

Taxonomic Study of Six *Sargassum* Species (Sargassaceae, Fucales) with Compressed Primary Branches in the Persian Gulf and Oman Sea Including *S. binderi* Sonder a New Record Species for Algal Flora, Iran

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Abstract

Six species of *Sargassum* C. Agardh (Sargassaceae) with compressed primary branches, including: *S. binderi* Sonder, *S. aquifolium* (Turner) C. Agardh, *S. oligocystum* Montagne, *S. swartzii* (Turner) C. Agardh, *S. crassifolium* J. Agardh and *S. cristaefolium* C. A. Agardh, were identified in the Persian Gulf and Oman Sea coasts, among which *S. binderi* is reported as newly recorded species in Iran for the first time. The specimens were collected from 15 stations along the Iranian southern shores in the autumn, winter and spring from 2010 to 2012. Anatomical and morphological studies were performed according to the valid identification keys. In taxonomy studies, 47 quantitative and qualitative morphological characters were selected. In order to analyze of data, clustering analysis was performed by UPGMA and PCA analyses. The results revealed that there were more qualitative than quantitative traits in species identification. The shape of receptacles, leaves, vesicles and stems were the most diagnostic characteristics in the species identification. The species including: *S. binderi*, *S. crassifolium* and *S. cristaefolium* have flattened triangular receptacles; while *S. crassifolium* and *S. cristaefolium* have duplicated leaves with fine teeth; *S. swartzii* has linear lanceolate leaves, pointed or crowned vesicles and *S. oligocystum* has broader lanceolate leaves with an acute to rounded apex, and often entire and spherical vesicles. *S. oligocystum* and *S. crassifolium* belong to the section *Acanthocarpicae*. Also, *S. cristaefolium* belongs to section *Sargassum* and *S. binderi*, *S. aquifolium* and *S. swartzii* belong to section *Binderianeae*.

Keywords: *Sargassum*; Persian Gulf and Oman Sea; Phaeophyta; Compressed branches; Iran.

Introduction

Sargassum C. Agardh represents the most species

rich genus of marine macroalgae in tropical regions [1] and morphologically, it is among the most complex phaeophyceae genera. Some species are economically

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important, especially in Asian countries where they are commonly used as food (soup and salad), liquid fertilizer and animal feeds. In addition, fucoidans extracted from the cell wall were discovered to have antitumor [2] and cytotoxic activities [3]. Here we focus on the six species of *Sargassum* with compressed primary branches in the Persian Gulf and Oman Sea. The Persian Gulf is a shallow sea, which experiences very high annual variation in seawater temperature. These extreme physical conditions impose stress on the scleractinian corals [4], which results in severe competition for space and light with *Sargassum*. Despite their ecological importance there have been studies focusing on the morphological and alginate extraction of *Sargassum* in the Persian Gulf and Oman Sea [5, 6, 7]. This can at least partly be attributed to the complex systematics of the genus, which is characterized by considerable morphological plasticity and the hundreds of species and intraspecific names which have been used [8]. Previous phycological studies in Persian Gulf were compiled by several authors [6, 7, 8, 9], and more ecologically oriented research was conducted by Sheppard *et al.* (1992) [4]. In addition, Sohrabipour & Rabii (1999) have identified 6 *Sargassum* species in this area [10]; while Gharanjik (2005) reported five *Sargassum* species in Sistan and Baluchestan coasts (Oman sea) in the southeast of Iran [11]. Recently, Shams *et al.* (2013) reported 19 *Sargassum* species in Persian Gulf and Oman Sea [12]. In this paper, we

described six *Sargassum* species with compressed primary branches, including: *S. binderi* Sonder, *S. aquifolium* (Turner) C. Agardh, *S. oligocystum* Montagne, *S. swartzii* (Turner) C. Agardh, *S. crassifolium* J. Agardh and *S. cristaefolium* C. A. Agardh and their clear distinguishable characters.

Materials and Methods

The specimens were collected from 15 localities ranging from Sistan and Baluchestan Province (between $25^{\circ} 03'$ and $31^{\circ} 28' N$; between $58^{\circ} 47'$ and $63^{\circ} 19' E$) to Bushehr Province (between $28^{\circ} 52' N$ and $50^{\circ} 44' E$) along the Iranian shores of the Persian Gulf and Oman Sea from December (2010- 2012), January (2010, 2011) and May (2010-2012) (Fig. 1, Table. 1). The complete thalli were collected from reef flats at low tide from a variety of habitats down to 3 m depth. The specimens were fixed in 4% formaldehyde, and the remainder was dried on herbarium sheets. The morphological characters used for analysis includes thallus length, holdfast and stem shape, primary and secondary branches, leaf length, width and shape at the apex, base and margin, vesicle length, width, pedicle and receptacle shape. Also, transverse sections of receptacles were prepared and stained using 1% aniline blue, intensified with 1% HCl. Specimens were studied using a Stemi 2000-C Zeiss stereo microscope and photographed by Canon Power shot G6 camera.

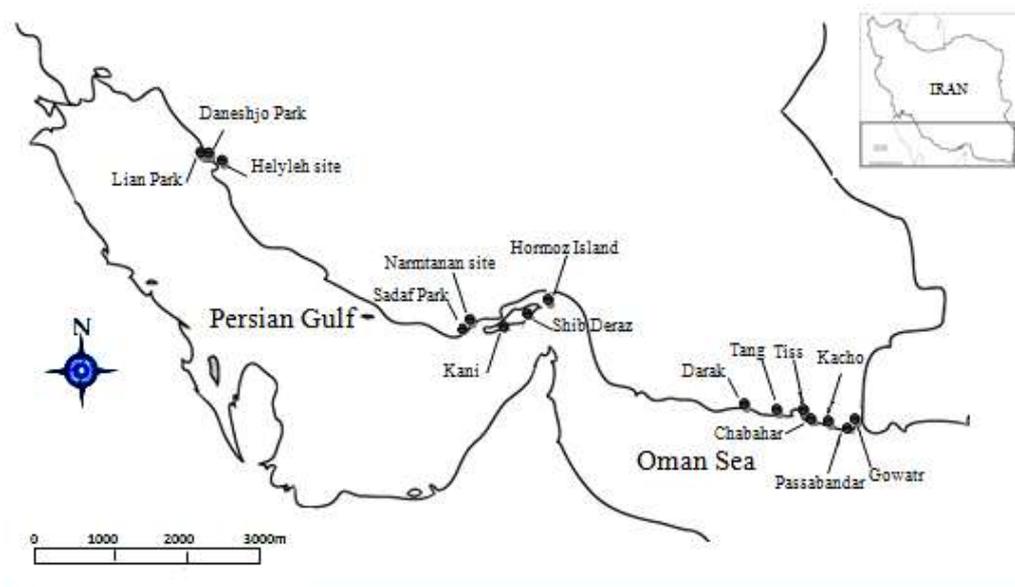


Figure 1. Study area and localities of collection for *Sargassum* along the Persian Gulf and Oman Sea seashore of Iran. Black circles show studied collected sites.

Table 1. *Sargassum* species and their collected sites in the Persian Gulf and Oman Sea.

Species Name	Collected Stations	Collected Date
<i>S. swartzii</i> (N24, T25, K2, K3, T215, T222)	Sistan and Baluchestan Province, Bushehr	January 2010, May 2012
<i>S. oligocystum</i> (N29, LS7, N25, LS2)	Bandar Lengeh, Qeshm Island, Bushehr	December 2011, May 2012
<i>S. cristaefolium</i> (N22, N50, N28, LS17, N56, N52, LS27, LS25, LS5, LS20, LS28, LS52)	Qeshm Island, Sistan and Baluchestan Province	January 2010, May 2011
<i>S. crassifolium</i> (GH5, Q10, Q15, Q13, N20, LS16)	Sistan and Baluchestan Province, Bandar Lengeh, Qeshm Island	May and December 2010-2011
<i>S. binderi</i> (NL20, NL22, NL23, NL25, NL204, LS207, N7)	Bandar Lengeh Province, Qeshm Island	January 2010-2011, December 2012
<i>S. aquifolium</i> (N14, N15, N16, LS6, N12, NL205, LS23, LS5, LS4, N2)	Bandar Lengeh Province, Bushehr, Qeshm Island	January 2010, May 2012

Identification was carried out based on the some taxonomic references [5, 6, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28 and 29]. In addition, in this study, the species were checked with available specimens of Belgium, Mexico, Australia, Indian Ocean and Japan in Ghent herbarium. It is noticeable that, the most of these syntypes previously had been checked with origin Holotype. Finally, all of the species nomenclatures were checked with AlgaeBase site. Iranian *Sargassum* species are deposited at the Herbarium of the University of Isfahan (HUI).

Results

All of the *Sargassum* species commonly grow on rocks and dead corals in littoral and sub-littoral sites. *Sargassum* species were collected from different sites along the Iranian southern coasts, identified, checked for synonymy accepted names with www.algaebase.org site and referred to its systematic groups. *Sargassum* density was much higher in Sistan and Baluchestan Province and Bandar Lengeh Province than other sites. In total, in taxonomical study regarding to 47 quantitative and qualitative morphological characters as shape and size of leaves, stem, receptacles and vesicles shape and size; six species belong to three Sections including of *Binderianae*, *Illicifoliae* and *Acanthocarpicae* were identified. An identification key to the *Sargassum* species with compressed primary branches of Iran is presented in the below.

Identification key for the Iranian *Sargassum* species with compressed primary branches

- 1- Leaf duplicated at the margin and apex.....2
 1- Leaf not as above.....3
 2- Leaves duplicated in apex and margin, bearing 1-3 spines on the pedicle.....*S. cristaefolium*
 2- Leaves duplicated in apex and margin, lacking spines on the pedicle.....*S. crassifolium*

- 3- Vesicles pointed, often crowned with mucronate at the apices, flattened stalk, receptacles flattened, often twisted.....*S. binderi*
 3- Vesicles pointed, often crowned with mucronate at the apices, terete, cylindrical stalk, receptacles compressed, not twisted, receptacles not as above.....4
 4- Leaves deeply dentate, spatulate, margin possibly double, cryptostomata large.....5
 4- Leaves slightly serrate or entire, linear, cryptostomata small*S. swartzii*
 5- Vesicles obovate and often not mucronate.....*S. oligocystum*
 5- Vesicles obovate and bearing leaflet, mucronate.....*S. aquifolium*

**Sargassum aquifolium* (Turner) C. Agardh [14, 15, 16, 22, 25, 27, 30].

Holotype: *S. bacciferum* (Turner) C. Agardh

Classification species: Subgenus *Sargassum*, Section *Binderianae*

Holdfast discoid, up to 8 mm in diameter. Stem terete, smooth or warty, up to 2.5 mm in diameter and 1 cm long. Primary branches flattened to compressed, smooth, up to 35 cm long and 1.8 mm in diameter; leaves large, lanceolate, simple, with asymmetrical bases, up to 4.5 cm long and 1.5 cm width, with rounded to acute apices, margins dentate with small teeth, midribs distinct near apices or vanishing midway; small cryptostomata are scattered in to rows on both sides of the midrib. Secondary branches spirally arranged, compressed, smooth, up to 35 cm long. Leaves lanceolate to linear; simple with asymmetrical bases; up to 5 cm long and 1.5 cm width; with rounded apices; dentate margins with sharp teeth. Vesicles spherical, sometimes elliptical, up to 18 mm long, 3.2 mm width, stalks terete, usually shorter than the vesicles (Fig. 2). Plants monoecious. Receptacles androgynous, flattened, often twisted, up to 1.6 cm long and 2 mm width, sharply dentate at the margin, simple to once to twice furcate. Receptacles arranged racemosely and



Figure 2. *Sargassum aquifolium* (Turner) C. Agardh a) Habit, b) leaves, c) vesicles. Scal bar: a= 5 cm, b, c = 5 mm

acantho-zygocarpi. However, there was not any receptacle in Iranian species.

Habitat: Coral flats and subtidal zone.

Ecology: This species usually grows in the lower portions of the intertidal zone on rock substrates or shallow subtidal zones. It was found only in Qeshm Island and Bandar Lengeh Province.

**Sargassum binderi* Sonder [14, 15, 16, 19, 20, 22, 25, 27, 30].

Holotype: *S. bacciferum* (Turner) C. Agardh

Classification species: Subgenus *Sargassum*, Section *Binderianae*

Holdfast discoid; up to 10 mm in diameter. Stem terete, smooth or warty; up to 2.5 mm in diameter and 1 cm long. Primary branches flattened to compressed, smooth, up to 40 cm long and 3 mm in diameter; leaves large, lanceolate, simple, with asymmetrical bases, up to

5.5 cm long and 1.5 cm width, with rounded to acute apices, margins entire to dentate with small teeth, midribs distinct near apices or vanishing midway, small cryptostomata are scattered in to rows on both sides of the midrib. Secondary branches spirally arranged, compressed, smooth, up to 40 cm long. Leaves lanceolate to linear; simple with asymmetrical bases; up to 5.5 cm long and 1.5 cm width; with rounded apices; margins dentate with sharp teeth. Vesicles spherical; sometimes elliptical, up to 20 mm long, and 4 mm width, often mucronate at the apices, sometimes entire, stalks flattened, usually longer than the vesicles (Fig. 3).

Plants monoecious. Receptacles androgynous, flattened, often twisted, up to 1.6 cm long and 2 mm width, sharply dentate at the margin, simple to once to twice furcate. Receptacles arranged racemously and zygocarpicae.

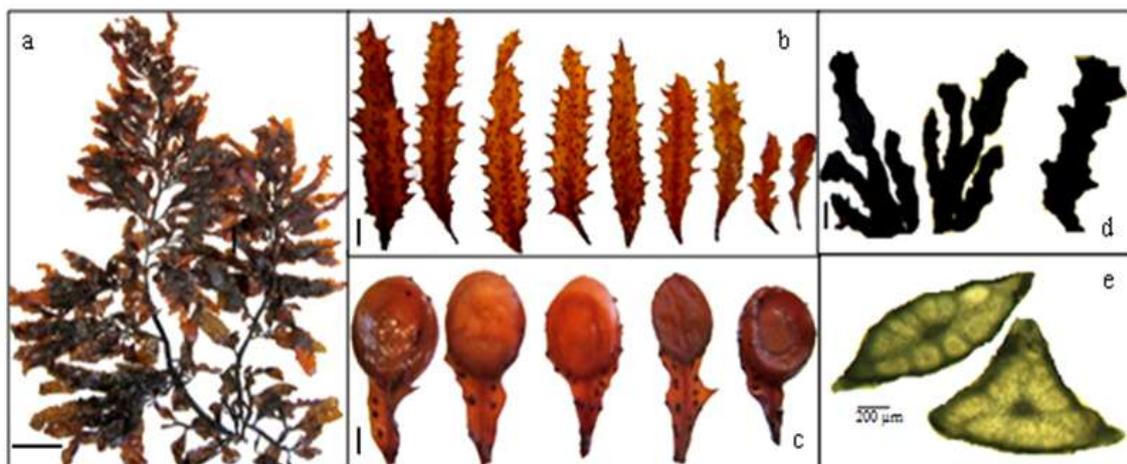


Figure 3. *Sargassum binderi* Sonder. a) Habit, b) leaves, c) vesicles, d) receptacles, e) transverse section of receptacle. Scal bar a= 5 cm, b, c, d = 5 mm

Habitat: Coral flats and subtidal zone.

Ecology: This is a new record species from Iran, usually grows in the lower portions of the intertidal zone on rock substrates or shallow subtidal zones. It was found only in Qeshm Island and Bandar Lengeh Province.

**Sargassum crassifolium* J. G. Agardh [14, 15, 16, 19, 20, 22, 25, 27, 30].

Holotype: *S. bacciferum* (Turner) C. Agardh.

Synonyms: *S. aquifolium* (Turner) C. Agardh

Classification species: Subgenus *Sargassum*, Section *Acanthocarpicae*

Thalli up to 85 cm high with discoid holdfast; up to 9 mm in diameter. Main and primary branches terete, smooth, up to 4 mm in diameter, 45 mm long. Leaves of the main branches coriaceous, lanceolate to oblanceolate, up to 30 long and up to 12 mm width, usually with rounded and double serrulate apices, margins dentate, midribs vanishing midway to distinct near apices, cryptostomata scattered or arranged in rows. Leaves on the primary branches coriaceous, with lanceolate-oblanceolate to lanceolate-oblanceolate, up to 25 mm long and up to 8 mm width. Midrib percurrent and distinct; margin duplicated; apex obtuse (Fig. 4). Cryptostomata are scattered or arranged in rows. Vesicles phyllocystic; up to 6 mm in diameter, bearing cryptostomata on the vesicles. Phyllocysts provided with marginal appendages or wings; stalks with lower part terete and upper part compressed to foliaceous, usually shorter or sometimes longer or equal to the vesicles; *S. crassifolium* is widely distributed and recognized by its duplicated margin and phyllocystic

vesicles. Iranian specimens showed great resemble to those of Philippines and Thailand.

Plants monoecious. Receptacles terete in lower part and slightly compressed in upper part, up to 15 mm long and 1.2 mm width, simple to furcated up to four times, with a warty surface, bearing spines at the apex, arranged in a cymose to compoundly cymose, pseudozygocarpic.

Habitat: Coral flats and subtidal zone.

Ecology: This species usually grows in the lower portions of the intertidal zone on rock substrates or shallow subtidal zones. It was found only in Qeshm Island and Bandar Lengeh Province.

**Sargassum cristaefolium* C. A. Agardh [14, 15, 16, 22, 25, 27, 30].

Holotype: *S. bacciferum* (Turner) C. Agardh

Synonyms: *S. ilicifolium* (Turner) C. Agardh

Classification species: Subgenus *Sargassum*, Section *Sargassum*

Thalli up to 90 cm high with discoid holdfast. Main and primary branches terete and smooth. cryptostomata are present on the main branches. Leaves of the main branches coriaceous, broad oblanceolate-lanceolate to ovate-obovate, up to 18 mm long and up to 6 mm broad. Midrib distinct and running halfway along the length of the leaf; margin duplicated. Apex obtuse. Cryptostomata randomly distributed. Leaves on the primary branches coriaceous, ovate to obovate, up to 12 mm long and up to 5 mm broad. Midrib distinct and running half way along the length of the leaf; margin duplicated. Apex obtuse. Cryptostomata scattered. Vesicles are spherical; up to 1 mm in diameter; apex obtuse and pedicel short.



Figure 4. *Sargassum crassifolium* J. G. Agardh. a) Habit, b) leaves, c) vesicles, d) receptacles, e) transverse section of receptacle. Scal bar a = 5 cm, b, c, d = 5 mm.

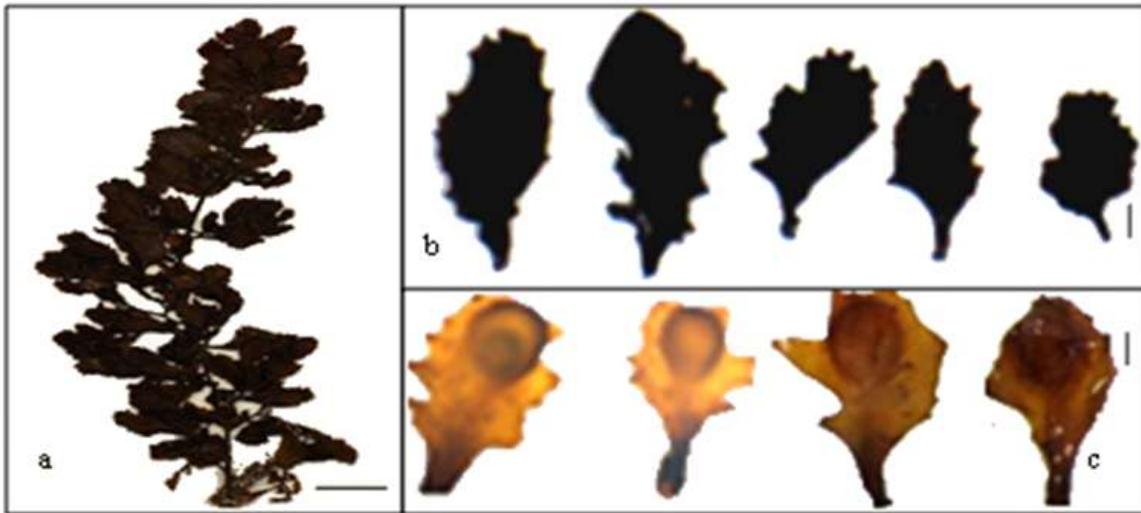


Figure 5. *Sargassum cristaefolium* C. A. Agardh a) Habit, b) leaves, c) vesicles. Scale bar: a= 5 cm, b, c = 5 mm.

The cryptostomata are present on the vesicles (Fig. 5). Plants monoecious. Receptacles terete in lower and slightly compressed in upper parts, up to 10 mm long and 8 mm width, simple to furcated up to four times, bearing spines at the apex, arranged in a cymose, pseudozygocarpic. Receptacles were not observed in the Iranian species, but according to others characters, these species showed great resemblance to those of Philippines and Malaysian.

Habitat: Coral flats and subtidal zone.

Ecology: This species usually grows in the lower portions of the intertidal zone on rock substrates or shallow subtidal zones. It has been found only in Qeshm Island and Bandar Lengeh Province.

**Sargassum oligocystum* Montagne [14, 15, 16, 19, 20, 22, 25, 27, 30].

Holotype: *S. bacciferum* (Turner) C. Agardh.

Synonym: *Carpacanthus oligocystum* (Montagne) Kützing

Classification species: Subgenus *Sargassum*, Section *Acanthocarpicae*

Thalli up to 100 cm high with discoid to scutate holdfast, up to 8 mm in diameter. Main and primary branches flattened to compressed, smooth, up to 43 cm long and 3 mm width. Leaves of the main branches membranous, lanceolate to spatulate, up to 41 mm long and up to 6 mm broad, with rounded apices, margins entire to dentate with small teeth, midribs vanishing to distinct near apices, small cryptostomata scattered. Leaves on the primary branches membranous, lanceolate, up to 38 mm long and up to 3.4 mm width. Midrib percurrent and distinct; margin sharply dentate, apex acute or obtuse, and cryptostomata scattered. Vesicles spherical or ellipsoidal, up to 2.6 mm in

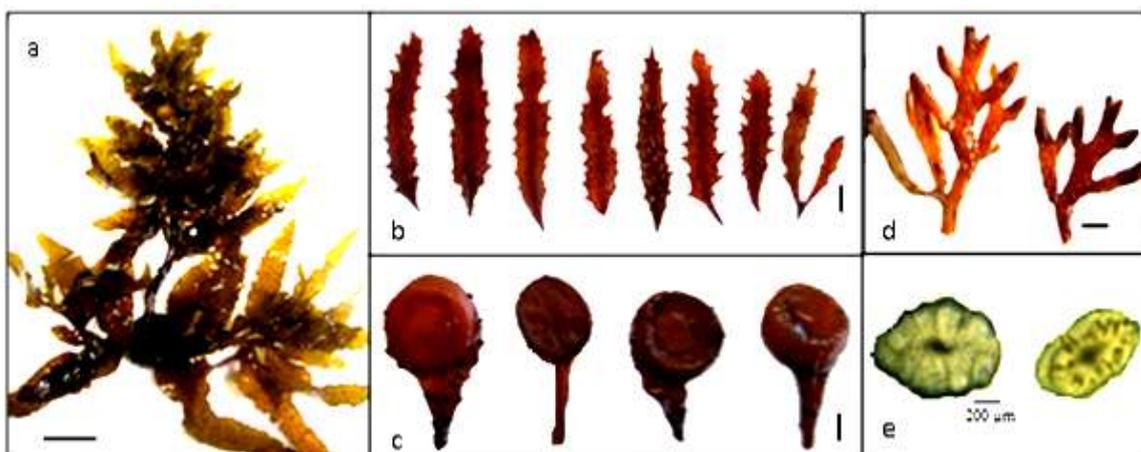


Figure 6. *Sargassum oligocystum* Montagne a) Habit, b) leaves, c) vesicles, d) receptacles, e) transverse section of receptacle. Scale bar: a= 5 cm, b, c, d = 5 mm.



Figure 7. *Sargassum swartzii* C. Agardh. a) Habit, b) leaves, c) vesicles, d) receptacles, e) transverse section of receptacle. Scale bar a = 5 cm, b, c, d = 5 mm.

diameter. Apex obtuse; rarely mucronate, stalks terete, usually shorter than the vesicles, bearing of cryptostomata on the vesicles. Some specimen had broader and longer leaves compared to others (Fig. 6). In addition, the vesicles of Qeshm Island were smaller and seldom exceeded 3 mm in diameter. In contrast, the vesicles of Bandar Lengeh species were around 4 mm in diameter. Plants monoecious. Receptacles androgynous, slightly compressed, up to 7 mm long and 3 mm width, warty or with a few marginal spines; simple to two or three times furcated, racemosely arranged, pseudozygocarpic.

Habitat: Coral flats and subtidal zone.

Ecology: This species usually grows in the lower portions of the intertidal zone on rock substrates or shallow subtidal zones. It has been found only in Qeshm Island, Bushehr and Bandar Lengeh Province.

**Sargassum swartzii* C. Agardh [14, 15, 16, 19, 20, 22, 25, 27, 30].

Holotype: *S. bacciferum* (Turner) C. Agardh.

Synonyms: *Fucus swartzii* Turner; *S. spathulaefolium* J. Agardh; *S. wightii* Greville ex J. Agardh; *S. acutifolium* Greville.

Classification species: Subgenus *Sargassum*, Section *Binderianae*

Thalli up to 86 cm high with discoid holdfast, up to 12 mm in diameter. Main and primary branches compressed and smooth. Leaves of the main branches coriaceous, linear lanceolate to linear oblanceolate, up to 26 long and up to 4 mm broad. Midrib distinct and percurrent; margin entire to occasionally tooth; apex acute or obtuse. Cryptostomata in rows; leaves of the primary branches coriaceous, linear lanceolate to linear oblanceolate, up to 25 long and up to 3 mm broad, midribs distinct near apices, cryptostomata small and

scattered. Margin entire to occasionally tooth; apex acute or obtuse, cryptostomata in rows. Vesicles elliptical to fusiform, up to 5 long and 2 mm width; crowned with horn-like spin, apex pointed or with a short leafy crown, margins entire, stalks terete to slightly compressed or terete in the lower and compressed in the upper part, usually shorter than the vesicles or sometimes longer. Cryptostomata present on the vesicles (Fig. 7). Plants monoecious; Receptacles slightly terete, up to 13 mm long and 1.7 mm width, simple to furcated 2–5 times, bearing spines at the apex, arranged in a cymosely to compound cymose, pseudozygocarpic.

Habitat: Coral flats and subtidal zone.

Ecology: This species usually grows in the lower portions of the intertidal zone on rock substrates or shallow subtidal zones. It was found only in Qeshm Island and Bandar Lengeh Province.

In total, in the taxonomy studies, 47 quantitative and qualitative morphological characters were selected. The clustering analysis of UPGMA show that these characters can be separated sections well (Fig. 8). *S. swartzii*, *S. aquifolium*, *S. binderi* and *S. crassifolium* classified together as a distinct clade (Sect. *Binderianae*), and *S. oligocystum* belong to Sect. *Acanthocarpicae* and *S. cristaefolium* belong to Sect. *Illicifolia* clustered together in a common clade. In addition, PCA analysis (Fig. 9) separated three sections as morphological characters well.

Discussion

In this study, six species of *Sargassum* with compressed primary branches including: *S. binderi* Sonder, *S. aquifolium* (Turner) C. Agardh, *S. oligocystum* Montagne, *S. swartzii* (Turner) C. Agardh,

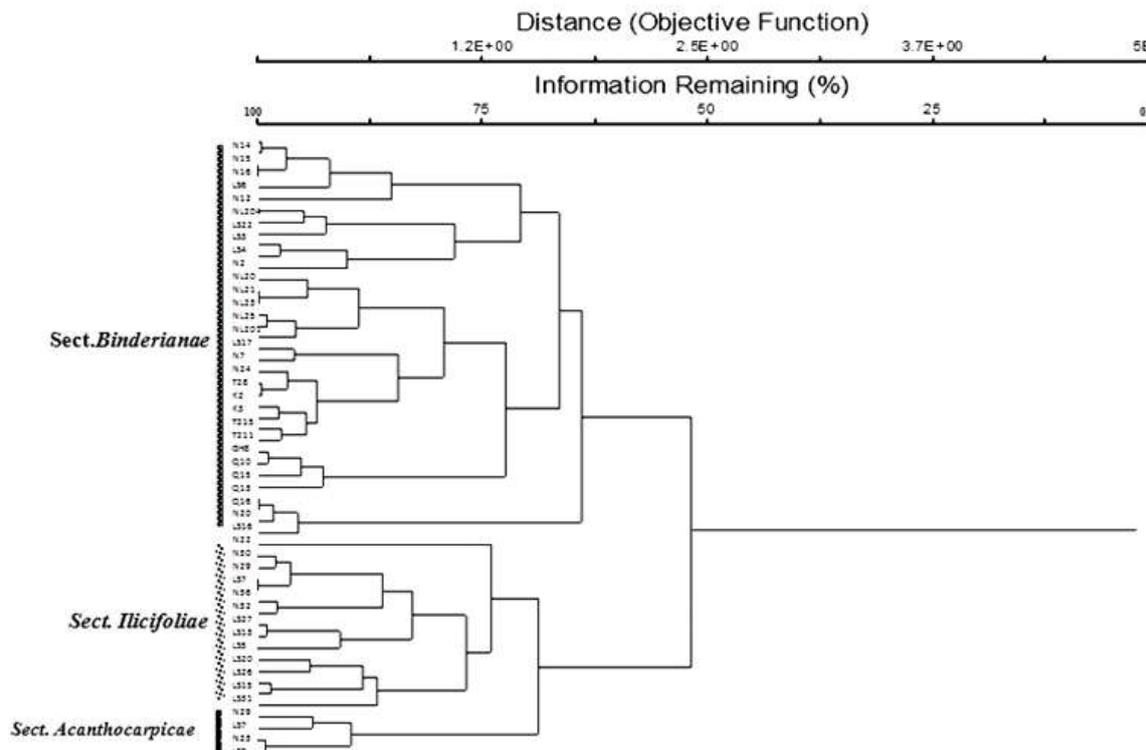


Figure 8. UPGMA dendrogram based on quality and quantity characters (Jaccard Coefficient)

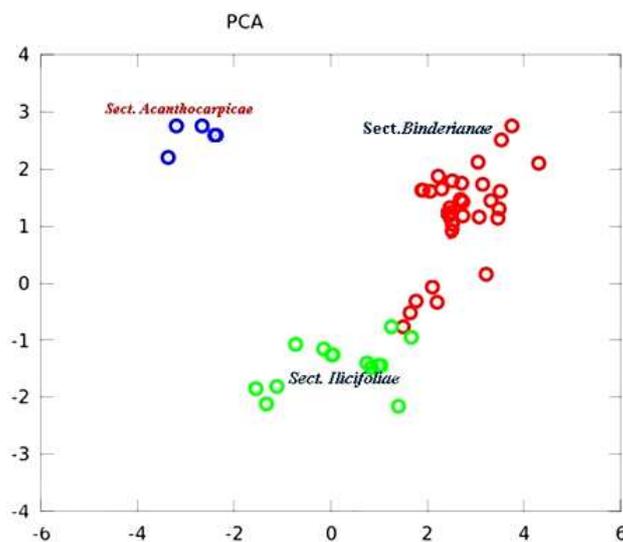


Figure 9. PCA analysis based on Morphological data for phenotypic populations

S. crassifolium J. Agardh and *S. cristaefolium* C. Agardh, were described from the Persian Gulf and Oman Sea of Iran. *S. binderi* was a new record species from Iranian coasts. The clear diagnostic traits of these species were clearly presented and discussed in the current study. In this study we observed that the *Sargassum* population developed in winter (December

and January). *S. binderi*, *S. crassifolium* and *S. cristaefolium* have flattened and sometimes triquetrous receptacles while *S. crassifolium* and *S. cristaefolium* have duplicated margins. *S. swartzii* has linear lanceolate leaves, pointed or crowned vesicles. *S. oligocystum* has broader lanceolate leaves with an acute to rounded apex, almost entire and spherical vesicles. *S.*

swartzii was reported by Tseng as an androgynous plant in which both male and female reproductive organs occur in the same receptacles [23]. In the *S. swartzii*, receptacles were slightly flattened and repeatedly furcated and arranged in cymosely. The Iranian specimens showed great resemblance to those from Vietnam, Malaysian and Thailand. *S. swartzii* was found in the Sistan and Baluchestan Province, Hormoz and Bushehr Province. Also, *S. binderi*, *S. aquifolium*, *S. crassifolium* and *S. cristaefolium* were found in Bandar Lengeh and Qeshm Island. The *S. oligocystum* only was observed in Bushehr Province. *S. crassifolium* and *S. cristaefolium* easily was differentiated from each other by leaves duplicated margin. *S. binderi* has been characterized by the receptacles with sharply spinous margin. Womersley and Bailey [29] suggested that *S. binderi* was a synonym of *S. oligocystum*, but this was disputed by Tseng and Lu [25, 26] and Ajisaka et al [16]. According to AlgaeBase, this species currently considered as synonym of *S. aquifolium*. However, we retain *S. binderi* on the basis of its characteristic receptacles with a clear spinous margin. Found *S. binderi* in Iran is closely similar to Thailand and China samples [19, 25] for its vesicles and receptacles morphology. *S. binderi* and *S. oligocystum* are often misidentified as they share some morphological characters especially in young plant, both species are monoecious. The result of the present study revealed the identical features of *S. oligocystum* and *S. aquifolium*. In this survey, *S. binderi*, *S. aquifolium* and *S. oligocystum* had large cryptostomata on their leaves [20, 30]. Silva *et al.* reported that this species was wrongly named as *S. acinaria* by some authors [31]. Also, Noro *et al.* showed that *Fucus swartzii* Turner is basionym for the *S. swartzii* (Turner) C. Agardh [21]. In addition, results of UPGMA clustering analysis based on Jaccard's similarity coefficient on the quantitative and qualitative data phenotypic populations of six species separate and classify their sections. Of 47 qualitative and quantitative traits, qualitative characters such as branching and leaf tip margins, shape and vesicles and receptacles shape were the best traits for identification. *S. crassifolium* nested with *S. aquifolium* in the same clade (in sect. *Binderianae*); and also, *S. cristaefolium* clustered under sect. *ilicifoliae* in a separated clade. In the other hand, we confirmed that *S. crassifolium* should be considered a synonyme of *S. aquifolium* as Guary and Guary, 2013. PCA analysis regard to diagnostic characters separated phenotypic populations belonging to three sections containing six species as well (Bandar Lengeh and Qeshm Island from Sistan and Baluchestan Province). In conclusion, this study show that the qualities and quantities traits add to anatomical studies

can be important in the *Sargassum* species identification.

References

1. Guiry M.D. and Guiry G.M. AlgaeBase Version 4.2. World-wide electronic publication, National University of Ireland, Galway, <http://www.algaebase.org>; searched on 5 February (2013).
2. Yamamoto I., Takahashi M., Suzuki T., Seino H. and Mori H. Antitumor effect of seaweeds, enhancement of antitumor activity by sulfation of a crude fucoidan fraction from *Sargassum kjellmanianum*. *Jap J Exp Med.* **54** (4): 143–151 (1984).
3. Stevan F.R. Cytotoxic effects against Hela cells of polysaccharides from seaweeds. *J Submicro Cytology and Pathology.* **33**: 477- 484 (2001).
4. Sheppard C.R.C., Price A.R.G. and Robert C. Marine Ecology of the Arabian Region Patterns and Processes in Extreme Tropical Environments. London, Academic Press 359 p. (1992).
5. Børgeson F. Marine Algae from the Iranian Gulf. Scientific investigations in Iran. Copenhagen, Denmark. **1**: 46-141 (1939).
6. Endlicher S.L. and Diesing C.M. Enumeratio algarum, quas et oram insulae Karek, sinus Persici, legit Theodorus Kotschy, Botanische Zeitung. **3**: 268- 269 (1845).
7. Nizamuddin M. and Gessner F. The Marine Algae of the Northern Part of the Arabian Sea and of the Persian Gulf. *Metero Forsch-Ergebnisse, Reihe.* Berlin **6**: 1- 42 (1970).
8. Silva P.C., Basson P.W. and Moe R.L. Catalogue of the Benthic Marine Algae of the Indian Ocean. University of California Publication in Botany, Los Angeles, California **79**:1- 1259 (1996).
9. Basson P.W. Checklist of marine algae of the Arabian Gulf. *Sour University, Kuwait***12**: 212-228 (1992).
10. Sohrabipour J. and Rabii R.A. List of marine algae of seashores of Persian Gulf and Oman Sea in the Hormozgan Province. *Iran J Bot.* **8**: 131-162 (1999).
11. Gharanjik B.M. Determination of biomass and expansion of algae and preparation of Persian Gulf and Oman Sea Algae Atlas. Offshore Fisheries Research Center. Published in: Research Institute of Fisheries of Iran. 135 p. (2005).
12. Shams M., Afsharzadeh S., Balali G. and De Clerck O. Revision *Sargassum* species (Fucales, Phaeophyceae) from Persian Gulf and Oman Sea (Iran) based on morphological and phylogenetical analyses. 18th National Symposium on Applied Biological Sciences, on February, Ghent University. Ghent, Belgium (2013).
13. Agardh C.A. Species Algarum, Fucoideae. Berling, Lund, 168 p. (1820).
14. Agardh J.G. Species, Genera et Ordines Algarum. Glycerup, Lund, Sweden, 363 p. (1820).
15. Agardh J.G. Species *Sargassorum* Austliae Descriptae et Dispositate. Kgl Svenska Vetenskapsakad, **23**, Handl, 133 p. (1889).
16. Ajisaka T., Phang S.M. and Yoshida T. Preliminary report of *Sargassum* species collected from Malaysian coast. In:

- Abbott, I. A (ed). Taxonomy of economic seaweeds with reference to some Pacific species. California Sea Grant College, University of California, La Jolla Journal, California, pp. 23-42 (1999).
17. De Clerck O. and Coppejans E. Marine algae of the Jubail marine wildlife Sanctuary, Saudi Arabia. A marine wildlife sanctuary for the Arabian Gulf. Environment research and conservation following the 1991 Gulf War Oil Spill., Riyadh and Senckenberg Research Institute, Frankfurt. pp. 199- 289 (1996).
 18. Grunow A. Additamenta ad Cognitionem Sargassorum. Verhandlungen der Kaiserlich-Königlichen Zoologisch-Botanischen Gesellschaft in Wien. **65**: 329– 448 (1915).
 19. Noiraksa T., Ajisaka T. and Kaewsuralikhit C. Species of *Sargassum* in the east coast of the Gulf of Thailand. *J Sci Society of Thailand*. **32** (1): 99-106 (2006).
 20. Noiraksa T. and Ajisaka T. Taxonomy and distribution of *Sargassum* (Phaeophyceae) in the Gulf of Thailand. *J Appl Phycol*. **20**: 963-977 (2008).
 21. Noro T., Ajisaka T. and Yoshida T. Species of *Sargassum* Subgenus *Sargassum* (Fucales) with Compressed Primary Branches. In: Taxonomy of Economic Seaweeds with reference to some Pacific species. California Sea Grant Collage. 23-31 pp. (1994).
 22. Setchell W. A. Hong Kong Seaweeds. Sargassaceae, Hong Kong National. **2**: 237-253 (1935).
 23. Tseng C. K. Common Seaweeds of China. Science Press, Beijing, China. 316 p. (1983).
 24. Tseng C.K., Yoshida T. and Chiang Y.M. East Asiatic species of *Sargassum* subgenus *Bactrophyucus* J. Agardh (Sargassaceae, Fucales), with keys to the section and species. In: Abbott, I. A, Norris, J. N (ed) Taxonomy of Economic Seaweeds with Reference to Some Pacific and Caribbean Species. California Sea Grant College. University of California, La Jolla Journal, California, pp. 1-15 (1985).
 25. Tseng C.K. and Lu B. Studies on the Malacocarpic *Sargassum* of china: II. *Racemosae* J. Agardh. In Abbott IA (ed.), Taxonomy of economic Seaweeds with reference to some Pacific and Western Atlantic Species III. California Sea Grant College. University of California, La Jolla, California, pp. 11-34 (1992).
 26. Tseng C.K. and Lu B. Flora Algarum Marinarum Sinicarum. Phaeophyta, Fucales. Science Press, Beijing. 237 p. (2000).
 27. Yoshida T., Ajisaka T., Noro T. and Horiguchi T. Species of the genus *Sargassum* subgenus *Schizophycus*. In: Abbott, I. A (ed) Taxonomy of Economic Seaweeds. California Sea Grant College. University of California. La Jolla, California. pp. 93-106 (2004).
 28. Yoshida T., Shimada S., Yoshinaga K. and Nakajima Y. Checklist of marine algae of Japan (revised in 2005). *Japan, J Phycol*. **53**: 180-228 (2005).
 29. Womersley H.B.S. and Bailey A. Marine algae of the Solomon Islands. Philosophical Transaction of the Royal Society of London. **259**: 257- 352 (1970).
 30. Gavino C. and Trono J. Diversity of the Seaweed Flora of the Philippines and Its Utilization. *Hydrobiologia*. **399**: 1-6 (1999).