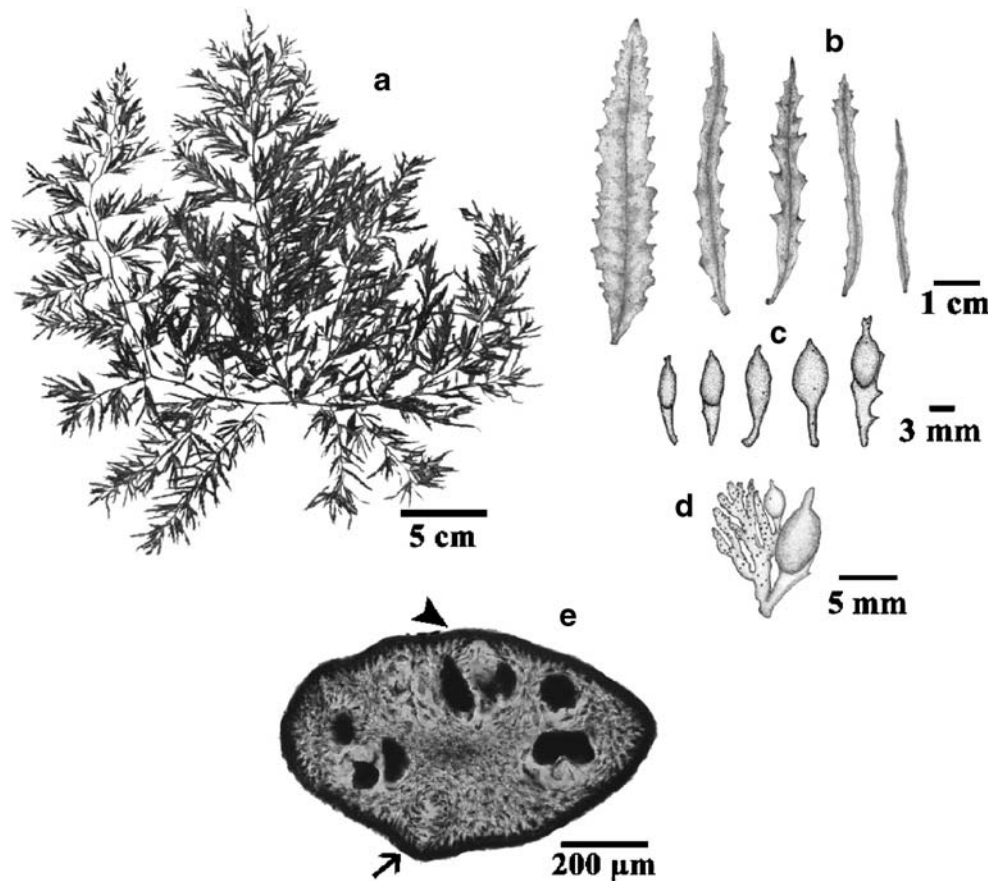
Holdfast discoid, up to 16 mm in diameter. Stem terete, smooth, sometimes warty, up to 5.3 mm in diameter and 16 mm long, producing 5–9 spirally arranged primary branches. Primary branches terete, smooth, up to 80 cm long and 3.9 mm in diameter; leaves broad lanceolate, thick, simple, with asymmetrical to cuneate bases, up to 55 mm long and 18 mm wide, with rounded blunt apices, margins entire to dentate with small teeth and wavy leaf edge, sometimes unequal leaf blades on both sides of the midrib, midribs distinct near apices, cryptostomata small and scattered. Secondary branches alternately arranged, terete, smooth, up to 37 cm long and 3.9 cm in branching interval; leaves lanceolate to oblong, simple, asymmetrical with cuneate bases, up to 39 mm long and 12.6 mm wide, with rounded apices, margins dentate with small teeth, midribs distinct near apices, cryptostomata small and scattered (Fig. 9b). Vesicles sub-spherical to obovoid, simple,

sometimes in pairs, up to 7.4 mm long, 5.8 mm wide and 5.6 mm thick, entire at the apices, sometimes mucronate, stalks terete, sometimes compressed, usually shorter than the vesicles, sometimes as long as the vesicles (Fig. 9c).

Plants dioecious. Male receptacles long, terete, sometimes slightly compressed and triquetrous in the upper part, with small spines at the apices and margins, terete in the lower part, up to 20 mm long and 1 mm wide, simple to once to twice furcate (Fig. 9d,e). Female receptacles triquetrous, up to 11 mm long and 2 mm wide, with a warty surface, bearing spines at the apex, simple to once furcate. Male and female receptacles arranged in a raceme, pseudozygocarpic with vesicles and leaves sometimes halozygocarpic (Fig. 9f,g).

Remark: *Sargassum siliquosum* occurred only in Surat Thani Province. Thai specimens closely resemble specimens from China, Malaysia and Singapore (Tseng and Lu 1992; Phang et al. 1995) in important features such as terete primary branches; lanceolate leaves with asymmetrical bases and rounded apices, vesicles that are solitary or paired, obovoid to subspherical, entire at the apices with

Fig. 10 *Sargassum swartzii* (Turner) C.A. Agardh. **a** Habit, **b** leaves, **c** vesicles, **d** androgynous receptacles, **e** transverse section of receptacles showing male conceptacles (arrow) and female conceptacles (arrowhead)



terete stalks, and receptacles arranged in a raceme. The Thai specimens slightly differ from those from the Philippines (Trono 1992, 1997) in having terete to slightly compressed primary and secondary branches; leaves of plants with more variation, and female receptacles are twisted.

Sargassum swartzii (Turner) C.A. Agardh (Fig. 10) C.A. Agardh 1824, p. 296; J.G. Agardh 1848, p. 328; 1889, p. 85, pl. 26.1; Reinbold 1913, p. 157; Grunow 1915, p. 381; Setchell 1935, p. 3, pl. 1; Yamada 1942, p. 25, Fig. 1; Pham 1967, p. 293, Fig. 13; Tseng 1983, p. 238, pl. 120, Fig. 1; Noro et al. 1994, p. 27, Figs. 4, 9; Tseng and Lu 1995a, p. 79, Fig. 10; Ajisaka 2002, p. 82, Figs. 12–15

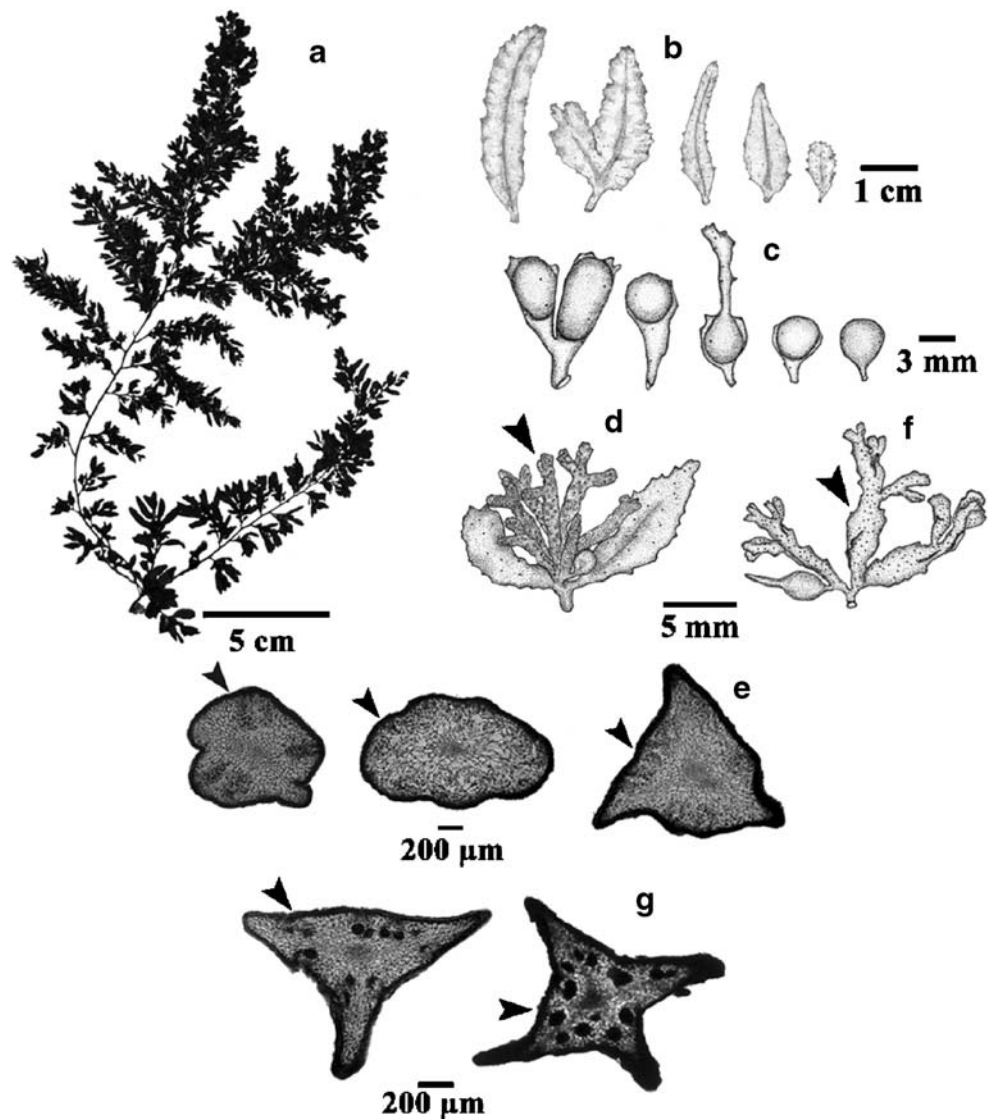
Holdfast discoid, up to 17 mm in diameter. Stem terete, smooth, up to 3.9 mm in diameter and 7.3 mm long, producing 4–8 spirally arranged primary branches. Primary branches compressed, smooth, up to 140 cm long and 5.9 mm wide. Leaves elongated lanceolate to linear lanceolate, simple, with asymmetrical bases, up to 80 mm long and 11 mm wide, usually with acute (or sometimes obtuse) at apices, margins dentate with small teeth, midribs distinct near apices, cryptostomata small and scattered to one row. Secondary branches distichously arranged, compressed, smooth, up to 63 cm long and 8.4 cm in branching interval;

leaves linear lanceolate, simple, with asymmetrical to cuneate bases, up to 74 mm long and 9 mm wide, with acute apices, margins slightly entire to dentate with small teeth, midribs vanishing to distinct near apices, small cryptostomata arranged in one row (Fig. 10b). Vesicles elliptical, simple, up to 10 mm long, 6.4 mm wide and 5.3 mm thick, apex pointed or with a short leafy crown, margins entire, stalks terete to slightly compressed or terete in the lower part and compressed in the upper part, usually shorter than the vesicles or sometimes longer (Fig. 10c).

Plants monoecious. Receptacles slightly terete, up to 16 mm long and 2.1 mm wide, simple to furcate 2–5 times, bearing spines at the apex, arranged in a cymose to compound cymose, pseudozygocarpic, vesiculate (Fig. 10d,e).

Remarks: Thai specimens of *S. swartzii* closely resemble those from China (Tseng and Lu 1995a, b) and Malaysia (Ajisaka 2002) in having leaves that are lanceolate to linear lanceolate and acute at the apices, vesicles that are elliptical, pointed at the apex, with entire margins and terete stalks, and compressed receptacles. Thai specimens distinctly differ from those of Australia (Noro et al. 1994) which have linear leaves; subspherical vesicles, and terete receptacles. *Sargassum swartzii* shows some resemblance to *S. binderi* and *S. oligocystum*, but can be distinguished

Fig. 11 *Sargassum* sp. **a** Habit, **b** leaves, **c** vesicles, **d** male receptacles (*arrowhead*), **e** transverse section of male receptacle showing male conceptacles (*arrowhead*), **f** female receptacles (*arrowhead*), **g** transverse section of female receptacle showing female conceptacles (*arrowhead*)



from those species by their slender leaves with shallow dentate to entire margins; small vesicles with terete stalks and entire margins; and receptacles arranged in a cymose. This species is also a new record for Thailand.

Sargassum sp. (Fig. 11)

Holdfast discoid, up to 13 mm in diameter. Stem terete, smooth, sometimes warty, up to 2.9 mm in diameter, 7.2 mm long, producing 3–14 spirally arranged primary branches. Primary branches terete, smooth, up to 54 cm long and 2.2 mm in diameter; leaves rather short, lanceolate to oblanceolate, simple, sometimes furcate with asymmetrical bases, up to 54 mm long and 10 mm wide, with rounded apices, margins dentate with small teeth, midribs distinct near apices, small cryptostomata scattered and arranged in one or two rows. Secondary branches alternately arranged (or in immature plants arranged alternately

in the lower part and spirally in the upper part), terete, smooth, up to 18 cm long and 2.4 cm in branching interval; leaves lanceolate, linear lanceolate to oblanceolate, simple, sometimes furcate with asymmetrical bases, up to 29 mm long and 7 mm wide, with rounded to slightly rounded or acute apices, margins dentate with small teeth, midribs distinct near apices, cryptostomata small and arranged in one or two rows (Fig. 11b). Vesicles spherical, sometimes obovoid or elliptical, simple, sometimes in pairs, up to 6.7 mm long, 4.3 mm wide and 4.3 mm thick, entire at the apices, sometimes mucronate or with a leafy crown at the apex, up to 5.8 mm long and 1.24 mm wide, stalks terete, sometimes compressed, usually shorter than the vesicles, sometimes longer (Fig. 11c).

Plants dioecious. Male receptacles long, terete, sometimes slightly compressed and triquetrous at the upper part, with small spines at the apices and margins, and terete in the lower part, up to 14 mm long and 1.5 mm wide, simple

Table 1 Comparison of ten species of Thai *Sargassum* in the Gulf of Thailand

Character	Species	<i>S. baccularia</i>	<i>S. hinderi</i>	<i>S. cinereum</i>	<i>S. crassifolium</i>	<i>S. longifructum</i>	<i>S. oligocystum</i>	<i>S. polycystum</i>	<i>S. siliquosum</i>	<i>S. swartzii</i>	<i>Sargassum</i> sp.
Holdfast Stem	Discoid		Discoid	Discoid	Discoid	Discoid	Discoid	Discoid	Discoid	Discoid	Discoid
	Terete, warty	Terete, smooth to warty	Terete, smooth	Terete, smooth	Terete, smooth	Terete, smooth	Terete, smooth	Terete, warty	Terete, smooth	Terete, smooth	Terete, smooth to warty
Primary branch	Terete, smooth	Flattened to compressed, smooth	Terete to subterete, smooth	Compressed to terete, smooth	Terete to subterete, smooth	Terete to subterete, smooth	Flattened to compressed, smooth	Terete, muricate with prolifically branched spines, transformed into stolon and secondary holdfast	Terete, smooth	Compressed, smooth	Terete, smooth
	Terete, smooth	Slightly compressed, smooth	Terete, smooth	Terete, smooth	Terete, smooth	Terete, smooth	Terete to slightly compressed, smooth	Terete, crowded with spines	Terete, smooth	Compressed, smooth	Terete, smooth
Leaves	Primary leaves	Lanceolate to linear, asymmetrical bases, rounded apices, margins dentate, midribs distinct near apices, cryptostomata scattered or in rows on both sides of the midrib	Lanceolate to slender lanceolate, asymmetrical bases, rounded to slightly acute apices, margins entire to dentate, midribs distinct near apices or vanishing midway, cryptostomata scattered	Membranous, lanceolate to linear lanceolate, asymmetrical to cuneate bases, rounded apices, margins dentate, midribs distinct near apices, cryptostomata scattered or two rows	Thick, elliptical to oblong, asymmetrical to cuneate bases, rounded and double serrulate apices, margins dentate, midribs vanishing midway to distinct near apices, cryptostomata scattered	Linear-elliptical to linear-lanceolate, asymmetrical to cuneate bases, rounded to acute apices, margins entire to dentate, midribs distinct near apices, cryptostomata scattered	Lanceolate to spatulate, asymmetrical bases, rounded apices, margins entire to dentate, midribs distinct, vanishing near apices, cryptostomata scattered	Elliptical, lanceolate to linear, asymmetrical to cuneate bases, with rounded to acute apices, margins dentate, midribs distinct, vanishing near apices, cryptostomata scattered to arranged in rows on both sides of the midrib	Thick, lanceolate, asymmetrical to cuneate bases, rounded blunt apices, margins entire to dentate, wavy leaf edge, sometimes unequal leaf blades on both sides of the midrib, midribs distinct near apices, cryptostomata scattered	Elongated lanceolate to linear-lanceolate, asymmetrical bases, acute or sometimes obtuse apices, margins dentate, midribs distinct near apices, cryptostomata scattered to in one row	Lanceolate, oblanceolate or sometimes furcated, asymmetrical bases, rounded apices, margins dentate, midribs distinct near apices, cryptostomata scattered or two rows
	Secondary leaves	Lanceolate to linear, asymmetrical bases, rounded apices, margins dentate, midribs distinct near apices, cryptostomata scattered or in rows on both sides of the midrib	Lanceolate to linear, asymmetrical to cuneate bases, rounded to acute apices, margins dentate, midribs vanishing near apices, cryptostomata scattered, sometimes arranged in rows on both sides of the midrib	Lanceolate to linear, asymmetrical to cuneate bases, rounded or sometimes acute apices, margins dentate, midribs distinct near apices, cryptostomata scattered	Elliptical-oval, lanceolate to oblong, asymmetrical to cuneate bases, rounded and double serrulate apices, margins undulate to dentate, midribs distinct near apices, cryptostomata scattered to one row	Linear-elliptical to linear, asymmetrical to cuneate bases, acute or sometimes rounded apices, margins dentate to entire, midribs distinct near apices, cryptostomata scattered to one row	Linear-elliptical to linear, asymmetrical to cuneate bases, rounded apices, margins entire to dentate, midribs vanishing near apices, cryptostomata scattered	Lanceolate to spatulate, asymmetrical bases, rounded apices, margins entire to dentate, midribs vanishing near apices, cryptostomata scattered	Linear-lanceolate to spatulate, asymmetrical to acunete bases, rounded to acute apices, margins dentate, midribs distinct, vanishing near apices, cryptostomata scattered to arranged in rows on both sides of the midrib	Lanceolate to oblong, asymmetrical to cuneate bases, rounded apices, margins dentate, midribs distinct near apices, cryptostomata scattered	Linear lanceolate, asymmetrical to cuneate bases, acute apices, margins dentate to entire, midribs distinct near apices, cryptostomata arranged in one row

Vesicles	Spherical to elliptical	Spherical to elliptical	Slightly spherical, obovoid or elliptical	Spherical to elliptical	Spherical to obovate	Sub-spherical to obovoid, simple to sometimes in pair	Elliptical	Spherical, obovoid or elliptical
Receptacle	Flattened, often twisted	Terete to slightly compressed	Long, terete to slightly compressed	Slightly compressed, warty to few spines at the margin, simple to furcate two or three times	Long, terete, warty surface, simple to once furcate	Long, terete, sometimes slightly compressed and triquetrous	Slightly terete, small spines at the apices and margins	Long, terete, sometimes slightly compressed and triquetrous at the upper part
Monococious								
Dioecious								
Male	Long, terete, simple to once to twice furcate	Long, terete	Long, terete to slightly compressed					Short triquetrous
Female	Triquetrous, simple to furcate	Short compressed and triquetrous	Flattened and sometimes triquetrous		Terete to slightly compressed, warty surface, simple to once furcate	Triquetrous, simple to once furcate		

to furcate once to twice (Fig. 11d,e). Female receptacles generally short triquetrous, up to 7 mm long and 2 mm wide, with a warty surface, bearing spines at the apex, simple to furcate three times. Male and female receptacles arranged in a raceme, pseudozygocarpic, vesiculate, sometimes halozygocarpic (Figure 11f,g).

Remarks: *Sargassum* sp. was found only in Songkhla Province. This unidentified species has many unique important characters that make identification difficult, including the the form of their leaves found at primary and secondary branches, which are rather short and lanceolate to furcated. Male receptacles are terete, sometimes slightly compressed and triquetrous at the upper part. Female receptacles of *Sargassum* sp. closely resemble those of *S. baccularia*. In *Sargassum* sp. female receptacles are short, triquetrous, up 7 mm long and 2 mm wide, while those of *S. baccularia* are triquetrous, up 10 mm long and 2 mm wide. Male and female receptacles of *Sargassum* sp. are arranged in a raceme, and are zygocarpic.

Discussion

In this study, ten species of *Sargassum* are reported from the Gulf of Thailand, three of which are new records for Thailand. Five species belong to the section Zygozarpicea (J.G.. Agardh) Setchell. The most common species was *S. polycystum* distributed widely in almost all of the study sites. *Sargassum crassifolium*, *S. siliquosum* and *S. swartzii* were the few found with zygozarpic receptacles. However, this is minor characteristic for identification. Morphological characters are summarized for these ten species of Thai *Sargassum* in Table 1.

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