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Cyanobacterial Diversity from Mangrove Sediment of South East Coast of India

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Abstract - Cyanobacterial diversity was studied in three different mangrove environments of Pichavaram (Lat.11º27′ N; Long. 79º47′ E), Porto Novo (Lat. 11º29′ N; Long. 79º47′ E), and Mudasal Odai (Lat. 11º28′ N and Long. 79º46′ E) in the southeast coast of India. Totally 68 species belonging to 28 genera and 10 families were recorded. The number of species was higher in Pichavaram than the other two-study areas. In Pichavaram, 63 species, 28 genera and 10 families were isolated. In Porto Novo, 53 species, 26 genera and 10 families were obtained. In Mudasal Odai, 40 species, 20 genera and 9 families were registered. Totally 58 species of non-heterocystous and 10 species of heterocystous cyanobacteria were observed. The family Oscillatoriaceae was dominant, represented with 34 species (75.8%). Out of 28 genera, Oscillatoria (14 *spp*.) was the dominant. Thirteen species were found common to all the three mangrove areas. Dominant species were four in Pichavaram, six in Porto Novo and four in Mudasal Odai. Abundant species were seven in Pichavaram, 11 in Porto Novo and five in Mudasal Odai. Co-abundant species were 18 in all the study areas.

Keywords - Cyanobacteria; Diversity; Mangroves; Sediment; Benthic forms

INTRODUCTION

Cyanobacteria are the largest group of photosynthetic prokaryotes, capable of fixing atmospheric nitrogen. They are unique in their wide spread occurrence, abundance and morphological diversity, which occur in almost every habitat on the earth for 3.5 billion years (Adams, 2000; Thajuddin and Subramanian, 2005). They are similar to gram-negative bacteria in their cell structure and biochemistry. They are also considered as algae because of their morphology, pigmentation and oxygen evolving photosynthesis in which photosystems PSII and PSI are connected in series. Cyanobacteria can grow under very low water potential; such species can resist desiccation and grow in the arid environments (deserts) or can tolerate high salinity to grow in hyper-saline ponds. Benthic cyanobacteria are abundant in mangrove environments (Thajuddin and Subramanian, 1992) and 20% of species that occur in saline conditions are truly marine. Cyanobacteria can be divided into euryhaline and stenohaline forms – those living in brine are hyper-saline and those in brackish water are hypo-saline (Desikachary, 1959).

Mangrove forests are among the world's most productive ecosystems, they provide a huge amount of carbon and nitrogen supply to the coastal waters, maintaining a rich coastal biodiversity (Kathiresan and Bingham, 2001). Cyanobacterial mat have been found in mangrove communities throughout the world (Potts, 1979, Hussian and Khoja, 1993; Thajuddin and Subramanian, 1995). There have been casual reports on the occurrence of cyanobacteria, but specific studies for mangroves are only limited (Khoja, 1987; Nagasathya and Thajuddin, 2008).

OBJECTIVES OF THE STUDY

The present investigation has been undertaken to the survey the cyanobacteria from mangrove sediment soil for their diversity in three mangrove areas, situated along the southeast coast of India.

MATERIALS AND METHODS

Cyanobacterial species were recorded in three different mangrove environments, namely Pichavaram (Lat.11º27′ N; Long. 79º47′ E), Porto Novo (is also known as Parangipettai, Lat. 11º29′ N; Long. 79º47′ E), and Mudasal Odai (Lat. 11º28′ N; Long. 79º46′ E). Benthic cyanobacterial mat was removed and suspended in a flask containing filtered seawater. The flask was sufficiently agitated to detach the sand particles from the mat. The sand particles were allowed to settle down, and the supernatant consisting of cyanobacteria was transferred to another 50 ml of filtered seawater flask. From the flask, 10 ml of the sample were drawn and observed under a light microscope. Thus, five random samplings were observed for each study area. Cyanobacterial species were identified by using taxonomic keys (Desikachary, 1959; Hum and Wicks, 1980).

RESULTS AND DISCUSSION

Totally 68 cyanobacteria species belonging to 28 genera and 10 families were recorded (Table 1). The number of species was higher in Pichavaram than in the other two-study areas. In Pichavaram, 63 species belonging to 28 genera and 10 families were isolated. In Porto Novo, 53 species under 26 genera and 10 families were obtained. In Mudasal Odai, 40 species of 20 genera and 9 families were registered (Fig. 1). There were more numbers of non-heterocystous forms than heterocystous ones. Totally 58 species were observed to be non-heterocystous forms and only 10 species were heterocystous forms. In Pichavaram, 53 species, Porto Novo 46 and Mudasal Odai 36 species were recorded as non-heterocystous forms. Heterocystous were 10 in Pichavaram, seven in Porto Novo, and four in Mudasal Odai were reported (Fig. 2).

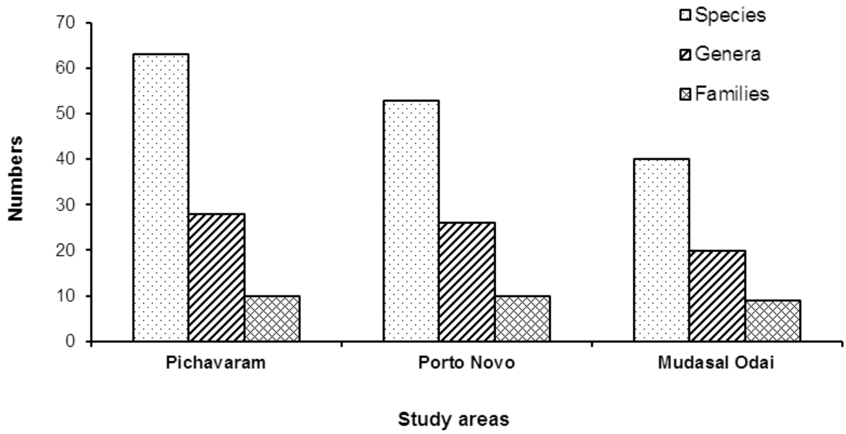

Fig. 1. Total number of cyanobacterial species, genera and families recorded in the three mangrove areas

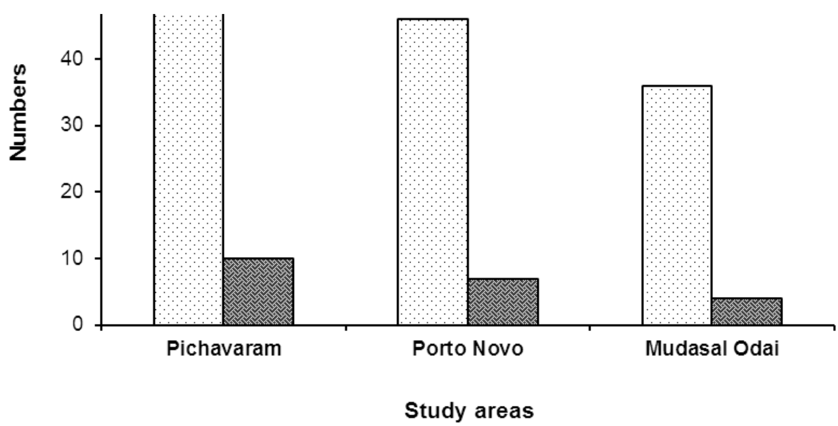

Fig. 2. Total number of heterocystour & non-heterocystous species recorded in three magrove areas

Dominant families

Of the 10 families recorded, two were dominant: Oscillatoriaceae with 34 species; and Chroococcaceae with 14 species) (Table 1). A similar trend was also seen with individual study area. The family Oscillatoriaceae was dominant, represented with 31 species (75.8%) in Pichavaram, 27 species (62.23%) in Porto Novo and 22 species (65.12%) in Mudasal Odai. The next dominant family was Chroococcaceae represented with 14 species (13.48%), 10 species (19.53%) and 10 species (21.17%) from Pichavaram, Porto Novo and Mudasal Odai respectively.

Table 1. Diversity of Cyanobacteria in different mangrove environments

No.	Name of Species	Sampling Station		
		I	**II**	**III**
I. Family: Chroococcaceae				
1.	*Microcystis litoralis* (Hansg) Forti.	+	-	-
2	*Microcystis aeruginosa* Kutz.	+	++	++
3.	*Chroococcus turgidus* (Kutz.) Nag.	+	++	++
4.	*Chroococcus minutus* (Kutz.) Nag.	+	+	++
5.	*Chroococcus minor* (Kutz.) Nag.	+	-	-
6.	*Gloeocapsa stegophila* (Itzigs.) Rabenh	+	+	+
7.	*Gloeocapsa pleurocapsoides* Novacek	+	-	+
8.	*Gloeocapsa crepidinum* Thuret	++	+++	-
9	*Aphanocapsa littoralis* Hansgirg	++	-	++
10	*Synechococcus elongatus* Nag.	+++	+++	-
11	*Synechocystis salina* Wislouch	+++	++++	++++
12	*Synechocystis pevalekii* Ercegovic	+	++	++
13	*Merismopedia glauca* (Ehrenb.) Nag.	+	++	++
14	*Merismopedia elegans* A. Br.	++	+	++
II. Family : Entophysalidaceae				
15	*Entophysalis granulosa* Kutzing	+	-	-
16	*Chlorogloea fritschii* Mitra	+	++	-

17	*Johannesbaptistia pellucida* (Dickie) Taylor et Drouet	+	+	+
III. Family : Dermocarpaceae				
18	*Dermocarpa olivacea* (Reinsch) Tilden	+	++	+
19	*Dermocarpa leibleinae* (Reinsch) Born. et Thur.	-	+	-
IV. Family : Pleurocapsaceae				
20	*Myxosarcina burmensis* Skuja	++	+++	+++
21	*Myxosarcina spectabilis* Geitler	+	++	-
V. Family : Hyellaceae				
22	*Xenococcus acervatus* Stechell et Gardner	++	+	+
23	*Hyella caespitosa* Bornet et Flahault	-	+	-
VI. Family : Oscillatoriaceae				
24	*Spirulina subsalsa* Oerst. ex Gomont	+++++	++++	+++++
25	*Spirulina labyrinthiformis* (Menegh.) Gomont	++	++	+
26	*Spirulina major* Kutz. ex Gomont	+	+	-
27	*Oscillatoria chalybea* (Mertens) Gomont	++	+	++
28	*Oscillatoria tenuis* Ag. ex Gomont	+	++	+
29	*Oscillatoria willei* Gardner em. Drouet	+++	++++	++
30	*Oscillatoria earlei* Gardner	+	-	-
31	*Oscillatoria salina* Biswas	+++	+++	+++
32	*Oscillatoria sancta* (Kutz.) Gomont	+	-	-
33	*Oscillatoria cortiana* Menegh.ex Gomont	++++	++++	+++
34	*Oscillatoria splendida* Grev.ex Gomont	++	-	+
35	*Oscillatoria curviceps* Ag. ex Gomont	++	++	+++
36	*Oscillatoria princeps* Vaucher ex Gomont	++	+++	-
37	*Oscillatoria chlorina* Kutz. ex Gomont	+	-	+
38	*Oscillatoria nigroviridis* Thwaites ex Gomont	++	++	++
39	*Oscillatoria formosa* Bory ex Gomont	+	+++	+
40	*Oscillatoria minnesotensis* Tilden	-	+++	-
41	*Trichodesmium erythraeum* Ehrenberg ex Gomont	+	+	++
42	*Phormidium stagnina* Rao, C.B.	++	+	-
43	*Phormidium fragile* (Menegh.) Gomont	++++	++++	++++
44	*Phormidium tenue* (Menegh.) Gomont	++++	++++	++++
45	*Phormidium valderianum* (Delp.) Gomont	+	++	-
46	*Phormidium ambiguum* Gomont	+	++	++

47	*Phormidium corium* (Ag.) Gomont	-	-	++
48	*Lyngbya martensiana* Menegh.ex Gomont	++	+	+
49	*Lyngbya confervoides* C.Ag. ex Gomont	++	+++	-
50	*Lyngbya majuscula* Harvey ex Gomont	+++	+++	+++
51	*Lyngbya chaetomorphae* Iyengar et Desikachary	++	-	++
52	*Lyngbya birgei* Smith, G.M.	++	++	-
53	*Lyngbya infixa* Fremy	-	+	-
54	*Lyngbya aestuarii* Liebm. ex Gomont	++	+	+
55	*Lyngbya mesotricha* Skuja	+	-	-
56	*Symploca hydnoides* Kutz. ex Gomont	+	++	-
57	*Microcoleus chthonoplastes* Thuret ex Gomont	+++	+++	++
VII. Family :Nostocaceae				
58	*Anabaena sphaerica* Bornet et Flahault	+	+	++
59	*Anabaena iyengarri* Bharadwaja	+	-	-
60	*Pseudanabaena limnetica* (Lammermann) Kom-arek	+	+++	++
61	*Raphidiopsis indica* Singh R.N	+++	-	-
VIII. Family : Scytonemataceae				
62	*Plectonema terebrans* Borneter Gomont	+	++	++
63	*Scytonema cincinnattum* Thuret ex Born. Et Flah.	++	++	-
IX. Family : Microchaetaceae				
64	*Microchaete grisea* Thuret ex Born. Et Flah.	+	+	-
X. Family : Rivulariaceae				
65	*Calothrix crustaceae* Thuret	+	++	+
66	*Calothrix contarenii* (Zanard.) Bornet et Flahault	+	-	-
67	*Calothrix scopulorum* (Webber et Mohr)	+	+	-
68	*Dichothrix baueriana* (Grun.) Born. Et Flah.	+	+	-
	Total	63	53	40

++++: Dominant; +++: Abundant; ++: Co-abundant; +: Present; -: Not found. Station I: Pichavaram; Station II: Porto Novo; Station III: Mudasal Odai.

Dominant Genera

Of total 28 genera registered, three were dominant, and they were *Oscillatoria* (14 species), *Lyngbya* (8 species) and *Phormidium* (6 species) (Table 1). A similar trend was true with individual study area. The genus *Oscillatoria* was dominant represented with 13 species (20.26%) in Pichavaram, 10 species (25.44%) in Porto Novo, and 10 species (17.89%) in Mudasal Odai. The next dominant genus was *Lyngbya*, represented with seven species (11.78%), six (9.57%) and five species (16.86%) respectively in Pichavaram, Porto Novo and Mudasal Odai. The next dominant genus was *Phormidium* represented with five species (14.01%) in Pichavaram, five (16.86%) in Porto Novo, and four species (21.23%) in Mudasal Odai.

Area-specific species

Some of the cyanobacterial species were site-specific (Table 1). For example, 9 species were isolated only from Pichavaram and they were *Microcystis litoralis, Chroococcus minor, Entophysalis granulosa, Oscillatoria earlei, O. sancta, Lyngbya mesotricha, Anabaena iyengarri, Radiopsis indica* and *Calothrix contarenii*. Four species were obtained only in from Porto Novo and they were *Dermocarpa leibleinae, Hyella caespitosa, Oscillatoria minnesotensis* and *Lyngbya infixa*. Only one species, *Phormidium corium* was recorded specifically from Mudasal Odai.

It is interesting to note that non-heterocystous filamentous forms are greater than unicellular or heterocystous filamentous forms. For example, in the present study, a total of 58 species was recorded as non-heterocystous forms and only 10 species as heterocystous forms and 14 species as unicellular forms (Fig. 2). Even in earlier investigations, this is the trend that the non-heterocystous filamentous forms dominate the saline environment (Thajuddin and Subramanian, 1992). A similar trend has been observed in the Balandron lagoon, Mexico (Toledo et al., 1995) and in mangrove ecosystem adjacent to Zanzibar town of Tanzania (Kyaruzi et al., 2003). A striking feature of cyanobacteria in hyper-saline environment is that all of them are non-heterocystous. The absence of heterocystous forms in hyper-saline environments is attributed to high sulphide content and its toxicity to the heterocystous forms (Howsley and Pearson, 1979). The anaerobic condition prevailing in the hyper-saline soil is believed to exclude the heterocystous forms (Oren and Shilo, 1979). Usually the proportion of hetercystous to non-heterocytous forms compared to free-living cyanobacteria is determined by the nitrogen status of the environment.

Many cyanobacterium have been observed in mangroves of different parts of the hyper-saline environment (Cepak and Komarek, 2010; Abed et al., 2011). The present study recorded that the cyanobacterium *Microcoleus chthonoplastes*, was one of the abundant species in Pichavaram and Porto Novo and co-abundant species in Mudasal Odai sampling sites. The distribution of *Microcoleus chthonoplastes* in cyanobacterial mat is considered to cosmopolitan in distribution (Garcia – Pichel et al., 1996). *Microcoleus* species are known to tolerate desiccation (Fleming et al., 2007) through the production of polyhydroxyl carbohydrates, which replace the water shell around cellular macromolecules, preventing denaturation (Potts, 1999).

Spirulina is used as food supplement because of its excellent nutrient composition and digestibility. It has high protein content (60 – 70%), 20% carbohydrate, 5% lipids, 7% minerals and 6% moisture. It is also a rich source of beta-carotene, thiamine and riboflavin and is one of the richest sources of vitamin B12. It is commercially available in the market in the form of powder, granules or flakes and as tablets and capsules (Thajuddin and Subramanian, 1995). However, marine species of *Spirulina* have not been attempted for human consumption in India. In the present study *Spirulina subsalsa* was one of the dominant species at all sampling sites.

Filamentous forms of *Phormidium fragile* and *P. tenue* were dominant species in the present study. *Phormidium fragile* is mucilaginous, lamellate, yellowish or brownish blue-green. Trichomes were more or less flexuous, entangled or nearly parallel, distinctly constricted at the cross walls, septa were not granulated, attenuated at the ends. The filaments were 1.2-2.3μ broad, pale blue-green, cells nearly quadrate, 1-3μ long, end cell acute-conical, calyptra was found absent. *Phoromidium tenue* was found pale blue-green, thin, membranous and expanded. Trichomes were straight or slightly bent, densely entangled, slightly constricted at the cross walls and attenuated at the ends. The filament was 1-2μ broad, pale blue-green, sheath thin, diffluent, coloured violet by chlor-zinc-iodide. The cells were observed up to 3 times longer than broad, 2.5-5µ long, septa not granulated, cross-walls were not commonly visible, end-cell acute-conical and calyptra was absent.

The present study recorded 68 species, belonging to 28 genera of marine cyanobacteria in mangroves (Table 1). The biodiversity of cyanobacteria varied with the area of sampling, in accordance with previous reports. For example, Thajuddin and Subramanian, (1992) have isolated 163 species from open sea, stagnant seawater, backwaters and saltpans from a 500 km stretch of the southeast coast of India. There were about 61 species cyanobacterial species in the hyper-saline environment of the saltpans (Nagasathya and Thajuddin, 2008), and 25 species from saltpan of Pudukkottai district, Tamil Nadu, India (Nedumaran and Manokaran, 2009).

The present work registered 14 genera (*Synechococcus, Entophysalis, Chlorogloea, Dermocarpa, Mixosarcina, Xenococcus, Hyella, Symploca, Pseudanabaena, Raphidiosis, Plectonema, Scytonema, Microchaete* and *Dichothrix*) as the new records for the first time in the study areas. The unicellular cyanobacterium *Synechococcus elongates* was abundant in Pichavaram and Porto Novo sampling sites, and it was absent in Mudasal Odai. The species - *Pseudanabaena, Scytoneme, and Synechococcus* – are recorded to be dominant in Antarctica flora (Broady et al., 1996). They were ten genera (*Anabaenopsis, Anacystis, Aphanothece, Gloeothece, Arthrospira, Nostoc, Nudularia, Clindrospermum, Stigonema* and *Schizothrix*) not able to trace out in the present study , but have been earlier recorded by other workers.

In the present study, the number of cyanobacterial species was higher in Pichavaram (63 species) than Porto Novo (53 species) and Mudasal Odai (40 species). Pichavaram area has a naturally developed mangrove forest with rich biodiversity and productivity. Other two areas do have mangrove forests artificially developed, but they are low in productivity and biodiversity. Benthic cyanobacteria were abundant in mangrove environments due to rich organic muddy substratum, relatively stagnant shallow water conditions, sheltered nature (hence reduced water movement), and optimum salinity conditions (15–30 ppt). Thajuddin and Subramanian (1992) have reported as many as 58 species of cyanobacteria belonging to 22 genera in backwaters and mangrove habitats of the southern east coast of India.

CONCLUSIONS

Cyanobacteria diversity depends on the density of mangroves, nature of the soil and water currents of the study areas. Oscillatoria species were recorded more in numbers followed by *Lyngbya* and *Phormidium* species. Non-heterocystous forms were found predominant as compared to heterocystous forms. The present work concluded that mangrove biotope is an excellent ecological niche for marine cyanobacterial species.

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LITERATURE CITED

Abed, R.M.M., S. Dobrestov, S. Al-Kharusi, A. Schramm, B. Jupp and S. Golubic.
2011. Cyanobacterial diversity and bioactivity of inland hypersaline microbial mats from a desert stream in the Sultanate of Oman. Fottea 11: 215-224.

Adams, D.G.
2000. Cyanobacterial phylogeny and development: questions and challenges. In Prokaryotic Development, Eds., Brun, Y.V. and L.J. Shimkets, ASM Press, Washington pp. 51-81.

Broady, P.A., R. Garrick and G.M. Anderson.
1996. Diversity, distribution and dispersal of Antarctic terrestrial algae. Biodiversity conservation 5: 1307-1335.

Cepak, V. and J. Komarek.
2010. Cytomorphology of six halotolerant coccoid cyanobacteria using DAPI fluorescent and transmission electron microscopy, compared with molecular data. Fottea 10: 229-234.

Desikachary, T.V.
1959. Cyanophyta. Indian Council of Agricultural Research, New Delhi p. 686.

Fleming, E.D., B.M. Bebout and R.W. Castenholz.
2007. Effects of salinity and light intensity on the resumption of photosynthesis in rehydrated cyanobacterial mats from Baja California Sur, Mexico. Journal of Phycology 43: 15-24.

Garcia-Pichel, F., L. Prufert-Bebout and G. Muyzer.
1996. Phenotypic and phylogenetic analyses show *Microcoleus chthonoplastes* to be a cosmopolitan cyanobacterium. Applied and Environmental Microbiology 62: 3284-3291.

Howsley, R. and W.H. Pearson.
1979. pH dependent sulphide toxicity to oxygenic photosynthesis in cyanobacteria. FEMS Microbiology Letters 6: 287-292.

Hum, H.J. and S.R.Wicks.
1980. Introduction and Guide to the Marine Blue-Green Algae. 5th edition. John Wiley and Sons, New York pp. 1-194.

Hussain, M.I. and T.M. Khoja.
1993. Intertidal and subtidal blue-green algal mats of open and mangrove areas in the Farasan Archipelago (Saudi Arabia) Red sea. Botanica Marina 36: 377-388.

Kathiresan, K. and B.L. Bingham.
2001. Biology of mangroves and mangrove ecosystems. Advances in Marine Biology 40: 81-251.

Khoja, T.M.
1987. New records of marine algae for the Red Sea coast of Saudi Arabia. Botanica Marina 30: 167-176.

Kyaruzi, J.J., M.S. Kyewalyanga and M.H.S. Muruke.
2003. Cyanobacteria composition and impact of seasonality on their

in situ nitrogen fixation rate in a mangrove ecosystem adjacent to Zanzibar town. Western Indian Ocean Journal of Marine Science 2: 35-44.

Nagasathya, A. and N. Thajuddin.
2008. Cyanobacterial diversity in the hypersaline environment of the saltpans of south eastern coast of India. Asian Journal of Plant Sciences 7: 473-478.

Nedumaran, T. and S. Manokaran.
2009. Cyanobacterial flora in some salt pans of Pudukkottai district, Tamil Nadu, India. Journal of Phytology 1: 169-171.

Oren, A. and M. Shilo.
1979. Anaerobic heterotrophic dark metabolism in the cyanobacterium *Oscillatoria limnetica*: sulfur respiration and lactate fermentation. Archives of Microbiology 122: 77-84.

Potts, M.
1979. Nitrogen fixation (acetylene reduction) associated with communities of heterocystous and non-heterocystous blue green algae in mangrove forests of Sinai. Oecologia 39:359-373.

Potts, M.
1999. Mechanisms of desiccation tolerance in cyanobacteria. European Journal of Phycology 34: 319-328.

Thajuddin, N. and G. Subramanian.
2005. Cyanobacterial biodiversity and potential applications in biotechnology. Current Science 89: 47-57.

Thajuddin, N. and G. Subramanian.
1992 Survey of cyanobacterial flora of the southern east coast of India. Botanica Marina 35: 305-314.

Thajuddin, N. and G. Subramanian.
1995. Additions to the new reports of marine cyanobacteria from the east coast of India. Phykos 34: 33-37.

Toledo, G., Y. Bashan and A. Soeldner.
1995. In vitro colonization and increase in nitrogen fixation of seedling roots of black mangrove inoculated by a filamentous cyanobacteria. Canadian Journal of Microbiology 41: 1012-1020.