BANO ET AL (2017), *FUUAST J.BIO*L., 7(2): 231-239

DISTRIBUTION OF EPIPHYTIC CYANOBACTERIA ON RED MACROALGAL SPECIES OCCURRING AT A ROCKY SHORE (BULEJI), KARACHI, PAKISTAN

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خلاصہ

موجودہ مطالعہ کے دوران cyanobacteria کی نوع بھولے جی کراچی کے ساحل سے معلوم ہوا کی گئی۔کل 67انواع سرخ الجی کے ساتھ چپکی ہوئی حالت میں اس گرہ کی پائی گئی ہیں۔ رودافائی سی انواع ہیں Melanothammus somalliens, Laurencia pinnatifida, ceramium monorencse, centroeras clavulatum, Hypxeapannusa, callibliphris fimbriata, Galaxaures oblongata موجود تھیں۔Cyanobetesia کی انواع کی جماعت بندی 4 آدرز میں کی گئی یعنی آڈر Nostocales میں Chroococcale 641میں Chamaesiphonales,17 میں 6اور pleurocapsales آڈر میں دو انواع رکھیں گئیں۔ سب سے زیادہ افراد یعنی 23انواع Hypnea pannusaپر جبکہ سب سے کم یعنی چھ انواع Calliblepharis fimbriata پر چپکی حالت میں پائی گئی۔
تین مختلف اقسام کے میڈیا (Miquels, MN, ASN)یا تو قدرتی تور پر تیار کیئے گئے یا مصنوعی سمندر کے پانی کو استعمال کیا گیا موجودی تجربات کے دوران

Abstract

In the present research the epiphytic species of cyanobacteria were recorded in the coastal region of Buleji, Karachi. In total 67 species of cyanobacteria were found attached to the surface of red algae. The rhodophycean species were *Galaxaura oblongata, Calliblipharis fimbriata, Hypnea pannosa, Centroceras clavlulatum, ceramium manorense, Laurencia pinnatifida* and *Melanothamnus somaliensis.* The species of cyanobacteria were classified in the four orders Nostocales, (41 species) Chroococcales (17 species), Chamaesiphonales (6 species) and Pleurocapsales (2 species). The highest number of cyanobacteria were attached with *Hypnea pannosa* (23 species) and the lowest number with *Calliblepharis fimbriata* (6 species). Three different media (ASNIII, MN and Miquel's) made of either natural or artificial seawater were used in this experiment.

Introduction

The epiphytic relationship of cyanobacteria appears to be symbiotic (Meeks and Elhai, 2002; Carpenter and Foster, 2002; Braun-Howland and Nierzwicki, 1990). The cyanobacterial associates receive carbon, nitrogen and other inorganic nutrients from the organisms it is attached to. For example, transfer of photosynthetic products, nitrogen and phosphorous has been shown (Yamamuro, 1999; Wetzel and Penhale, 1979; Penhale and Thayer, 1980; Harlin and Craigie, 1975; McRoy and Georing, 1974; Harlin, 1973). In return, plants are protected from the grazers (O'Neil and Roman, 1992; Hutchinson, 1975). Plants also obtain organic material from symbiotic cyanobacterial counterparts. Endosymbiotic cyanobacteria have been shown to fix dinitrogen and its products are used up by the plants in exchange of carbon and photosynthesis reductants supply to cyanobacteria (Lesser, *et al.*, 2004; Lesser, *et al.*, 2007). Such endosymbiosis is known for a variety of systems, viz, Ascomycetes (Gehrig *et al* 1996; Fogg *et al*, 1973), diatoms (Carpenter *et al.*, 1999; Villareal, 1989; Martinez *et al*., 1983), bryophytes from *Azolla* (McCowen, *et al.*, 1981; Kaplan and Peter, 1998), gymnosperm species of cycads (Thajuddin *et al.*, 2010; Stewart *et al.*, 1980) and angiosperm *Gunnera* (Johansson and Bergman, 1994; Rai, 1990a). Epiphytic cyanobacterial diazotrophs have also been reported from macroalgal species (Capone 1977; Capon *et al.*, 1977). Nitrogen fixing bacteria and cyanobacteria are, for example, reported on *Codium* and *Sargassum* species (Hamersley *et al*., 2015; Gerard *et al*., 1990; Phlips, *et al*., 1986; Carpenter, 1972; Hanson, 1977; Head and Carpenter, 1975). In nature, a variety of cyanobacteria attach themselves to submerged plants. Some of the epiphytic species are included in taxonomic work from India (Thajuddin and Subramanian, 2005; Desikachary, 1959).

From Pakistan epiphytic cyanobacteria are also reported from freshwater habitats (Malik *et al*., 2012; Ahmed *et al*., 2010; Shameel, 1987). A few reports are available marine environments (Uzair *et al.*, 2012; Javed *et al*., 2011; Bano and Siddiqui, 2004. Shameel and Butt 1984; Shameel and Tanaka, 1992; Saifullah and Taj, 1995; Nizamuddin and Gessner, 1970). As marine epiphytic cyanobacteria from Pakistani waters is scarcely known, studies on the epiphytic cyanobacteria from rocky shore of Karachi was conducted. The present research was undertaken with a view to expand the pool of knowledge regarding epiphytic cyanobacteria, particularly those growing on macroalgal species inhabiting intertidal zone of Buleji coast.

Materials & Methods

A total of 7 seaweeds were randomly collected from Buleji, a rocky coast of Karachi. List of the species is set out in Table (1). Seaweeds species were kept separately in polythene bags and brought to the laboratory. The seaweeds were gently washed with sterilized seawater to remove loosely attached epiphytic species and other organisms. The seaweeds were divided into different portions, for example, frond, utricle and rhizoids. Each portions was separately inoculated in tubes containing three different types of media ASNIII, MN and Miquel's media and incubated under cool florescent light (12L/ 12D) at 30 ± 2^{o}C.

All seaweeds were inoculated in triplicates and in some cases where growth was either low or unobservable experiments were repeated more rigorously. The field materials and growth obtained in culture tubes were observed under the light microscope. The taxonomic assessments Rippka *et al.,* 1979; Desikachary, 1959; Anagnostidis and Komarek, 1985, 1988, Komarek and Anagnostidis, 1986, 1989.

Results

Epiphyte species of cyanobacteria growing on red seaweeds (Rhodophyte) were observed and results are expressed in (Tables 1 and 2). A total of comprising 67 cyanobacterial species pertaining to 21 genera distributed among 4 orders (Chroococcales, Chamaesiphonales, Pleurocapsales and Nostocales) identified from seven species of red algae (Tables 1 and 2). Species in the order Stigonematales were not observed (Tables 1 and 2). The observed species mostly belongs to the orders Chroococcales (17 species) and Nostocales (42 species). The orders Chamaesiphonales and Pleurocapsales represented only 6 and 2 species respectively. (Table 1 and 2). Table 1 also shows that the Nostoccalean genera *Phormidium* (17 species) and *Oscillatoria* (8 species) were dominating among cyanobacterial flora. The other genera represented only a few species were *Dermocarpa* (5 species), *Lyngbea* (5 species), *Gloeocapsa* (3 species), *Chroococcus* (3 species), *Merismopedi*a (3 species), *Komvophoron* (3 species), *Psuedoanabaena* (3 species), *Spirulina* (3 species), *Synechocystis* (2 species), *Gloeothece* (2 species), and *Planktothrix* (2 species) (Table 1). A few genera (eight) represented by one species (Table 1). No cyanobacterial species belonging to orders Chamaesiphonales and Pleurocapsales were observed with associated with some red algae species (*Calliblepharis fimbriata*, *Galaxaura oblongata*, *Centroceras clavulatum*, and *Laurencia pinnatifida* (Table 1 and 2). Table 1 and 2 also illustrate the abundance of cyanobacteria on each species of red algae. A large number of cyanobacteria species were guested on *Hypnea pannosa* (23 species) and *Ceramium manorense* (20 species). The other rhodophytic species had variable numbers of cyanobacteria, such as, *Galaxaura oblongata* (23 species), *Laurencia pinnatifida* (17 species), *Centroceras clavulatum* (15 species), *Melanothamnus somaliensis* (15 species) and *Calliblepharis fimbriata* (6 species). A species-specific association also observed between cyanobacteria and rhodophytic species. Out of 67 species of cyanobacteria, over 50% species (39 species) were showed species-specific association i.e., attached to any one species of red algae (Table 1 and Fig.1). *Ceramium manorense* (9 species) and *Hypnea pannosa* (8 species) have greater number of species-specific cyanobacteria, whereas, *Galaxaura oblongata* (7 species) *Centroceras clavulatum* (5 species), *Melanothamnus somaliensis* (4 species) and *Laurencia pinnatifida* (6 species) had low numbers of associative cyanobacteria (Table 1 and Fig.1).

Epiphytic cyanobacteria were grown in all three media and result are described (Table 1). A large number of cyanobacteria (45 species) were grown in ASNIII medium. There were 33 and 30 species of cyanobacteria observed in Miguel's and MN media, respectively. 9 species were common in all three media while 17, 10 and 8 species appeared only in ASNIII, MN and Miquel's media (Table 1 & Fig.2).

Discussion

The information presented here put in to the regional wide range of records, and at the same time provide evidence the presence of various species cyanobacteria details from the other part of the globe in the northern Arabian Sea bordering Pakistan.

In all marine environments, available surfaces are quickly colonized by a diversity of life forms. However, these organisms grow on plants and macroalgae they are described epiphytes. Symbioses among cyanobacteria and marine organisms are sufficient and common among marine plants and animals (Rosenberg and Paerl, 1980). In the marine environment, symbioses are well-known to occur between cyanobacteriaand sponges, Ascidians (sea squirts), and Echuroid worms in the benthos, and diatoms, dinoflagellates and a protozoan with the plankton (Carpenter and Foster 2002).

The macroalgal species provide excellent substratum (stratum, nutrient and current) for the attachment and growth of various cyanobacterial species. In the current investigation, a number of the species of cyanobacteria among 67 species of cyanobacteria may be mandatory to be epiphytic in the marine environment. The species of macroalgae collected in this study were commonly distributed at the intertidal zone of rocky coast (Buleji). Cyanobacterial growth was observable on most of the species by naked eye. It is interesting to note that various species of cyanobacteria observed as epiphytic, which have previously been reported the same as edaphic, epilithic and planctonic from India (Desikachary, 1959), and also as epizoic from freshwater habitats from Pakistan (Khalid *et al*., 2014; Saifullahet *al.*,1997; Hussein and Anjum, 1982; Anjum *et al.*, 1980). The observed species have been reported from marine as well as freshwater habitats from different parts of the world (Ulcay *et al*., 2015; Aleem, 1980; Desikachary, 1959; Thajuddin and Subramanian, 1990, 1992, 1994; Santra and Pal, 1988; Shameel and Butt, 1984).

The observed cyanobacterial species, such as *Gloeocapsa compacta, Gloeothece rhodochlmys, Dermocarpa leibleiniae, Oscillatoria pseudogaminata, Phormidium angustissimum,* and *P. fragile*were attached on most of macroalgal species.This could be due to species preference of the habitat. Most of the cyanobacterial species reported in the study as epiphytic forms were also reported from various types of soil and hard substrata in terrestrial and aquatic habitats, such as, river soil, cultivated and non-cultivated soil, mud mangrove swamps, pneumatophores of mangrove, beach rocks, stones surfaces, associated with sea grasses and on macroalgae (Rigonato *et al*., 2012; Larkum, *et al*., 2012; Vizzini, *et al*., 2002; Borowitzka, *et al*., 2007; Saifullah and Ahmed, 2007; Bano and Siddiqui, 2004; Toledo *et al.*, 1995; Santra and Pal, 1988; Santra *et al.*, 1988; Maity *et al.*, 1987; Aleem, 1980; Desikachary, 1959). *Phormidium fragile* and *P. tenue* have also been described as epizoic on freshwater turtle and snail shells (Hussein and Anjum, 1982; Anjum*et al.*, 1980). The occurrence of *Chl* d-containing cyanobacteria in epiphytic biofilms on a red alga (*Gelidium caulacantheum*) occupied the pneumatophores of a temperate region mangrove (*Avicennia marina*) (Larkum, *et al*., 2012).

In the marine environment spongy surface of macroalgae provide a favorable habitat for attachments of cyanobacteria. Attachment of cyanobacteria and variability of species composition of associative cyanobacteria may simply be a function of variation in the habitat of macroalgae as noted above. It seems true for many species growing on surface macroalgae are also observed in other niches of Buleji coast (Bano and Siddiqui, 2017 a, b, 2004, 2003,). Furthermore, the taxonomy and morphology of epiphytic algae in the Indus-Delta were reported (Tanaka and Shameel 1992).

In addition, a lot of species recorded here have been reported from marine and freshwater habitats from India (Desikachary, 1959; Aleem, 1980; Santra and Pal, 1988; Santra *et al*., 1988; Maity*et al.*, 1987; Anand and Hooper, 1987; Thajuddin and Subramanian, 1990, 1992, 1994), and other parts of the world (Hussein and Khoja, 1993; Bauld, 1981; Hogdson and Abbot, 1992; Khoja, 1987).

The present study provide a basic information about epiphytic cyanobacteria on a variety of macroalgal species inhabiting the rocky shore of Buleji and confirms the presence of many species reported from other parts of the world in the Northern Arabian Sea bordering Pakistan.
Thus, advance research work has to be undertaken to obtain information about the diversity of epiphytic cyanobacteria in the marine environment.

Acknowledgments

The authors are thankful to Vice Chancellor, Lasbela University of Agriculture Water and Marine Science, for his invariable support for providing facilities. We also thank to the staff of faculty of Marine Science of LUAWMS for their assistance during preparation of this manuscript.

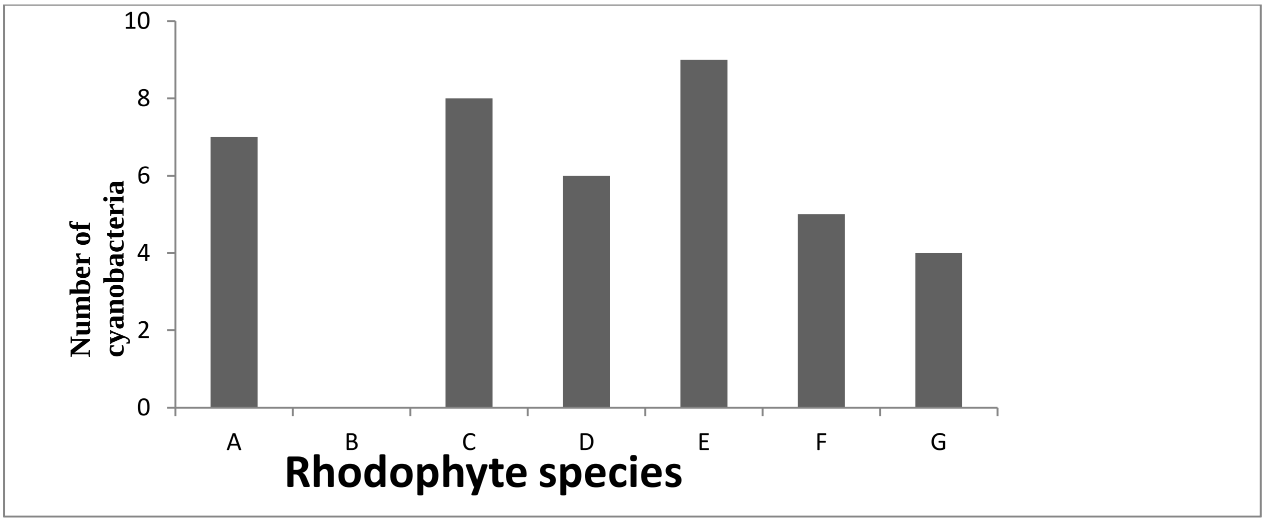

Fig. 1. Species-specific cyanobacteria associated with A- *Galaxaura oblongata*, B- *Calliblipharis fimbriata* C- *Hypnea pannosa*, D- *Centroceras clavlulatum*, E- *Ceramium manorense*, F- *Laurencia pinnatifida*, G- *Melanothamnus somaliensis*

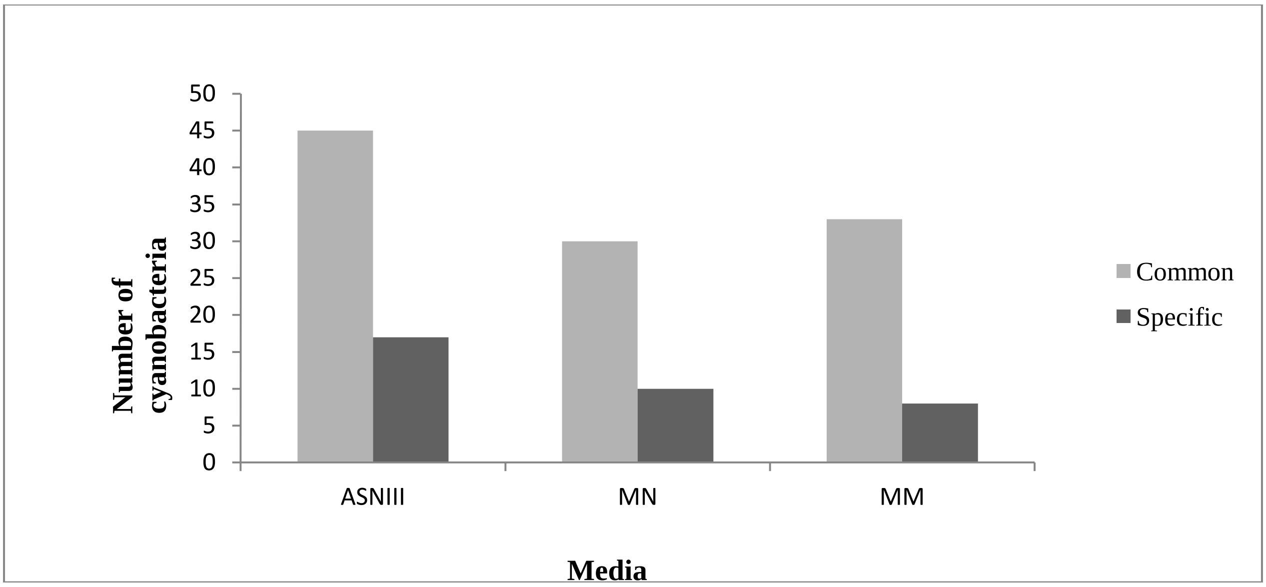

Fig. 2. Cyanobacterial species were common in all three media but some species showed up only in one specific medium.

Table1. Distribution of cyanobacterial species on seven different species of rhodophytes inhabiting a rocky shore of Buleji, near Karachi.

Cyanobacterial species	Medium*	*Galaxaura oblongata*	*Callibliphairs fimbriata*	*Hypnea pannosa*	*Centroceras clavlulatum*	*ceramium manorense*	*Laurencia pinnatifida*	*Melanothamnus somaliensis*
Chroococcales								
Synechocystis pevalekii	ASNIII, MN	-	-	-	-	-	+	+
S. aquatilis	MN	-	-	-	-	-	+	-
Gloeocapsa compacta	ASNIII, MM	+	+	+	-	-	-	-
G. cripidinum	ASNIII	+	+	-	-	-	-	-
G. punctata	MN, MM	-	-	+	-	-	-	-
Chroococcus cohaerence	MN	-	-	+	-	-	-	-
C. minutus	MN, MM	-	-	+	-	+	-	-
C. minor	ASNIII, MM	+	-	-	-	+	-	-
Synechococcus cedrorum	MN	-	-	-	-	+	-	-
Gloeothece samoensis	MN	-	-	-	-	-	-	+
G. rhodochlmys	ASNIII, MM	+	-	+	-	+	+	-
Aphanocapsa littoralis	ASNIII, MM	+	-	+	-	-	-	-
Aphnothece bullosa	ASNIII	+	-	-	-	-	-	-
Merismopedia elegans	MN	-	-	+	-	-	-	-
M. glauca	MN	-	-	-	+	-	-	-
M. tenuissima	MM	-	-	+	-	-	-	-

Coelosphaerium kuetzingianum	MN	-	-	+	-	-	-	-
Chamaesiphonales								
Chrroococidiopsis indica	MN	-	-	+	-	-	-	-
Dermocarpa leibleiniae	ASNIII, MN, MM	-	-	+	+	+	+	+
D. clavata	MN	-	-	-	-	-	+	-
D. flahaultii	MM	-	-	-	+	-	-	-
D. versicolor	MM	-	-	-	-	+	-	-
D. olivacea	ASNIII, MN, MM	-	-	-	-	-	+	-
Pleurocapsales								
Myxosarcina burmensis	ASNIII, MN, MM	-	-	+	-	-	-	+
Hyella caespitosa	ASNIII	-	-	-	+	-	-	-
Nostocales								
Borzia susedana	ASNIII, MM	-	-	-	-	-	+	-
Komvophoron schmidlei	ASNIII, MN, MM	-	-	-	-	+	-	+
K. pallidum	MM	-	-	-	-	-	+	-
K. minutum	MN, MM	-	-	-	-	-	+	+
Psuedoanabaena galeata	ASNIII, MN, MM	-	-	-	-	-	+	+
P. catenata	ASNIII, MN	-	-	+	+	-	-	-
P. papillaterminata	MN	-	-	-	-	+	-	-
Lyngbea gardnerii	ASNIII	-	-	-	-	+	-	-
L. nordgarddhii	ASNIII, MM	+	+	-	-	-	-	-
L. allogei	ASNIII	+	-	-	-	-	-	-
L. cryptovaginata	ASNIII	-	-	-	-	-	-	+
L. borgertii	ASNIII	-	-	-	-	-	-	+
Oscillatoria acuminata	ASNIII	+	-	-	-	-	-	-
O. fremyii	ASNIII, MN	-	-	-	-	-	+	-
O. tenuis	ASNIII	+	-	-	-	-	-	-
O. okenii	MM	-	-	-	-	+	-	-
O. limosa	ASNIII	-	-	-	-	+	-	-
O.schultzii	ASNIII, MN	-	-	+	-	-	-	-
O. quadripunctata	ASNIII	-	-	-	+	-	-	-
O. pseudogaminata	ASNIII, MN, MM	+	+	+	+	+	+	-
Spirulina labyrinthiformis	ASNIII, MM	+	-	+	-	-	-	-
S. subsalsa	ASNIII	+	-	-	-	-	-	-
S. major	ASNIII	-	-	-	+	-	-	-
Planktothrix compressa	MM	-	-	-	+	-	-	+
P. clathrata	ASNIII, MM	-	-	-	+	-	+	+
Phormidium purpurascence	ASNIII, MM	+	+	-	-	-	-	-
P. molle	ASNIII	+	-	-	-	-	-	-
P. tenue	ASNIII, MM	-	-	+	+	-	-	-
P. insigni	ASNIII	-	-	+	-	-	-	-
P. angustissimum	ASNIII, MN, MM	-	-	+	+	+	-	+
P. corium	ASNIII, MM	+	-	-	-	-	-	-
P. mucosum	MN, MM	-	-	+	+	+	-	-
P. africanum	ASNIII, MN	-	-	+	-	-	+	-
P. amplivaginatum	ASNIII, MN	-	-	-	-	-	+	+

P. fragile	ASNIII, MN, MM	+	+	+	+	+	+	-
P. ambiguum	ASNIII, MN	-	-	+	-	+	-	-
P. retzii	ASNIII, MM	-	-	+	-	+	-	-
P. mucicola	ASNIII, MN, MM	+	-	-	-	-	+	+
P.laminosum	MM	-	-	-	+	-	-	-
P. papyraceum	ASNIII	-	-	-	-	+	-	-
P. lucidum	ASNIII	-	-	-	-	-	-	+
P. valdrrianum	MM	-	-	-	-	+	-	-

*ASNIII, MN (Rippka *et al*., 1979), MM (Imai ,1977)

Table 2. Total number of species observed on surface of rhodophyte species. Species are also grouped according to their taxonomic orders.

Cyanobacterial orders	***Galaxaura oblongata***	***Callibliphari s fimbriata***	***Hypnea pannosa***	***Centroceras clavlulatum***	***ceramium manorense***	***Laurencia pinnatifida***	***Melanothamnus somaliensis***
Chroococcales	6	2	9	1	4	3	2
Chamaesiphonales	-	-	2	2	2	3	1
Pleurocapsales	-	-	1	-	1	-	1
Nostocales	12	4	11	12	13	11	11
Total	18	6	23	15	20	17	15

References

Ahmed, M., Stal, L. J. and Hasnain, S. (2010). Association of non-heterocystous cyanobacteria with crop plants. *Plant and Soil*, 336(1-2): 363-375.

Aleem, A. A. (1980). Cyanopyta from Sierra Leon (West Africa). *Bot. Mar.* 23: 59-61.

Anagnostidis, K. and J. Komárek. (1985). Modern approach to the classification system of cyanophytes, 1– Introduction. – *Arch. Hydrobiol. Suppl. 71/Algological Studies* 38/39: 291-302.

Anagnostidis, K. and Komárek. J. (1988). Modern approach to the classification system of cyanophytes, 3– Oscillatoriales. – *Arch. Hydrobiol. 80/Algological Studies* 50–53: 327-472.

Anand, N. and Hooper. S.K. (1987). Blue green algae in the rice field in Kerala State. India. *Hydrobiologia*. 144: 223-232.

Anjum, G., F. Hussein and Haq. I. (1980). Algae from turtle shells. Pak. J. Bot., 12: 201-203.

Bano A. and Siddiqui, P. J. A. (2017). Distribution of epiphytic cyanobacteria on green macroalgal species occurring at a rocky shore (Buleji), Karachi, Pakistan. International J. of Biol. & Biotech., 1 4 (1): 23-32.

Bano A. and Siddiqui, P. J. A. (2017). Distribution of epiphytic cyanobacteria on brown macroalgal species occurring at a rocky shore (Buleji), Karachi, Pakistan. International J. of Biol. & Biotech., 1 4 (2): 257-263.

Bano, A. and Siddiqui. P. J. A. (2003). Intertidal cyanobacterial diversity on a rocky shore at Buleji near Karachi, Pakistan. *Pak. J. Bot.*, 35 (1): 27-36.

Bano, A. and Siddiqui, P.J. A. (2004). Characterization of five marine cyanobacterial species with respect to their pH and salinity requirements. *Pak. J. Bot.*, *36* (1): 133-144.

Bauld, J. (1981). Occurrence of benthic microbial mats in saline lakes. Hydrobiol.81: 87-111.

Borowitzka, M.A., Lavery, P.S. and van Keulen, M. (2007). Epiphytes of seagrasses. In: *Seagrasses: Biology, Ecologyand Conservation* (Pp. 441-461). Springer Netherlands.

Braun-Howland, E.B. and Nierzwicki-Bauer, S.A. (1990). Occurrence of the 32-kDa Q B-binding protein of photosystem II in vegetative cells, heterocysts and akinetes of *Azolla carotiniana* cyanobionts. *Planta*, *180*(3): 361-371.

Capone, D. G. (1977). N_2 (C_2H_2) fixation by macroalgal epiphytes. *In Proc. 3rd int. coral Reef Symp* [Rosenstiel School of Marine and Atmospheric Science, University of Miami, Miami, Florida] (pp. 337-342).

Capone, D. G., Taylor, D. L., and Taylor, B. F. (1977). Nitrogen fixation (acetylene reduction) associated with macroalgae in a coral-reef community in the Bahamas. *Marine Biology*. 40 (1): 29-32.

Carpenter, E.J. (1972). Nitrogen fixation by blue-green epiphytes on pelagic *Sargassum*. *Science.* 178: 1207-1209.

Carpenter, E. J. and Foster, R.A. (2002). Marine cyanobacterial symbioses. In: *Cyanobacteria in symbiosis* (pp. 11-17). Springer Netherlands.

Carpenter, E.J., Montoya, J.P., Burns, J., Mulholland, M.R., Subramaniam, A. and Capone, D.G. (1999). Extensive bloom of a N_2-fixing diatom/cyanobacterial association in the tropical Atlantic Ocean. 185:.273-283.

Desikachary, T.V. (1959). Cyanophyta. Monographs in algae. New Delhi. Indian council of Agricultural Research.

Fogg, G. E., Stewart, W. D. P., Fay, P. and Walsby, A. E. (1973). *The blue-green algae*. Pp. 495. Academic Press, N. Y.

Gehrig, H., Schüßler, A. and Kluge, M. (1996). Geosiphon pyriforme, a fungus forming endocytobiosis with *Nostoc* (Cyanobacteria), is an ancestral member of the glomales: Evidence by SSU rRNA Analysis. *Journal of Molecular Evolution*, *43*(1): 71-81.

Gerard, V.A., Dunham, S.E. and Rosenberg, G. (1990). Nitrogen-fixation by cyanobacteria associated with *Codium fragile* (Chlorophyta): environmental effects and transfer of fixed nitrogen. *MarineBiology*, 105(1):.1-8.

Hamersley, M.R., Sohm, J.A., Burns, J.A. and Capone, D. G. (2015). Nitrogen fixation associated with the decomposition of the giant kelp *Macrocystis pyrifera*. *Aquatic Botany*, 125: 57-63.

Hanson, R. B. (1977). Pelagic *Sargassum* community metabolism: Carbon and nitrogen. *J. of Exp. Mar. Biol .and Ecol.* 29(2): 107-118.

Harlin, M. M. (1973). Transfer of products between epiphytic marine algae and host plants1, 2. *J. of Phyco.*, 9(3): 243-248.

Harlin, M. M., and Craigie, J. S. (1975). The distribution of photosynthate in *Ascophyllum nodosum* as it relates to epiphytic *Polysiphonia lanosa12*. *J. of Phy.* 11 (1): 109-113.

Head, W. D. and Carpenter, E. J. (1975). Nirogen fixation associated with marine macroalgae *Codium fragile*. *Limno. Oceanog*., 20: 815-823.

Hogdson, L. M. and Abbot. A. I. (1992). Nearshore benthic marine algae of Kape Kina 'U Maui. *Bot. Mar*. 35: 535-540.

Hussein, F. and Anjum, G. (1982). Algae from snail shells. *Pak. J. Bot.* 14: 189-190.

Hussein, I.M. and Khoja, T.M. (1993). Intertidal and sub-tidal blue-green algal mats of open and mangrove areas in the Farasan Archipelago (Saudi Arabia), Red sea. *Bot. Mar*. 36: 377-388.

Hutchinson, G. E. (1975). A treatise on limnology v.3 Wiley.

Imai, T. (1977). The culture of microorganisms used as feed. In: Aquaculture shallow seas. Progress in shallow sea culture. Takeo Imai (eds.) Translated from Japanese Oxford and IBH Publishing Company pp.565-578. New Delhi, Bombay, Calcutta.

Javed, F., Qadir, M.I., Janbaz, K.H. and Ali, M. (2011). Novel drugs from marine microorganisms. *Critical reviews in microbiology*, 37 (3): 245-249.

Johansson, C. and Bergman, B. (1994). Reconstitution of the symbiosis of *Gunnera manicata* Linden: cyanobacterial specificity. *New Phytologist*, 126(4): 643-652.

Kaplan, D.R.O.R.A. and Peters, G. A. (1998). The *Azolla-Anabaena azollae* relationship. XIV. Chemical composition of the association and soluble carbohydrates of the association, endophyte-free *Azolla*, and the freshly isolated endophyte. *Symbiosis-Rehovot-*, 24: 35-50.

Khalid, M., Nabiha, A., Sla, B., Bashir, R. and Shameel, M. (2014). Taxonomic studies of freshwater algae from Taxila, Pakistan. *Proceeding of the Pakistan Academy of Science*, *51*(1), pp.61-66.

Khoja, T.M. (1987). New record of marine algae for the Red sea coast of Saudi Arabia. *Bot. Mar.* 30: 167-176.

Komárek, J. and Anagnostidis, K. (1986). Modernapproach to the classification system of cyanophytes, 2– Chroococcales. – *Arch. Hydrobiol. 73/Algological Studies* 43:157-226.

Komárek, J. and Anagnostidis, K. (1989). Modern approach to the classification system of Cyanophytes, 4– Nostocales. – *Arch. Hydrobiol. Suppl. 82/Algological Studies* 56: 247-345.

Larkum, A.W., Chen, M., Li, Y., Schliep, M., Trampe, E., West, J., Salih, A. and Kühl, M. (2012). A Novel Epiphytic Chlorophyll d-containing Cyanobacterium Isolated from a Mangrove-associated Red Alga. *Journal of phycology*, 48(6): 1320-1327.

Lesser, M.P., Falcón, L.I., Rodríguez-Román, A., Enríquez, S., Hoegh-Guldberg, O. and Iglesias-Prieto, R. (2007). Nitrogen fixation by symbiotic cyanobacteria provides a source of nitrogen for the scleractinian coral *Montastraea cavernosa*. *Marine Ecology Progress Series*, 346: 143-152.

Lesser, M.P., Mazel, C.H., Gorbunov, M.Y. and Falkowski, P.G. (2004). Discovery of symbiotic nitrogen-fixing cyanobacteria in corals. *Science*. 305 (5686): 997-1000.

Maity, H., G. Bandhyopadhay and Santra. S. C. (1987). Algal flora of saline habitat of Sundarban, West Bengal and its possible role in reclamation of soil. *J. Inian Soc. Coastal Agri. Res.*, 5 (1): 325-331.

Malik, K.A., Mirza, M.S. and Ladha, J.K. (eds), (2012). Nitrogen Fixation with Non-Legumes*: Proceedings of the 7th International Symposium on Nitrogen Fixation with Non-Legumes, held 16–21 October 1996 in Faisalabad, Pakistan* (Vol. 79). Springer Science & Business Media.

Martínez, L., Silver, M.W., King, J.M. and Alldredge, A. L. (1983). Nitrogen fixation by floating diatom mats: A source of new nitrogen to oligotrophic ocean waters. *Science*, 221(4606:.152-154.

McCowen, S.M., MacArthur, L. and Gates, J. E. (1986). Azolla fern lectins that specifically recognize endosymbiotic cyanobacteria. *Current Microbiology*, *14*(6): 329-333.

McRoy, C.P. and Goering, J. J. (1974). Nutrient transfer between the seagrass Zostera marina and its epiphytes. *Nature*, 248(5444): 173-174.

Meeks, J.C. and Elhai, J. (2002). Regulation of cellular differentiation in filamentous cyanobacteria in free-living and plant-associated symbiotic growth states. *Microbiology and Molecular Biology Reviews*, 66 (1): 94-121.

Nizamuddin, M., and Gessner, F. (1970). The marine algae of the northern part of the Arabian Sea and of the Persian Gulf. Gebrueder Borntraeger.

O'Neil, J.M. and Roman, M.R., (1992). Grazers and associated organisms of *Trichodesmium.* In *Marine pelagic cyanobacteria: Trichodesmium and other diazotrophs*) (pp. 61-73). Springer Netherlands.

Penhale, P.A. and Thayer, G. W. (1980). Uptake and transfer of carbon and phosphorus by eelgrass (Zostera marina L.) and its epiphytes. *Journal of Experimental Marine Biology and Ecology*, *42*(2): 113-123.

Phlips, E.J., M. Willis, and Verchick, A. (1986). Aspects of nitrogen fixation in *Sargassum* communities off the coast of Florida. J. Exp. Mar. Biol. Ecol. 102: 99-119.

Rai, A. N. (1990a). Cyanobacteria in Symbiosis *In: Handbook of symbiotic cyanobacteria*. (ed. A. N. Rai) pp. 9-41 CRC Press, Boca Raton Florida.Inc.

Rai, A. N. (1990b). *Handbook of symbiotic cyanobacteria*. CRC Press, Inc.

Rigonato, J., Alvarenga, D.O., Andreote, F.D., Dias, A.C.F., Melo, I.S., Kent, A. and Fiore, M.F. (2012). Cyanobacterial diversity in the phyllosphere of a mangrove forest. *FEMS microbiology ecology*, *80*(2), pp.312-322.

Rippka, R., J. Deruelles, J.B. Waterbury, M. Herdman and Stanier, R.Y. (1979). Generic assignments, strain histories and properties of pure cultures of cyanobacteria. *J. Gen. Microbiol.* 111**:** 1-61.

Rosenberg, G. and Paerl, H.W. (1980) Nitrogen fixation by blue-green algae associated with the siphonaceous green seaweed *Codium decorticatum*: effects of ammonium uptake, *Marine Biology* 61, 151–158.

Saifullah, S. M., and Taj, G. (1995). Marine algal epiphytes on pneumatophores of mangroves of Karachi. *The Arabian Sea Living Marine Resources and the Environment, AIBS, Vangurad Books (PVT) Ltd., Lahore*, 407-417.

Saifullah, S.M. and Ahmed, W. (2007). Epiphytic algal biomass on pneumatophores of mangroves of Karachi, Indus Delta. *Pak. J. Bot*, 39(6): .2097-2102.

Saifullah, S.M., Aisha, K. and Rasool, F., 1997. Algal epiphyte on mangrove of BALOCHISTAN, PAKISTAN. *Pak. J. Bot*, *29*(2), pp.191-197.

Santra, S.C. and Pal, U. C. (1988). Marine algae of mangrove delta region West Bengal, India: Benthic forms. *Indian Biolo.* 20(2): 30-41.

Santra, S.C., U.C. Pal, H. Maity and Bandhyopadhaya, G. (1988). Blue green algae in saline habitat of West Bengal: *A systematic account. Biol. Mem*., 14(1): 81-108.

Shameel, M. (1987). A preliminary survey of seaweeds from the coast of Lasbela, Pakistan. *Botanica Marina*. 30(6): 511-516.

Shameel, M. and Butt. N. I (1984). On the occurrence of Cyanophyta from Karachi, Pakistan. *Pak. J. Bot.* 16: 75-79.

Stewart, W.D.P., Rowell, P. and Rai, A.N. 1980. Symbiotic nitrogen-fixing cyanobacteria. In *Nitrogen fixation: proceedings of the Phytochemical Society of Europe symposium*. (W. D. P. Stewart and J. R. Gallon, eds.) p. 239. Academic press London.

Thajuddin, N. and Subramanian, G. (1994). Marine cyanobacterial flora of South India. *Curr. Res. Pl. Sci.,* .pp. 1-16.

Thajuddin, N. and Subramanian, G. (1990). Cyanobacterial phytoplanktons of the Gulf of Mannar region. Proc. Natl. Symposium on cyanobacterial nitrogen fixation NFBGA, IARA, New Delhi pp. 457-463.
Thajuddin, N. and Subramanian, G. (1992). Survey of cyanobacterial flora of the Southern East coast of India. *Bot. Mar.,* 35: 305-314.
Thajuddin, N. and Subramanian, G. (2005). Cyanobacterial biodiversity and potential applications in biotechnology. *Current Science*, 89:47-57.
Thajuddin, N., Muralitharan, G., Sundaramoorthy, M., Ramamoorthy, R., Ramachandran, S., Akbarsha, M.A. and Gunasekaran, M. (2010). Morphological and genetic diversity of symbiotic cyanobacteria from cycads. *Journal of basic microbiology*, 50(3): .254-265.
Toledo, G., Bashan, Y. and Soeldner, A. 1995. Cyanobacteria and black mangroves in Northwestern Mexico: colonization, and diurnal and seasonal nitrogen fixation on aerial roots. *Canadian Journal of Microbiology*, *41*(11), pp. 999-1011.
Ulcay, S., Taşkin, E., Kurt, O. and Öztürk, M. 2015. Marine benthic Cyanobacteria in Northern Cyprus (Eastern Mediterranean Sea). *Turkish Journal of Botany*, 39(1): 173-188.
Uzair, B., Tabassum, S., Rasheed, M. and Rehman, S. F. (2012). Exploring marine cyanobacteria for lead compounds of pharmaceutical importance.*The Scientific World Journal*, *2012* .pp.1-10.
Villareal, T.A. (1989). Division cycles in the nitrogen-fixing Rhizosolenia (Bacillariophyceae)-Richelia (Nostocaceae) symbiosis. *British Phycological Journal*, 24(4): 357-365.
Vizzini, S., Sara, G., Michener, R.H. and Mazzola, A., 2002. The role and contribution of the seagrass Posidonia oceanica (L.) Delile organic matter for secondary consumers as revealed by carbon and nitrogen stable isotope analysis. *Acta Oecologica*, *23*(4): 277-285.
Wetzel, R. G., and Penhale, P. A. (1979). Transport of carbon and excretion of dissolved organic carbon by leaves and roots/rhizomes in seagrasses and their epiphytes. *Aquatic Botany*. 6: 149-158.
Yamamuro, M. (1999). Importance of epiphytic cyanobacteria as food sources for heterotrophs in a tropical seagrass bed. *Coral reefs*, 18(3): 263-271.