Current Trends in Biotechnology and Pharmacy
Vol. 15 (4) 436 - 446, October 2021, ISSN 0973-8916 (Print), 2230-7303 (Online)
DOI: 10.5530/ctbp.2021.4.46

A Review on Pharmaceutically Potent Bioactive Metabolites of Seagrass *Cymodoceaceae* Family

Parthasarathi Perumal[1], Umamaheswari Arthanari[1], Elumalai Sanniyasi[2*]
[1]Department of Plant Biology and Plant Biotechnology, Presidency College (Autonomous), Chennai - 600 005, Tamil Nadu, India
[2]Department of Biotechnology, University of Madras (Guindy Campus), Chennai - 600 025, Tamil Nadu, India
Corresponding author : ananandal@gmail.com

Abstract

Marine organisms are natural sources that provide a wide variety of pharmaceutical applications for curing human diseases. The bioactive components from marine organisms such as algae, plants, animals and microbes show various biological properties. Out of which seagrasses, a marine flowering plants that are widely distributed in tropical and subtropical regions and plays an important role in the support for marine coastal species and human livelihoods. The secondary metabolites of seagrasses exhibits wide variety bioactivity such as antitumor, antibacterial, antifungal, antioxidant and antimacrofouling. This review outlines the taxonomical classifications of seagrasses and the main objective is discuss the biological insights of seagrass family *Cymodoceaceae* and a total of 5 genera and 18 species have been acknowledged. This paper highlights the morphological characterization, phytoconstituents of the *Cymodoceaceae* species and its applications in addressing the solution for biological problems.

Keywords: Seagrasses, Cymodoceaceae, Phytoconstituents, Bioactive components, antitumour, antioxidant

Introduction

Seagrasses are monocotyledonous marine angiosperms (flowering plants) that inhabit coastal ecosystems worldwide. The taxonomical diversity of seagrasses are low and it provides many ecosystem services (1,2). They are found only in coastal and estuarine areas around the world (3). Seagrasses are found in shallow waters (4) and hence, are found most-predominantly along the coastlines of all continents excluding the South and North Arctic Circle (5).

The Seagrass ecosystem serves as a nutrient supplier of high productivity in coastal water areas, thereby increasing their socioeconomic importance. It supports various kinds of organic matter and nutrients. The seagrass ecosystems are the breeding ground of many marine organisms and a very productive nursery. It provides an appropriate substratum for epiphytes and also acts as a sediment stabilizer. They are a good source of food for marine herbivores. Seagrasses are sufficient for removing nutrients from marine waters and surface debris and therefore, they are important for the control of water quality of coastal waters (1,6).

Seagrasses look like terrestrial grasses on the coastal surface and there are seventy-three estimated species in six families worldwide (7,8). **Figure 1** depicts the geographical distribution and diversity distribution of seagrasses along the coastline, where dark green indicates high species diversity and light green indicates low species diversity (5,9).

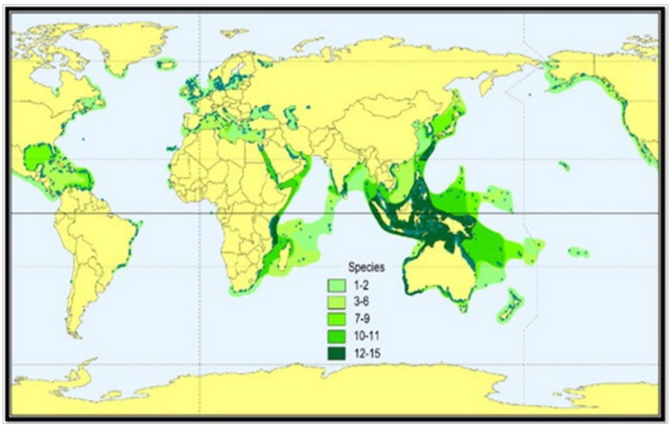

Figure 1: The geographical distribution of seagrass (9).

Seagrasses play an important role in the marine ecosystem as an important food source, for instance, green sea turtles, manatees, dugongs, and seahorse for the megaherbivorous. In addition to this, seagrasses also provide shelter to several animals, including commercially, and essential fishery species. Seagrass beds also provide important ecological services to estuarine fisheries, wildlife, and the marine environment (4,10,11). Seagrass beds are also significant territories for game fish such as snook, permit, bonefish, and tarpon. Seagrasses also play a major role in preserving water quality and marine organisms (12).

In recent years, the biological indicators of estuarine water quality have received much from seagrasses and they are ecologically sensitive to improving nutrient and eutrophication. Seagrasses adjust water flow; they participate in nutrient cycling progression, food web structure and are stabilizing agents in coastal sedimentation and erosion processes (8,13). The secondary metabolites from seagrasses are defence mechanisms under biological applications.

Vol. 15 (4) 436 - 446, October 2021, ISSN 0973-8916 (Print), 2230-7303 (Online)
DOI: 10.5530/ctbp.2021.4.46

Also, research on plants research has brought to limelight bioactive natural products produced by them in response to physical, chemical, and biological changes in the environment (14).

Studies carried out on seagrasses

Seagrasses serves as a potent marine source for seagrass-based natural products and their development. The effects of seagrasses in climate change in the Pacific Island Countries were investigated by the University of South Pacific (15). Similarly, seagrass serves as a biological indicator of health of the coastal ecosystem (16). The seagrass beds may represent an important component in the ecological system of tropical coastal zones in the Western Indian Ocean (17). In China, the distribution of seagrasses and their locations, community structure, ecological evaluation, epiphytes, ecological functions have been well documented (18).

Research activities on socio-ecological changes concerning marine seagrasses and the development of potential pharmaceutical drugs from seagrasses were the main themes of coastal research in Australia (19). The University of Plymouth (UK) has explored the importance of seagrass habitats for fishery species, to highlight possible factors to identify areas of seagrass ecology (20). Biodiversity and environmental changes of coastal seagrass populations have been studied by Swansea University, UK (21).

In India, seagrass-based research was initiated in the late 19th century with a strong base in marine natural products due to the availability of a 7500 km stretch of a long coastline and coastal resources. About thirteen different species of seagrasses have been reported in Indian coastline; which are *Cymodocea rotundata*, *Cymodocea serrulata*, *Enhalus acoroides*, *Halodule pinifolia*, *Halodule uninervis*, *Halophila beccarii*, *Halophila decipiens*, *Halophila ovalis*, *Halophila ovalis* sp. ramamurthiana, *Halophila ovata*, *Halophila stipulacea*, *Thalassia hemprichii*, and *Syringodium isoetifolium* (22).

Studies on the relationship between seagrass and climate change have also been conducted in the coastal scenario of India. The biomass of seagrass *Syringodium isoetifolium* was used as a feedstock for biomethane production (23). Climate change mitigation and seagrass ecosystem metabolism occurred in Palk Bay, the Southeast Coast of India (24). Antibacterial activity of the associated microbes of *Syringodium isoetifolium* a seagrass collected from the Southeast coast of India was reported by Ravikumar et al. (25) Similarly, another team has collected five different seagrasses viz, *Cymodocea serrulata*, *Halophila beccarii*, and *Syringodium isoetifolium* and reported the bioactivity against insect-transmitted diseases from the human population (26). Simultaneous studies on the study of seagrass community analysis, rhizobacterial population and nitrogen fixation have been carried out in the Gulf of Mannar coast (27).

Taxonomic classification of seagrass

Seagrasses are classified into six different families including *Cymodoceaceae*, *Hydrocharitaceae*, *Posidoniaceae*, *Potamogetonaceae* or *Zannichelliaceae*, *Ruppiaceae* and *Zosteraceae* (28-30). Seagrasses are classified under order Alismatales with 6 families; 14 genera and 86 species, well depicted in **Figure 2** with taxonomic classification retrieved from Angiospermic Phylogenetic Group – IV (31) system of classification.

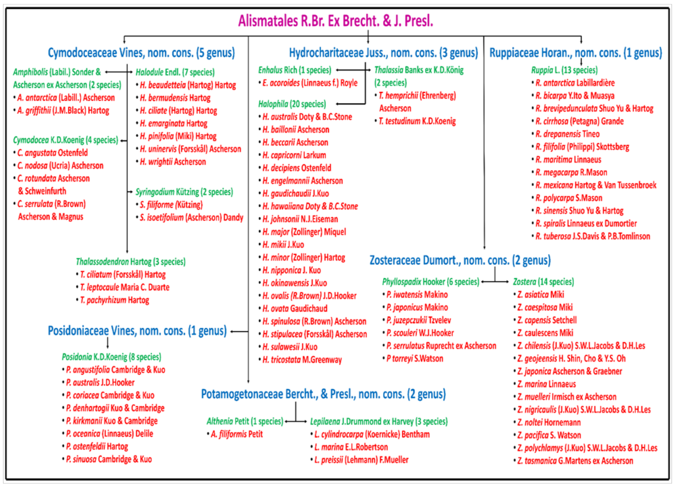

Figure 2: Schematic representation showing the taxonomical classification of seagrass containing Order (Purple), Family (Blue), Genus (Green) and Species (Red) (31).

Family *Cymodoceaceae* - An overview

Cymodoceaceae is small, consisting entirely of seagrasses but ecologically it is an essential family (32). Most generally occupy the subtidal zone in the tropical or subtropical regions and grow for 0.5 to 40 m in the depths. They regularly appear as extensive meadows of vegetation and are of vast importance in the production of accumulation to support marine food webs. Further, they contribute to the stabilization of sediments, grazing fields for turtles and dugongs, and a secluded environment (33).

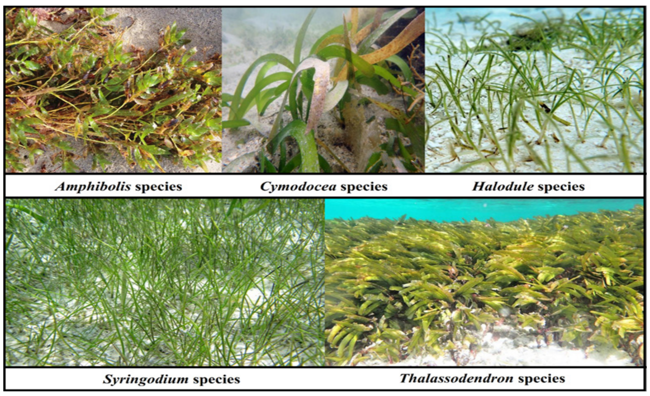

Figure 3: The five genera of seagrass Cymodoceaceae species.

Vol. 15 (4) 436 - 446, October 2021, ISSN 0973-8916 (Print), 2230-7303 (Online)
DOI: 10.5530/ctbp.2021.4.46

Cymodoceaceae are marine organisms and can be classified in about five genera (Fig. 3) including *Amphibolis* - 2 species (*Amphibolis antarctica*, *Amphibolis griffithii*), *Cymodocea* - 4 species (*Cymodocea angustata*, *Cymodocea nodosa*, *Cymodocea rotundata*, *Cymodocea serrulata*), *Halodule* - 7 species (*Halodule beaudettei*, *Halodule bermudensis*, *Halodule ciliate*, *Halodule emarginata*, *Halodule pinifolia*, *Halodule uninervis*, *Halodule wrightii*), *Syringodium* - 2 species (*Syringodium filiforme*, *Syringodium isoetifolium*), and *Thalassodendron* - 3 species (*Thalassodendron ciliatum*, *Thalassodendron leptocaule*, *Thalassodendron pachyrhizum*) (34,35).

Scientific classification of family Cymodoceaceae

Empire	:	Eukaryota
Kingdom	:	Plantae
Phylum	:	Tracheophyta
Sub-phylum	:	Euphyllophyta
Infraphylum	:	Spermatophyta
Superclass	:	Angiospermae
Class	:	Monocots
Subclass	:	Alismatidae
Order	:	Alismatales

Morphological characters of the family Cymodoceaceae

Based on the five genera, vegetative morphology appears to be in two groups. Group one shows the species *Amphibolis* and *Thalassodendron* in which green leaves are arranged in groups on tall woody-textured, stiff rhizomes, sympodial branches, arranged in clusters on tall narrow stems with stalked anthers. Group 2 shows the leaves of the species *Cymodocea*, *Syringodium*, and *Halodule* arranged in short internodes on stems, are herbaceous, and in which rhizomes look spongy, monopodial, and have sessile anthers (33,36,37). Paul et al. (38) include the seagrasses species *H. uninervis* for consumption through average preference together with juvenile fish and adult fish. Meyer et al. (39) explains the extract of seagrass *H. uninervis* show that the whole plants should not be experienced but rather considered as "low preference". And these plants *H. uninervis* also contain the capacity to supply several deterrents.

Amphibolis antarctica

The rhizome with a branched root node has 1, rarely 2. Erect stem up to 1.5 m long, with 6 to 10 leaves at the end of the stem; base, leaf sheath margins overlapping. The length and width of the blades up to 20 to 50 mm and 2 to 10 mm. Usually, blades are warped about approximately 180 degrees in the distal half; 2 acute lateral teeth with the cut or semicircular apex. Female flowers have pericarpic lobes in two whorls with 4 lobes. Seedling combs of pericarpic lobes with 13 to 18 bristles in each broad lobe and 7 to 11 bristles in each narrow lobe (40).

Amphibolis griffithii

The rhizome with 1 rarely 2, roots are branched at each node. Erect stems up to 1 m long, with 3 to 5 leaves at the end of the branches. In their whole length, leaf sheath margins overlap. Blade 30 to 100 mm long, 2 to 7 mm wide, usually not turned in the distal half; apex deeply notched with 2 obtuse lateral teeth. The female flowers have 4 pericarpic lobes into one whorl. In each broad lobe 18 to 26 bristles with seedling combs and each narrow lobe 11 to 15 bristles (40).

Cymodocea angustata

The unbranched root node with rhizome and leaves have a short erect stem beating 2 to 3. Slightly obconical leaf sheath, an open circular scar on the erect stem shed separation. Blades linear, up to 60 cm long, 3 to 6 mm wide, tapering toward the apex, with 9 to 13 longitudinal veins; apex obtuse, serrate, serratures sometimes bifurcate. Fruits are sub-circular in outline, laterally compressed, 6 mm long. In this species, the male reproductive structures are still unidentified (40).

Cymodocea nodosa

A short erect stem bearing up to 2 to 5 leaves and the rhizomes along with each node are attached strongly to the branched root. The linear leaf sheaths are slightly obconical, when shed they leave behind a closed circular scar on the erect stem. Length of the leaf blades up to 30 cm and 2 to 4 mm width, longitudinal veins up to 7 to 9; rounded apex, sometimes slightly irregular. Fruits are 1.5 mm thick, 8 mm long and, 6 mm wide, semicircular, laterally compressed, dorsal side with 3 parallel ridges, length of the beak apical 1 to 2.5 mm (40).

Cymodocea rotundata

The leaves short erect stem bearing 2 to 7 and 1 to 3 erratically branched roots at each node with the rhizome. Blades are linear, often rather semi-circular, up to 15 cm long, 2 to 4 mm wide, with 9 to 15 longitudinal veins; apex is rounded, and sometimes they are slightly emarginated. Slightly obeonieal leaf sheath, becoming a scarious mass when shed leaving a closed circular sear on the erect stem. The fruits 1 or 2, sessile, outline appear semi-circular, laterally compacted, 10 mm long, 6 mm wide, 1.5 mm thick, dorsal side with 3 parallel ridges, the median one with 6 to 8 acute teeth, the ventral ridge with 3 to 4 teeth (40).

Cymodocea serrulata

The rhizome with every node, 2 to 3 sparingly branched and, a short erect stem bearing 2 to 5 leaves.

Vol. 15 (4) 436 - 446, October 2021, ISSN 0973-8916 (Print), 2230-7303 (Online)
DOI: 10.5530/ctbp.2021.4.46

Leaf-sheath broadly triangular, narrow at the base when shed leaving an open circular scar on the erect stem. Blades linear to falcate, up to 15 cm long, 4 to 9 mm wide, with 13 to 17 longitudinal veins, apex obtuse, serrate to dentate. Fruits up to 7 to 9 mm long, 3.75 to 4.5 mm wide, and 2 mm thick, elliptic in outline, laterally compressed, dorsal side with 3 equivalent, blunt ridges. This species usually grows together with *C. rotundata*, but can be distinguished from the latter species by having a triangular leaf sheath, when shed they leave behind open scars on the erect stem; the leaf blades of this species also have more longitudinal veins, 13 to 17, and an obtuse serrated apex (40).

Halodule beaudettei

The leaf blade up to 5 to 20 cm length and 0.5 to 1.5 mm width; the apex tridentate, lateral teeth 1 to 10 times longer than lengthy sharp central tooth. In this species, the reproductive morphology has not been well described. Compare to *H. wrightii*, in this species *H. beaudettei* the leaf apex morphology is distinguished (40).

Halodule bermudensis

The leaf blade up to 25 cm length and 0.75 to 1.25 mm width; the well-developed apex with lateral teeth; comparatively, the inner surfaces are convex. These species often have some secondary processes. In this species, the reproductive morphology has not been well described too, and this species has been collected and described from the Bermuda Islands (41).

Halodule ciliate

The length of the leaf blade up to 5 to 6 cm and, 0.5 to 1 mm width. These species have a minute irregular median tooth with apex. They have a different morphological character, having a dentate to ciliate margin and, the lateral teeth which are only slightly shorter (40).

Halodule emarginata

The length of the leaf blade up to 11 cm and the width 1.5 mm; the rounded apex irregular or slightly serrulate, lateral teeth are ordinary, however sometimes absent. In this species, the reproductive morphology has not been known (40).

Halodule pinifolia

The leaf blade length up to 5 to 29 cm and, the width 0.3 to 1.5 mm; the apexes are rounded along with minute serrations, the two lateral teeth are developed poorly. The length of the male flower with stalk is 10 mm and, the length of the anthers is 2.5 to 3 mm but the two dissimilar heights of the anthers are 0.5 mm. 13 mm long, single style with the female flower. The Diameter of fruit ovoid up to 2 to 2.5 mm. The morphology of blade apes diverse and these species have mystified with narrow-leaved *H. uninervis* (40).

Halodule uninervis

The length of the leaf blade up to 15 cm and the width 0.25 to 5 mm. Lateral teeth are well-developed and the apex has a short central tooth. Above 6 to 20 mm length male flower stalk, anther height different from 2 to 3 mm with 0.25 to 0.5 mm. 28 to 42 mm as long as a single style to the female flower. The ovoid subglobose fruit up to 1.75 to 2.5 mm. The two dissimilar morphological forms can be recognizable from *H. uninervis*. At the same time, the wide-leaved and narrow-leaved *H. uninervis* species are found frequently. The wide-leaved forms are mainly grown in the marine environment. At the same time, in both marine and brackish waters the narrow-leaved forms can be established (40).

Halodule wrightii

Length of the leaf blades up to 2 to 22 cm and 0.2 to 1.0 mm width; a blade apex has present along with two short horns and sometimes the blades have three horn-like points; the lateral teeth are larger and the median tooth are short; the end part of the inner surface has a triangular form which is more or less concave, irregular serrations and, sometimes they are very small. The length of the male flower with stalk up to 2 cm and, the length of the anther up to 3.5 to 5 mm. The two dissimilar heights of the anthers are 0.5 mm. The style of the female flower is 28 mm elongated. The diameter of the fruit up to 1.5 to 2 mm (40).

Syringodium filiforme

The rhizomes among 2 to 4 short-branched roots, the leaves are round containing 2 to 3 nodes at each other. The shoots are inflexible; the 2 peripheral veins have cutting edges and, the length is 30 cm, diameter of the veins up to 1 to 2 mm, also the central vein has the same diameter. Fruits up to 6 to 7 mm long, 3.5 to 5 mm wide and 1.5 mm thick, and diagonally wedge-shaped (40).

Syringodium isoetifolium

The roots are 1 to 3 short-branched among rhizomes and each node has 2 to 3 straight shoots with round leaves. Peripheral veins, cutting edge up to 1 to 2 mm in diameter and 30 cm length, central vein significantly larger diameter than 7 to 15 peripheral veins. Fruit slant ellipsoid, 1.5 mm thick, 1.75 to 2 mm wide and, 3.5 to 4 mm long (40).

Thalassodendron ciliatum

These species have healthy rhizomes with 1 to 5 brownish, woody, much-branched roots at every fourth rhizome node. The branched erect stems are little, up to 65 cm long at nodes after root beating nodes. Leaf-blades are linear, semi-circular, up to 15 cm long, 6 to

13 mm wide with 17 to 27 longitudinal veins, margin with teeth, apex rounded, comparatively emarginate. Male flower with 4 to 6 alternating bracts, anthers are 6 to 7 mm long. From the female flower ovary 2 mm long, 4 mm long style, 20 mm long stigmata. False fruit up to 3.5 to 5 cm long and these species are viviparous reproduction (40).

Thalassodendron leptocaule

The seagrasses *T. leptocaule* are dioecious, perennial seagrass; the diameter of rhizomes 3 mm with a sympodial branch; the vertical rhizomes are rare; usually, roots are much-branched, 0.5 to 6 mm internodes are much condensed. Scales are 5 mm, and broadly ovate, dark brown. Stems are 70 cm long and 1 to 2 mm in width. These are erect; little branched or unbranched, and per shoots the leaves with 4 to 6. The length of the leaf sheaths up to 10 to 30 mm and the width 3 to 9 mm. 10 mm circular scars with irregular space. The leaf blades are usually falcate; the length up to 3 to 9 and the width 30.3 to 0.7 cm; leaf apex are united; the median and lateral veins are slightly prominent; the cells between secondary veins present 15 to 23 rows. Male flower enclosed leafy bract, sessile; anthers are 2.5 mm long, 2 dorsally connate lengths attached at the same height with short terminal appendage have 5mm. The female flowers have covered with 3 leafy bracts; all are differentiated into heath and a blade, with 0.5 to 0.75 mm. The outermost first bract with a sheath up to 13 to 5 mm, the blades are slightly smaller; the second bract with a sheath 16 to 22 mm, and blades are somewhat longer or shorter; third bracts are 14 to 20 mm in size, the blades are identical or longer, the apex with slightly falcate, the ovary ellipsoid size are 1.5 to 2 mm; obscurely veined, style divided into 2 stigmatic arms, with 12 to 16 mm. Seedlings are viviparous (34).

Thalassodendron pachyrhizum

The 2 thick, hard woody roots at every fourth node with rhizome robust. The branched erect stem little, up to 20 cm long developing from the nodes following the root-bearing nodes. Leaf-blades are linear, semi-circular, up to 30 cm long, 6 to 14 turn wide, with longitudinal veins 13 to 19, rounded apex, serrated. 4 to 6 alternating bracts with male flower, anthers up to 20 mm long, with a pointed attachment, and a slightly bifurcated tip. Female flower with ovary up to 2 mm long, style 1 mm long, stigmas 20 turns long. The false fruits are 5.5 to 7 cm long. These are viviparous reproduction (40).

Secondary metabolites from family *Cymodoceaceae* species

The Secondary metabolites from *Cymodoceaceae* phytoconstituents are given in **Table 1**. The author Zapata and McMillan (42) investigated the occurrence of compound phenolic acids in the study of extraction procedures using paper chromatography

Table 1: An overview of the identified phytoconstituents from family *Cymodoceaceae.*

S. No	Compound name	Species	Reference source	S. No	Compound name	Species	Reference source
1	Brominated briarane diterpene	*C. nodosa*	(46)	16	Gentisic acid	*C. rotundata*, *C. serrulata*, *H. uninervis*, *T. ciliatum*, *H. wrightii*, *S. filiforme*, *S. isoetifolium*	(42)
2	Caffeic acid	*C. rotundata*, *C. serrulata*, *H. uninervis*, *T. ciliatum*, *H. wrightii*, *S. filiforme*, *S. isoetifolium*, *A. antarctica*, *A. griffithii*	(42,50)	17	Isofucosterol	*C. serrulata*, *H. uninervis*	(43)
3	Caftaric acid	*S. filiforme*	(50)	18	Meroterpenoid	*C. nodosa*	(46)
4	Campesterol	*C. serrulata, H. uninervis*	(43)	19	Phenylheptanoids	*C. nodosa*	(45)
5	Cholesterol	*C. serrulata, H. uninervis*	(43)	20	p-Hydroxybenzoic acid	*C. rotundata*, *C. serrulata*, *H. uninervis*, *T. ciliatum*, *H. wrightii*, *S. filiforme*, *S. isoetifolium*, *A. antarctica*, *A. griffithii*	(42,50)
6	Cichoric acid	*C. nodosa*, *S.filiforme*	(48,50)	21	Protocatechuic acid	*C. rotundata*, *C. serrulata*, *H. uninervis*, *T. ciliatum*, *H. wrightii*, *S. filiforme*, *S. isoetifolium*, *A. antarctica*, *A. griffithii*	(42)
7	Cinnamic acid	*S. filiforme*	(50)	22	Vanillic acid	*C. rotundata*, *C. serrulata*, *H. uninervis*, *T. ciliatum*, *H. wrightii*, *S. filiforme*, *S. isoetifolium*, *A. antarctica*, *A. griffithii*	(42,50)
8	Coumaric acid	*C. rotundata*, *C. serrulata*, *H. uninervis*, *T. ciliatum*, *H. wrightii*, *S. filiforme*, *S. isoetifolium*, *A. antarctica*, *A. griffithii*	(42)	23	Stigmasterol	*C. serrulata*, *H. uninervis*	(43)
9	Coutaric acid	*S. filiforme*	(50)	24	Sulfated caffeoyl quinic acid	*S. filiforme*	(49)
10	Dicoumaroyltartaric acid	*S. filiforme*	(50)	25	β-Sitosterol	*C. serrulata*, *H. uninervis*	(43)
11	Diferoyltartaric acid	*S. filiforme*	(50)	26	6-β-hydroxy-(20R) -24-ethylcholesta-4-en-3-one	*C. nodosa*	(47)
12	Diterpene hydrocarbons	*A. Antarctica*	(44)	27	6-β-hydroxy-(20R) -24-ethylcholesta-4,22-dien-3-one	*C. nodosa*	(47)
13	Fertaric acid	*S. filiforme*	(50)	28	(20R)-22E-24-ethylcholesta-4,22-dien- 3-one	*C. nodosa*	(47)
14	Ferulic acid	*C. rotundata*, *C. serrulata*, *H. uninervis*, *T. ciliatum*, *H. wrightii*, *S. filiforme*, *S. isoetifolium*, *A. antarctica*, *A. griffithii*	(42)	29	(20R) -24-ethylcholesta-4-en-3-one	*C. nodosa*	(47)
15	Gallic acid	*C. rotundata*, *C. serrulata*, *H. uninervis*, *T. ciliatum*, *A. antarctica*	(42)				

technique: p-Hydroxybenzoic acid, Protocatechuic acid, Vanillic acid, Gallic acid, Gentisic acid, Coumaric acid, Caffeic acid, Ferulic acid compounds were detected from the species *C. rotundata*, *C. serrulata*, *H. uninervis*, *T. ciliatum*. The seagrass species *H. wrightii*, *S. filiforme*, *S. isoetifolium* identified the compounds p-Hydroxybenzoic acid, Protocatechuic acid, Vanillic acid, Gentisic acid, Coumaric acid, Caffeic acid, Ferulic acid. Species *A. antarctica* investigated compounds p-Hydroxybenzoic acid, Protocatechuic acid, Vanillic acid, Gallic acid, Coumaric acid, Caffeic acid, Ferulic acid. Seagrass *A. griffithii,* the identified compounds are p-Hydroxybenzoic acid, Protocatechuic acid, Vanillic acid, Coumaric acid, Caffeic acid, Ferulic acid.

The distributed sterol compounds were analyzed by Gillan et al. (43). Interestingly, all the five compounds: Cholesterol, Campesterol, β-Sitosterol, Isofucosterol, and Stigmasterol were detected in different quantities in these two investigated species: *C. serrulata* and *H. uninervis*. In *A. antarctica*, compound: Diterpene hydrocarbons (Diterpenoids) were identified (44).

The authors Kontiza et al. (45,46) investigated the species *C. nodosa* and showed the compound Phenylheptanoids and in addition to that investigated ketosteroids compounds like: (20R) -24-ethylcholesta-4-en-3-one, (20R)-22E-24-ethylcholesta-4,22-dien-3-one, 6-β-hydroxy-(20R) -24-ethylcholesta-4- en-3-one, 6-β-hydroxy-(20R) -24-ethylcholesta- 4,22-dien-3-one (47). Likewise, Kontiza et al. (46) identified the compounds Meroterpenoid and Brominated briarane diterpene. The high amount of compound Cichoric acid was found by Grignon-Dubois and Rezzonico (48) in the detritus from the same specimens of *C. nodosa*.

Apart from the virtual studies the author Zapata

Vol. 15 (4) 436 - 446, October 2021, ISSN 0973-8916 (Print), 2230-7303 (Online)
DOI: 10.5530/ctbp.2021.4.46

and McMillan (42) and Gillan et al. (43) reported to the best of their knowledge that there are no secondary metabolites reported from species of the genus *Halodule*. In *S. filiforme*, Harborne and Williams (49) reported on the incidence partially characterized by compound derivatives like sulfated caffeoyl quinic acid. Nuissier et al. (50) identified in the fresh leaves and detritus of leaves, the main phenolics compounds Cichoric acid and Caftaric acid from *S. filiforme*. Besides that, traces of tartaric acid derivatives like Coutaric acid, Dicoumaroyltartaric acid, Fertaric acid, Diferoyltartaric acid were detected. And traces of simple phenolic acids like p-Hydroxybenzoic acid, Vanillic acid, Caffeic acid, Cinnamic acid were also detected.

The secondary metabolites from seagrass *C. nodosa* act as allelopathic effects of a competing organism. The author identified the compound sesquiterpene caulerpenyne but the co-occurring compounds, caulerpin and caulerpicin, have an inhibitory effect on the studied seagrass species (51).

Bioactivities reported from seagrass *Cymodoceaceae* family

Phytochemical analysis

Three different extracts like methanol, ethanol, and acetone were used as the qualitative phytochemical test from *C. rotundata* species. Ethanol and methanol extracts showed positive phytoconstituents such as tannins, saponins, resins, proteins, acidic compounds, reducing sugars, terpenoids, cardiac glycosides, alkaloids, saponins and cardiac glycosides. The phytocomponents saponins and cardiac glycosides are absent in the acetone extract. The compounds flavonoids, catechols, phenols showed negative results in all the three extracts (52). Hardoko et al. (53) explained the secondary metabolites of hexane, ethyl acetate, and ethanol extracts from seagrass *C. serrulata* showed flavonoid, polyphenol, alkaloid, and terpenoid. At the same time the author has investigated and reported that these compounds can be used as anti-inflammation, anticancer, antibacterial, and antifungal drugs.

The author has identified the phenolic compounds present in the seagrass species *H. pinifolia* and reported that phenolic compounds are high-level antioxidant agents, these compounds include reactive superoxide radical, hydroxyl radical, peroxide radicals and nitric oxide radicals because it scavenges toxic free radicals (54). Baehaki et al. (55) identified the methanol extract of *H. uninervis* shows phytochemical compounds like flavonoids, alkaloids, steroids, and phenols.

Antimicrobial activity

The aqueous methanol extracts from the marine species of seagrasses *H. pinifolia* and *S. isoetifolium* act as the zone of inhibition against the marine fouling bacterial strains. No zone of inhibition has shown *H. pinifolia* against any of the tested bacteria, but *H. pinifolia* showed simply weak inhibition against the *Anterobacteriaceae*. The weak zone of inhibition has been shown from *S. isoetifolium* against the strains of *Anterobacteriaceae*, *Alkalegenes*, *Arthrobacterium*, *Flavobacterium* and *Pseudomonas* (56).

The organic extracts from *H. beaudettei* and *S. filiforme* were extracted and fractionated from the lipophilic and hydrophilic constituents. The most active inhibiting growth was shown in all the fractions of *H. beaudettei* against *Halophytophthora spinosa*, *Schizochytrium aggregatum*, and *Pseudoalteromonas bacteriolytica*. The fractions from *S. filiforme* were shown to be active as against *Schizochytrium aggregatum* and *Pseudoalteromonas bacteriolytica* (57).

The author has investigated antifungal activity from the seagrasses *H. wrightii* and *S. filiforme* against *Dendryphiella salina*, *Lindra thalassiae*, and the three species of *Fusarium*. The organic extract of *S. filiforme* has shown the inhibiting the growth of *Lindra thalassiae* and, *Fusarium* species. The extract, *H. wrightii*, showed active against the most susceptible *Fusarium* species (58).

The secondary metabolites like phenylheptanoids, meroterpenoid, and brominated briarane diterpene from *C. nodosa* were evaluated for their antibacterial activity (46) and in particular, the compound meroterpenoid was found to possess pronounced activity. Kumar et al. (59) described antibacterial activity using the agar diffusion test assay obtained from the organic solvent extracts from *C. serrulata*. The author has reported that methanol and ethyl acetate extracts have the most pronounced activity against human pathogens of *Bacillus cereus*, *Bacillus subtilis*, *Escherichia coli*, *Micrococcus luteus*, *Salmonella paratyphi*, *Salmonella typhimurium*, and *Staphylococcus aureus*. Recently, Iyapparaj et al. (60) investigated the organic solvents (dichloromethane, acetone and methanol) of *C. serrulata* and *S. isoetifolium* extracts. The methanol extracts showed maximum inhibition of both *C. serrulata* and *S. isoetifolium* against biofilm-forming bacteria and antimicroalgal activity.

The author Kannan et al. (61) investigated hexane, chloroform and, the methanol extracts of seagrasses *H. pinifolia* and *C. serrulata* against seven pathogens *Staphylococcus aureus*, *Vibrio cholera*, *Shigella dysentriae*, *Shigella bodii*, *Salmonella paratyphi*, *Pseudomonas aeruginosa* and *Klebsiella pneumoniae*. The n-hexane extracts of *H. pinifolia* and *C. serrulata* shown absent in the zone of inhibition against *S. aureus*; whereas methanol and chloroform extracts showed better antibacterial activity against all the tested pathogens.

Antimacrofouling activity

The author has investigated antimacrofouling activity using the assay; a mollusc foot adherence assay, an antimussel bioassay, and an anticrustacean assay from dichloromethane, acetone, and methanol extracts of *C. serrulata* and *S. isoetifolium*. Maximum activity was seen in methanol extracts of both *C. serrulata* and *S. isoetifolium*, respectively (60).

Anticancer activity

The compound cymodienol from *C. nodosa* species showed *in vitro* cytotoxicity in opposition to two human lung cancer cell lines. At the same time as the compound, cymodiene (phenylheptanoids) from the same source *C. nodosa* was moderately active against two human lung cancer cell lines (45). Kolsi et al. (62) investigated the sulfated polysaccharide isolated from *C. nodosa* extract and has shown potential *in vitro* antitumor activity in human HeLa cell line from cervical cancer.

The author has reported fresh leaves of hexane, ethyl acetate, and ethanol extracts from *C. serrulata* used as *in vitro* anticancer activity against the HeLa cell line. The hexane extract has no anticancer activity, whereas ethyl acetate and ethanol extracts have shown potential anticancer activity against the HeLa cell line (53). The ethyl acetate fraction of *H. pinifolia* was tested against the MCF-7 breast cancer cells and normal Vero cell line for cytotoxicity activity. The secondary metabolites have shown no changes in the Vero cell line but they showed toxicity against MCF-7 cancer cells (63).

Antioxidant activity

The author has isolated the phenolics group with more than one free hydroxyl compounds from *T. ciliatum* and showed antioxidant activity by DPPH radical scavenging assay method (64). The study report has shown that a sulfated polysaccharide extracted from *C. nodosa* seagrass acts as closely correlated to the reducing power and total antioxidant activity (62) Simultaneously, Kolsi et al. (62) reported that the secondary metabolites from seagrasses have natural antioxidant activity.

In vitro total antioxidant activities of seagrasses are limited. The species *H. pinifolia* showed stronger antioxidant activity than *S. isoetifolium* when thin-layer chromatography was used (65). Athiperumalsami et al. (66) reported the highest antioxidant activity in the methanolic extract of *H. pinifolia* tested by nitric oxide scavenging assay. The methanolic extract of *H. uninervis* species showed, the presence of flavonoids resulting in the formation of stable free radicals from DPPH scavenging assay. At the same time, the presence of phenol compound inactivates oxidants from reducing power (55).

Conclusion

Seagrasses have very important role to play in the aquatic ecosystem, and seagrasses are an important coastal system that gives shelter, food, habitat, and nursery areas in the world's oceans. Worldwide, seagrasses provide sediment stabilizing, filtering, and other ecosystem services. Most importantly, many people depend on coastal seagrasses for agricultural survival like farming, fishing, and medicinal utility. Especially, the seagrass biomass used as human food by the coastal population. Morphological basis of seagrasses and anatomical studies are important for the documentation of variations within the species. Phytochemical, physiological and biological researches are deposited in the herbaria databases for future study and to improve the species. The seagrasses ecosystem directly relates to the human population in terms of biological services such as health sector, agricultural and industrial applications.

The seagrass species *Cymodoceaceae* is unique to marine environment. Marine mammals such as sea cows, sea dungeons and green turtles may contribute to the higher calorific value of seagrasses which gives us enormous responsibility for their long lifespan. Phenolic, alkaloids, and sulfated polysaccharides compounds present in *Cymodoceaceae* make them perspective and recoverable bioactive substances. Therefore, the attractive factors of seagrasses may have significant economic importance. The natural bioactive compounds from seagrasses are the primary focus for the researches and they are currently monitored for antioxidant, antimicrobial, antitumor, anti-inflammatory and anti-proliferative activity. The phenolic content of the seagrasses demonstrates the successful therapeutic applications for treatment of cancer. Several studies have reported that phenols are the major contributor to the antioxidant capacities of seagrasses. We conclude that seagrasses have strong antioxidant properties due to the total phenolic content.

The chemical composition, nutritional values and bioactive components existing *Cymodoceaceae* seagrasses species also have various biological properties like cytotoxic, antimacrofouling and antimicrobial activities. Consequently, further bioassays purification and structural characterization of these biological metabolites will yield significant information about their usage in pharmaceuticals, nutraceuticals, cosmetics, and functional food industries, in addition to alternative medicine and natural therapies. Scientific conservation will provide a sustained coastal ecosystem. India needs to undertake a thorough survey of seagrasses and its bioprospecting aspects in all the coastal areas for a better future in pharmaceuticals, food and feed industries.

Acknowledgement

The authors deliver their sincere gratitude to the Head, Department of Plant Biology and Plant Biotechnology, Presidency College (Autonomous), Chennai - 600 005 and the Head, Department of Biotechnology, University of Madras, Guindy Campus, Chennai - 600 025 for providing their guidance and support.

Conflict of interest

The authors claim that there is no conflict of interest.

References

1. Paramasivam, K., Venkataraman, K., Venkatraman, C., Rajkumar, R. and Shrinivaasu, S (2015). Diversity and distribution of sea grass associated macrofauna in Gulf of Mannar biosphere reserve, Southern India. Marine Faunal Diversity in India, 137-160.

2. Dewsbury, B.M., Bhat, M. and Fourqurean, J.W. (2016). A review of seagrass economic valuations: gaps and progress in valuation approaches. Ecosystem Services, 18: 68-77.

3. Kawaroe, M., Nugraha, A.H., Juraij, J. and Tasabaramo, I.A. (2016). Seagrass biodiversity at three marine ecoregions of Indonesia: Sunda Shelf, Sulawesi Sea, and Banda Sea. Biodiversitas, 17(2): 585-591.

4. Costanza, R., d'Arge R., Groot, R.D., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'Neill, R.V., Paruelo, J., Raskin, R.G., Sutton, P. and Van Den Belt, M. (1997). The value of the world's ecosystem services and natural capital. Nature, 387(6630): 253-260.

5. Phillips, R.C. and Durako, M.J. (2000). Global status of seagrasses. In Elsevier Science Inc..

6. Wahab, I., Madduppa, H. and Kawaroe, M. (2017). Seagrass species distribution, density and coverage at Panggang Island, Jakarta. IOP Conference Series: Earth and Environmental Science, 54(1): 012084.

7. McRoy, C.P. and Helfferich, C. (1977). Seagrass ecosystems: a scientific perspective. Mareel Dekker. Inc., New York, pp.314.

8. Hemminga, M.A. and Duarte, C.M. (2000). Seagrass ecology. Cambridge University Press.

9. Short, F., Carruthers, T., Dennison, W. and Waycott, M. (2007). Global seagrass distribution and diversity: a bioregional model. Journal of Experimental Marine Biology and Ecology, 350(1-2): 3-20.

10. Beck, M.W., Heck, K.L., Able, K.W., Childers, D.L., Eggleston, D.B., Gillanders, B.M., Halpern, B., Hays, C.G., Hoshino, K., Minello, T.J., Orth, R.J., Sheridan, P.F. and Weinstein, M.P. (2001). The identification, conservation, and management of estuarine and marine nurseries for fish and invertebrates: a better understanding of the habitats that serve as nurseries for marine species and the factors that create site-specific variability in nursery quality will improve conservation and management of these areas. Bioscience, 51(8): 633-641.

11. De Wilde, P.A.W.J., Kastoro, W.W., Berghuis, E.M., Aswandy, I., Al Hakim, I. and Kok, A. (1989). Structure and energy demand of the benthic soft-bottom communities in the Java Sea and around the islands of Madura and Bali, Indonesia. Netherlands Journal of Sea Research, 23(4): 449-461.

12. Lirman, D., Ault, J.S., Fourqurean, J.W. and Lorenz, J.J. (2019). The coastal marine ecosystem of south Florida, United States. In World Seas: an Environmental Evaluation, 427-444.

13. Phillips, R.C. and Milchakova, N.A. (2003). Seagrass ecosystems. Biology and Ecology, 350: 3-20.

14. Jeyapragash, D., Subhashini, P., Raja, S., Abirami, K. and Thangaradjou, T. (2016). Evaluation of *in-vitro* antioxidant activity of seagrasses: signals for potential alternate source. Free Radicals and Antioxidants, 6(1): 77-89.

15. Brodie, G. and N'Yeurt, D.R.A. (2018). Effects of climate change on seagrasses and seagrass habitats relevant to the Pacific Islands. Pacıfıc Marıne Clımate Change Report Card Science Review, 112-131.

16. Vieira, V.M., Lopes, I.E. and Creed, J.C. (2018). The biomass–density relationship in seagrasses and its use as an ecological indicator. BMC Ecology, 18(1): 44.

17. Gullström, M., de la Torre Castro, M., Bandeira, S.O., Björk, M., Dahlberg, M., Kautsky, N., Rönnbäck, P. and Ohman, M.C. (2002). Seagrass ecosystems in the western Indian Ocean. Ambio, 31(7): 588-596.

18. Shi, Y., Fan, H., Cui, X., Pan, L., Li, S. and Song, X. (2010). Overview on seagrasses and related research in China. Chinese Journal of Oceanology and Limnology, 28(2): 329-339.

19. Sullivan, B.K., Trevathan-Tackett, S.M., Neuhauser, S. and Govers, L.L. (2018). Host-pathogen dynamics of seagrass diseases under future global change. Marine Pollution Bulletin, 134: 75-88.

20. Jackson, E.L., Rowden, A.A., Attrill, M.J., Bossey, S.J. and Jones, M.B. (2001). The importance of seagrass beds as a habitat for fishery species.

Oceanography and marine biology, 39: 269-304.

21. Unsworth, R.K.F., McKenzie, L.J., Collier, C.J., Cullen-Unsworth, L.C., Duarte, C.M., Eklöf, J.S., Jarvis, J.C., Jones, B.L. and Nordlund, L.M. (2019). Global challenges for seagrass conservation. Ambio, 48(8): 801-815.

22. Newmaster, A.F., Berg, K.J., Ragupathy, S., Palanisamy, M., Sambandan, K. and Newmaster, S.G. (2011). Local knowledge and conservation of seagrasses in the Tamil Nadu State of India. Journal of Ethnobiology and Ethnomedicine, 7(1): 37.

23. Banu, J.R., Tamilarasan, K., Rani, R.U., Gunasekaran, M., Cho, S.K. and Ala'a, H. (2019). Dispersion aided tenside disintegration of Seagrass *Syringodium isoetifolium:* Towards biomethanation, kinetics, energy exploration and evaluation. Bioresource Technology, 277: 62-7.

24. Ganguly, D., Singh, G., Ramachandran, P., Selvam, A.P., Banerjee, K. and Ramachandran, R. (2017). Seagrass metabolism and carbon dynamics in a tropical coastal embayment. Ambio, 46(6): 667-679.

25. Ravikumar, S., Gnanadesigan, M., Saravanan, A., Monisha, N., Brindha, V. and Muthumari, S. (2012). Antagonistic properties of seagrass associated *Streptomyces* sp. RAUACT-1: a source for anthraquinone rich compound. Asian Pacific Journal of Tropical Medicine, 5(11): 887-890.

26. Ali, M.S., Ravikumar, S. and Beula, J.M. (2012). Bioactivity of seagrass against the dengue fever mosquito *Aedes aegypti* larvae. Asian Pacific Journal of Tropical Biomedicine, 2(7): 570-3.

27. Raja, S., Thangaradjou, T., Sivakumar, K. and Kannan, L. (2012). Rhizobacterial population density and nitrogen fixation in seagrass community of Gulf of Mannar, India. Journal of Environmental Biology, 33(6): 1033.

28. den Hartog, C. and Kuo, J. (2007). Taxonomy and biogeography of seagrasses. In Seagrasses: biology, ecologyand conservation. Springer, Dordrecht, 1-23.

29. Les, D.H. and Tippery, N.P. (2013). In time and with water... the systematics of alismatid monocotyledons. Early events in monocot evolution, 83: 118-164.

30. Kuo, J. and Den Hartog, C. (2000). Seagrasses: A profile of an ecological group. Biologia Marina Mediterranea, 7(2): 3-17.

31. Chase, M.W., Christenhusz, M.J.M., Fay, M.F., Byng, J.W., Judd, W.S., Soltis, D.E., Mabberley, D.J., Sennikov, A.N., Soltis, P.S. and Stevens, P.F. (2016). An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG IV. Botanical Journal of the Linnean Society, 181(1): 1-20.

32. Short, F.T., Polidoro, B., Livingstone, S.R., Carpenter, K.E., Bandeira, S., Bujang, J.S., Calumpong, H.P., Carruthers, T.J.B., Coles, R.G., Dennison, W.C., Erftemeijer, P.L.A., Fortes, M.D., Freeman, A.S., Jagtap, T.G., Kamal, A.H.M., Kendrick, G.A., Kenworthy, W.J., La Nafie, Y.A., Nasution, I.M., Orth, R.J., Prathep, A., Sanciangco, J.C., Van Tussenbroek, B., Vergara, S.G., Waycott, M. and Zieman, J.C. (2011). Extinction risk assessment of the world's seagrass species. Biological Conservation, 144(7): 1961-1971.

33. Kuo, J. and McComb, A.J. (1998). Cymodoceaceae. In *Flowering Plants· Monocotyledons*. Springer, Berlin, Heidelberg, 133-140.

34. Duarte, M.C., Bandeira, S. and Romeiras, M.M. (2012). Systematics and ecology of a new aspecies of seagrass (*Thalassodendron*, Cymodoceaceae) from Southeast African coasts. Novon: A Journal for Botanical Nomenclature, 22(1): 16-24.

35. Browne, C.M., Milne, R., Griffiths, C., Bolton, J.J. and Anderson, R.J. (2013). Epiphytic seaweeds and invertebrates associated with South African populations of the rocky shore seagrass *Thalassodendron leptocaule*—a hidden wealth of biodiversity. African Journal of Marine Science, 35(4): 523-531.

36. Den Hartog, C. (1970). Origin, evolution and geographical distribution of the seagrasses. Verhandelingen-Koninklijke Nederkindse Akademie van Wetenschappen Afdeling Natuurkunde, 59: 12-38.

37. Tomlinson, P,B. (1982). Helobiae (Alismatidae). Metcalfe, CR (ed.), Anatomy of the monocotyledons, 7.

38. Paul, V.J., Nelson, S.G. and Sanger, H.R. (1990). Feeding preferences of adult and juvenile rabbitfish *Siganus argenteus* in relation to chemical defenses of tropical seaweeds. Marine Ecology Progress Series, 60(1): 23-34.

39. Meyer, K.D., Paul, V.J., Sanger, H.R. and Nelson, S.G. (1994). Effects of seaweed extracts and secondary metabolites on feeding by the herbivorous surgeonfish *Naso lituratus*. Coral Reefs, 13(2): 105-112.

Vol. 15 (4) 436 - 446, October 2021, ISSN 0973-8916 (Print), 2230-7303 (Online)
DOI: 10.5530/ctbp.2021.4.46

40. Kuo, J. and Den Hartog, C. (2001). Seagrass taxonomy and identification key. Global seagrass research methods, 33: 31-58.

41. den Hartog, C. (1964). An approach to the taxonomy of the sea-grass genus Halodule Endl. (Potamogetonaceae). Blumea, 12(2): 289-312.

42. Zapata, O. and McMillan, C. (1979). Phenolic acids in seagrasses. Aquatic Botany, 7: 307-317.

43. Gillan, F.T., Hogg, R.W. and Drew, E.A. (1984). The sterol and fatty acid compositions of seven tropical seagrasses from North Queensland, Australia. Phytochemistry, 23(12): 2817-2821.

44. Dunlop, R.W. (1985). Diterpenoid hydrocarbons in the sea grass *Amphibolis antartica*. Phytochemistry, 24(5): 977-9.

45. Kontiza, I., Vagias, C., Jakupovic, J., Moreau, D., Roussakis, C. and Roussis, V. (2005). Cymodienol and cymodiene: new cytotoxic diarylheptanoids from the sea grass *Cymodocea nodosa*. Tetrahedron Letters, 46(16): 2845-7.

46. Kontiza, I., Stavri, M., Zloh, M., Vagias, C., Gibbons, S. and Roussis, V. (2008). New metabolites with antibacterial activity from the marine angiosperm *Cymodocea nodosa*. Tetrahedron, 64(8): 1696-1702.

47. Kontiza, I., Abatis, D., Malakate, K., Vagias, C. and Roussis, V. (2006). 3-Keto steroids from the marine organisms *Dendrophyllia cornigera* and *Cymodocea nodosa*. Steroids, 71(2): 177-181.

48. Grignon-Dubois, M. and Rezzonico, B. (2013). The economic potential of beach-cast seagrass–*Cymodocea nodosa*: a promising renewable source of chicoric acid. Botanica Marina, 56(4): 303-311.

49. Harborne, J.B. and Williams, C.A. (1976). Occurrence of sulphated flavones and caffeic acid esters in members of the fluviales. Biochemical Systematics and Ecology, 4(1): 37-41.

50. Nuissier, G., Rezzonico, B. and Grignon-Dubois, M. (2010). Chicoric acid from *Syringodium filiforme*. Food Chemistry, 120(3): 783-8.

51. Raniello, R., Mollo, E., Lorenti, M., Gavagnin, M. and Buia, M.C. (2007). Phytotoxic activity of caulerpenyne from the Mediterranean invasive variety of *Caulerpa racemosa*: a potential allelochemical. Biological Invasions, 9(4): 361-8.

52. Mani, A.E., Bharathi, V. and Patterson, J. (2012). Antibacterial activity and preliminary phytochemical analysis of seagrass *Cymodocea rotundata*. International Journal of Microbiology, 3(2): 99-103.

53. Hardoko, P.D. and Yuli, E. (2016). Anticancer potential of seagrass leaves *Cymodecea serrulata* crude extract on HeLa cell. Journal of Chemical and Pharmaceutical Research, 8(1): 571-6.

54. Rengasamy, R.R.K., Rajasekaran, A., Micheline, G.D. and Perumal, A. (2012). Antioxidant activity of seagrasses of the Mandapam coast, India. Pharmaceutical Biology, 50(2): 182-7.

55. Baehaki, A., Supriadi, A. and Pratama, M.C. (2016). Antioxidant activity of methanol extract of *Halodule uninervis* seagrass from the coastal of Lampung, Indonesia. Research Journal of Pharmaceutical, Biological and Chemical Sciences, 7(3): 1173-7.

56. Devi, P., Solimabi, W., D'Souza, L., Sonak, S., Kamat, S.Y. and Singbal, S.Y.S. (1997). Screening of some marine plants for activity against marine fouling bacteria. Botanica Marina, 40(2): 87-91.

57. Engel, S., Puglisi, M.P., Jensen, P.R. and Fenical, W. (2006). Antimicrobial activities of extracts from tropical Atlantic marine plants against marine pathogens and saprophytes. Marine Biology, 149(5): 991-1002.

58. Ross, C., Puglisi, M.P. and Paul, V.J. (2008). Antifungal defenses of seagrasses from the Indian River Lagoon, Florida. Aquatic Botany, 88(2): 134-141.

59. Kumar, C.S., Sarada, D.V.L., Gideon, T.P. and Rengasamy, R. (2008). Antibacterial activity of three South Indian seagrasses, *Cymodocea serrulata*, *Halophila ovalis* and *Zostera capensis*. World Journal of Microbiology & Biotechnology, 24(9): 1989-1992.

60. Iyapparaj, P., Revathi, P., Ramasubburayan, R., Prakash, S., Palavesam, A., Immanuel, G., Anantharaman, P., Sautreau, A. and Hellio, C. (2014). Antifouling and toxic properties of the bioactive metabolites from the seagrasses *Syringodium isoetifolium* and *Cymodocea serrulata*. Ecotoxicology and environmental safety, 103: 54-60.

61. Kannan, R.R.R., Arumugam, R. and Anantharaman, P. (2010). Antibacterial potential of three seagrasses against human pathogens. Asian Pacific Journal of Tropical Medicine, 3(11): 890-3.

62. Kolsi, R.B.A., Gargouri, B., Sassi, S., Frikha, D., Lassoued, S. and Belghith, K. (2017). *In vitro* biological properties and health benefits of a novel

Vol. 15 (4) 436 - 446, October 2021, ISSN 0973-8916 (Print), 2230-7303 (Online)
DOI: 10.5530/ctbp.2021.4.46

sulfated polysaccharide isolated from *Cymodocea nodosa*. Lipids in Health and Disease, 16(1): 1-11.

63. Girija, K., Hemalatha, A. and Anantharaman, P. (2013). *In vitro* Antiproliferative activity of Seagrass *Halodule pinifolia* (Miki) on MCF7 Human Breast Cancer Cell Line. Advances in Bioresearch, 4(4): 134-7.

64. Hamdy, A.H.A., Mettwally, W.S.A., Abou El Fotouh, M., Rodriguez, B., El-Dewany, A.I., El-Toumy, S.A.A. and Hussein, A.A. (2012). Bioactive phenolic compounds from the Egyptian Red Sea seagrass *Thalassodendron ciliatum*. Zeitschrift für Naturforschung C, 67(5-6): 291-6.

65. Kannan, R.R.R., Arumugam, R., Meenakshi, S. and Anantharaman, P. (2010). Thin layer chromatography analysis of antioxidant constituents from seagrasses of Gulf of Mannar Biosphere Reserve, South India. International Journal of ChemTech Research, 2(3): 1526-1530.

66. Athiperumalsami, T., Rajeswari, V.D., Poorna, S.H., Kumar, V. and Jesudass, L.L. (2010). Antioxidant activity of seagrasses and seaweeds. Botanica Marina, 53(3): 251-7.