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Original Research Article

Occurrence, Distribution, Hydrocarbon degradation studies of fungi isolated from South East coast of Tamil Nadu, India

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Abstract

The present study was confined to the Manakudi mangrove ecosystem in Kanyakumari District, Tamil Nadu comprising of Sanguthurai (S1), Chothavilai (S2), Vivekananda Rock (S3), Vattakottai Fort (S4) and Chinnamuttom (S5). Water, sediment, seafoams and natural substrates of mangrove plants (*Avicennia marina*, *Rhizophora mucronata*, *Sonneratia* sp. and *Excoecaria agallocha*) were collected to isolate the fungi. The water and sediment sample were collected separately and analysed. A total of 135 fungal species were isolated and enumerated by plating, baiting and direct observations techniques. Colony growth rate of the fungi was studied on seven different types of solid media (PDA, SDA, CMA, CZA, MA, RBA, and OMA). Effect of different ecological parameters such as pH (5-9), temperature (20-60ºC), salinity (5-40%), metals (FeSO4 and ZnSO4), carbon (CMC, starch and mannitol) and nitrogen sources (ammonium nitrate and calcium nitrate) on the growth of fungi was also determined. Screening and assay of fungal enzymes such as alpha amylase, alkaline protease, cellulase, pectate lyase, lipase, xylanase, phosphatase and laccase were studied on fungi isolated from mangrove habitat. Estimation of fungal protein, lipids, amino acids and rhamnolipids were studied. 31 species of fungi showed zone of clearance for amylase and protease followed by cellulase with 23 species, phosphatase (19 sp.), laccase (17sp.), xylanase (13sp.), lipase (11 sp.) and pectate lyase (12 sp.). Enzyme assays were also done. 19 species of fungi were isolated from marine samples Biodegradation of petroleum products by fungi.

Keywords: mangrove ecosystem, fungi, Biodegradation.

Introduction

Fungi are known to play vital roles either as decomposers, symbionts of plants and animals and also parasites on plants in different ecosystem. Decomposition of organic matter in river, marine and estuarine waters is brought about by diverse aquatic biota namely, bacteria, fungi, nematodes and worms.

Fungal biotechnology has become an integral part of human welfare. Nature represents a formidable pool of bioactive compounds and is more than ever a strategic source for new and successful commercial product. Among the microorganisms, fungi are well recognized to produce a wide variety of most valuable pharmaceutical chemicals, agrochemicals and industrial products. Recent advances made in genomics, proteomics and combinatorial chemistry show that nature maintains compounds that are the essence of bioactivity, within the host and environment. So the major challenging task is to explore the unexplored fungal wealth in our country and reveal their potential applications.

The petroleum industry is responsible for the generation of high amounts of organic residues, as well as for the pollution of soils, rivers and seas. The potentiality of the microorganisms, pointed out in

literature as agents of degradation of several compounds, indicates biological treatments as the most promising alternative to reduce the environmental impact caused by oil spills. It is known that the main microorganisms consuming petroleum hydrocarbons are bacteria and fungi.

Objectives

Based on the necessary basic information obtained on marine fungi and marine ecosystem, the present study has been undertaken in the proposed study area in marine ecosystem of Kanyakumari , Tamil Nadu with the following objectives,

- Isolation and identification of fungi from the sampling areas
- Physico- chemical parameters of water samples
- Frequency, density, abundance of fungi
- Species richness, diversity, evenness and Similarity indices of fungi in five stations
- Eco -taxonomical characterization of fungi
- Biodiversity of fungi
- Growth and Morphological characteristics of fungi on various media
- Effect of physical and chemical parameters on fungal growth
- Screening and Assay of Fungal Enzyme
- Estimation of Protein, Lipids, Amino acids and Rhamnolipids of fungi
- Biodegradation of petroleum products by fungi

Materials and Methods

Study area

Manakudy is a small village located at 7 kms distance from Kanyakumari, the nearest town which is one among the best tourist places in India. Kanyakumari uncovers the joining of three huge marine worlds; these are the Indian Ocean, the Arabian Sea and the Bay of Bengal. The geographical location of Manakudy estuary is found to be at 8.1160 latitude and 77.4882 longitudes. It is found at Manakudi and adjacent villages where the Sanguthurai, Chothavilai, Vivekananda Rock, Vattakotai fort and Chinnamuttom.

Isolation of mycoflora by plating techniques

After sampling, within 24 hrs the water samples from each station were subjected to appropriate dilutions (10^{-2} to10^{-5}) and 0.1 ml of sample was aseptically transferred into the plates containing Potato dextrose agar/ Czapek dox agar/Corn meal agar/Rose Bengal agar with addition of mixture antibiotics, Tetracycline and Penicillin (Spread plate method) The plates were incubated at room temperature (28°C) for 4-5 days. Control plates were also maintained. Sterilization of glasswares and preparations of media were carried out as per the method described by Booth (1971).

Physico – chemical analyses of water and sediment samples

The water and sediment sample were collected separately and analysed.

Effect of physical and chemical parameters on fungal growth (Booth, 1971; Boyd and Kohlmeyer, 1982; Aneja, 2001).

In this study, the most dominant fungal species (31 sp.) were selected and studied for biomass, effect of various parameters such as pH, temperature, salinity and carbon and nitrogen sources

Screening and Assay of Fungal Enzymes

In this fungal enzyme study, 31 species of fungi (most dominant) were selected and screened for the production of 8 microbial enzymes (alpha amylase, alkaline protease, cellulase, pectate lyase, lipase, xylanase, phosphatase enzymes acid and alkaline and laccase).

Biodegradation of hydrocarbon study (Nwachukwu, 2000)

Totally, 19 species of fungi were selected based on frequency of occurrence for hydrocarbon degradation.

Results and Discussion

Enumeration of taxa

The fungi belonging to different genera which were isolated by plating and baiting techniques were enumerated with morphological and ecological descriptions. The system of classification was based on "**The Fifth Kingdom - Mycota (ed.) Kendrick (1992)** for the arrangement of genera under their respective orders and families.

Ecology of fungi

Physico-chemical status of water and sediment samples with respect to fungal distribution

Altogether 135 fungi belonging to 48 genera comprising 97 Deuteromycotina, 21 Ascomycotina, 11 Zygomycotina, 1 Oomycota, 1 Chytridiomycota and 1 Basidiomycotina were isolated.

Species diversity of fungi in the mangrove ecosystem

During the four month study period, a total of 135 fungal species were enumerated from five sampling stations S1, S2, S3, S4, and S5 by plating and baiting techniques and also direct observation of the fungal spores in the centrifuged sediment layer of the sea foams. Among these, 67 species were represented in S1, 61 in S2, 53 in S3, 63 in S4 and 56 in S5. Maximum fungal diversity was observed in S1 with represented by 67 species and minimum of 53 species was isolated in S3.

Occurrence of fungi in the Marine water

In this study, totally 87 species of fungi were isolated and enumerated from the water samples by dilution-plating technique. Among the fungi isolated 2 species belonged to Chytridiomycetes; 5 belonged to Zygomycetes; 6 to Ascomycetes and 69 to Deuteromycotina. Of all these, *Aspergillus* were found to be dominate genus with 30 species, followed by *Curvularia* (6 species), *Penicillium* (11 species), *Alternaria* (3 species) and 5 species of *Cladosporium***.**

Occurrence of fungi in the estuarine sediment samples

11fungi to Zycomycotina, 5 to Ascomycotina and 81 belonged to Deutromycotina . As like in the water samples, in sediments samples also the genus *Aspergillus* was also found to be dominant (represented with 30 species), followed by *Curvularia* (8 species), *Penicillium* (12 species) *Drechslera* (5) and *Alternaria* (4 species), Cladosporium (6 species)**.**

Seasonal variation of species

At species level of the total 135 species recorded, 68 species were found exclusively in post monsoon, 64 in summer, and 112 in Pre- monsoon and 68 species in monsoon .

Frequency of occurrence, density, abundance and relative frequency of fungi in all the five sampling stations

Accordingly 31 species belonged to 100% of frequency of occurrence followed by 13 sp. with 80%, 10 with 60%, 19 with 40% and 32 sp. were 20% observed in the mangrove eco- systems.

Growth characteristics of fungi on various parameters

Colony growth rate of the fungi was studied on seven different types of solid media (PDA, SDA, CMA, CZA, MA, RBA, and OMA). Effect of different ecological parameters such as pH (5-9), temperature (20-60ºC), salinity (5-40%), metals ($FeSO_4$ and $ZnSO_4$), carbon (CMC, starch and mannitol) and nitrogen sources (ammonium nitrate and calcium nitrate) on the growth of fungi was also determined.

Screening and activity of fungal enzyme

In this study, all the 31 species showed zone of clearance in alpha amylase and alkaline protease on selective screening media followed by cellulase with 23 sp., pectate lyase with 12 sp., lipase with 11 sp., xylanse with 13 sp., phosphatase activity was observed in 19 sp. and laccase in 17 sp. were showed zone of clearance around the colony on selective screening media.

Biodegradation of hydrocarbon studies

Totally, 19 species of fungi were studied for hydrocarbon degradation. Among the fungi, *Aspergillus, Penicillium, Rhizopus, Cladosporium, Neurospora, Mucor and Fusarium* showed maximum hydrocarbon degradation.

Table 1. Documentation of fungi isolated during the study period (JAN 2013 TO DEC 2013)

Total number of species	=	135
True marine fungi	=	19
Terrestrial fungi	=	116

Stations wise,

In Sanguthurai	=	67
In Chothavilai	=	61
In Vivekananda Rock	=	53
In Vattakottai fort	=	63
In Chinnamuttom	=	56

Seasons wise,

During post-monsoon	=	68
During summer	=	64
During pre-monsoon	=	112
During monsoon	=	68

Substrate wise,

From water	=	87
From sediment	=	98
From sea foams	=	40
From natural substrares	=	66

Table 2. Fungi isolated from all the five sampling stations during the study period

Name of the fungi	S1	S2	S3	S4	S5
Mycota Chytridiomycota					
Allomyces arbusculus	+	+	-	-	-
Oomycota					
Achlya ambisexualis	-	-	+	-	-
Zygomycota					
Cunninghamella elegans.	+	-	-	-	-
Absidia spinosa	+	-	+	-	-
Mucor flavus	-	-	+	-	-
M. pusillus	+	+	-	+	-
Mucor sp.	+	+	-	+	+
Rhizopus arrhizus	-	+	-	-	+
Rhizopus oryzae	+	+	+	+	+
R. nigricans	+	+	+	+	+
R. stolonifer	+	+	+	+	+
Actinomucor elegans	+	+	-	-	+
Syncephalastrum racemosum	-	-	+	-	-
Ascomycotina					
Saccharomyces sp. 1	-	-	+	+	-
Saccharomyces sp. 2	-	+	-	+	+
Saccharomyces sp. 3	+	+	-	-	-
Saccharomyces sp. 4	+	-	-	+	+
Bicrouania maritima	-	-	-	-	-
Didymella avicenniae	-	-	-	-	-
Leptosphaeria peruviana	-	-	-	-	-
Leptosphaeria sp.1	-	-	-	-	-

Massarina armatispora	-	-	-	-	-
Massarina cystophorae	-	-		-	-
Ploespora aquatica	-	+	-	-	-
Quintaria lignatilis	-	-	-	-	-
Trematosphaeria lineolatisopsora	+	-	-	-	-
Verrculina enalia	-	-	-	-	-
Emericella nidulans	+	-	-	+	-
Chaetomium globosum	-	-	+	-	-
Thielavia terricola	-	-	-	-	+
Neurospora crassa	+	+	+	+	+
Arenariomyces trifurcatus	-	-	-	-	-
Halosphaeria maritima	-	-	-	-	-
Lophiostoma mangrovei	-	-	-	-	-
Lulworthia grandispora	-	-	-	-	-
Torpedospora ambispinosa	-	-	-	-	-
Basidiomycotina					
Phanerochaete chrysosporium	-	-	-	-	-
Deuteromycotina					
Aspergillus alliceus	-	+	-	-	+
Aspergillus candidus	+	+	+	+	+
A. carbonarius	+	+	+	+	+
A. castaneus	+	+	-	+	+
A. chevalieri	+	-	-	+	+
A. clavatus	+	+	-	+	+
A. conicus	+	+	+	+	+
A. erthrocephalus	+	+	-	+	+
A. flavus	+	+	+	+	+
A. fumigates	+	+	+	+	+
A. funiculosus	+	+	+	+	+
A.humicola	+	-	+	+	-
A. japonicas	-	-	+	+	-
A. luchuensis	+	+	-	+	+
A. nidulans	+	+	+	+	+
A. niger	+	+	+	+	+
A. ochraceus	+	+	-	+	+
A. oryzae	+	+	+	+	+
A. parasiticus	-	-	-	-	+
A. repens	+	+	+	+	-
A. ruber	+	-	-	-	-
A. sacchari	+	+	+	+	+
A. sparsus	-	-	-	-	+
A. sulphureus	+	+	+	+	+
A. sydowi	+	+	+	+	+
A. tamari			-		
A. terreus	+	+	+	+	+

A. terricola	+	+	-	+	+
A. ustus	+	+	+	+	+
A. versicolor	+	+	+	+	+
A. wentii	+	+	+	+	+
Botrytis bassiana	-	-	-	+	-
Cephalosporium acremonium	-	-	-	+	-
P. citrinum	+	+	+	+	+
P. digitatum	+	-	+	+	-
P. expansum	+	-	-	+	+
P. frequentans	-	-	-	+	+
P. funiculosum	-	-	-	-	+
P. griseum	+	+	-	-	-
P. janthinellum	+	+	+	+	+
P. lanosum	-	-	-	-	+
P. luteum	-	-	-	+	-
P. purpurrescens	+	+	+	-	-
P. restrictum	-	-	+	+	-
P. rubrum	+	+	-	+	+
Trichoderma viride	+	+	-	-	+
Varicosporina ramulosa	-	-	-	-	-
Verticillium luteo -album	+	-	-	+	-
Alternaria brassicola	+	-	-	+	+
A. cincerariae	-	-	+	-	-
A. citri	+	+	-	-	+
A. crassa	+	-	-	-	-
A. dennisii	-	-	-	-	-
A. humicola	+	-	-	-	-
A. petroselini	-	-	-	-	-
A. solani	-	-	-	-	-
A. triticicola	-	-	-	-	-
A. tenuissima	-	-	-	-	-
Bidenticula cannae	-	-	+	-	-
Bipolaris tetramera	-	+	-	-	-
Cercospora beticola	-	-	+	-	-
Cirrenalia tropicalis	-	-	-	-	-
Cladosporium apicale	+	+	-	+	+
C. britannicum	+	+	+	+	+
C. gallicola	-	-	+	+	-
C. herbarum	-	-	+	-	-
C. tenuissimum	+	+	-	+	-
C. uredinicola	+	+	+	-	+
Clavatspora bulbosa	-	-	-	-	-
Cochlibolus sativus	-	+	-	+	-
Curvularia andropogonis	-	-	-	-	-
C. geniculata		+	-	+	+
C. inaqualis	-	+	+	+	+
C. indica	+	-	-	-	-
C. lunata	+	+	+	+	-
C. pallescens	-	+	-	-	-
C. palmarum	-	+	+	-	-
C.richardiae	-	+	-	-	-
C. subulata	-	+	-	-	-

C. tritici	-	-	-	+	+
C. tuberculata	-	+	-	-	-
C. uncinata	-	-	+	-	-
Drechslera avenacea	-	-	+	-	+
D. indica	+	-	-	+	-
D. japonica	+	-	-	+	+
D. stenospila	-	-	-	+	-
D. tripogonis	-	-	+	+	-
H. velutinum	-	-	-	-	-
Nigrospora sphaerica	+	-	+	-	-
Periconia laminella	-	-	-	-	-
Scolecobasidium gyrocarpi	+	+	+	-	-
Tetraploa aristata	-	-	-	-	-
Fusarium moniliforme	+	-	+	-	-
F. oxysporum	+	+	+	+	-
F. semitectum	+	+	+	+	+
F. subulatum	+	-	-	-	-
Ascochyta vulgaris	-	-	+	-	+
Phoma humicola	-	+	-	-	-
Total no. of Fungi	**67**	**61**	**53**	**63**	**56**

(+) - Present
(–) - Absent

Table 3. List of Fungi isolated from various marine substrate samples collected in the study area.

Name of the fungi	Water	Sediment	Sea foams	Natural substrates
Mycota				
Chytridiomycota				
Allomyces arbusculus	+	-	-	+
Oomycota				
Achlya ambisexualis	+	-	-	+
Zygomycota				
Cunninghamella elegans	-	+	-	+
Absidia spinosa	+	+	-	-
Mucor flavus	-	+	+	-
M. pusillus	+	+	-	-
Mucor sp.	+	+	+	+
Rhizopus arrhizus	+	+	-	-
R. oryzae	+	+	-	+
R. nigricans	+	+	+	-
R. stolonifer	+	+	-	-
Actinomucor elegans	+	+	-	-
Syncephalastrum racemosum	-	+	-	-
Ascomycotina				
Saccharomyces sp. 1	+	-	-	+
Saccharomyces sp. 2	+	+	-	-
Saccharomyces sp. 3	-	+	-	-

Saccharomyces sp. 4	+	-	-	-
Bicrouania maritime	-	-	-	+
Didymella avicenniae	-	-	-	+
Leptosphaeria peruviana	-	-	-	+
Leptosphaeria sp.1	-	-	-	+
Massarina armatispora	-	-	-	+
Massarina cystophorae	-	-	-	-
Ploephora aquatica	+	-	-	-
Quintaria lignatilis	-	-	-	+
Trematosphaeria lineolatisopsora	-	-	-	+
Verrculina enalia	-	-	-	+
Emericella nidulans	+	+	-	+
Chaetomium globosum	-	+	-	+
Thielavia terricola	+	+	-	-
Neurospora crassa	+	+	-	+
Arenariomyces trifurcates	-	-	+	-
Halophaeria maritima	-	-	+	-
Lophiostoma mangrovei	-	-	-	+
Lulworthia grandispora	-	-	-	+
Torpedospora ambispinosa	-	-	-	+
Basidiomycotina				
Phanerochaete chrysosporium	-	-	-	+
Deuteromycotina				
Aspergillus alliceus	+	-	-	-
Aspergillus candidus	+	+	-	+
A. carbonarius	+	+	-	+
A. castaneus	+	+	-	-
A. chevalieri	+	+	+	+
A. clavatus	+	+	-	+
A. conicus	+	+	+	+
A. erthrocephalus	+	+	+	+
A. flavus	+	+	-	+
A. fumigates	+	+	+	+
A. funiculosus	+	+	-	+
A. humicola	+	+	-	-
A. japonicas	-	+	-	-
A. luchuensis	+	+	-	+
A. nidulans	+	+	+	+
A. niger	+	+	+	+
A. ochraceus	+	+	-	+
A. oryzae	+	+	+	+

A. parasiticus	+	+	-	+
A. repens	+	+	-	-
A. ruber	+	+	-	-
A. sacchari	+	+	-	+
A. sparsus	+	+	-	-
A. sulphureus	+	+	+	+
A. sydowi	+	+	+	+
A. tamari	+	+	-	-
A. terreus	+	+	+	+
A. terricola	+	+	-	+
A. ustus	+	+	-	+
A. versicolor	+	+	+	+
A. wentii	+	+	+	+
Botrytis bassiana	-	-	+	-
Cephalosporium acremonium	+	+	-	-
P. citrinum	+	+	+	+
P. digitatum	+	+	-	+
P. expansum	+	+	-	-
P. frequentans	+	+	-	+
P. funiculosum	+	+	+	-
P. griseum	+	+	-	-
P. janthinellum	+	+	-	+
P. lanosum	-	+	-	-
P. luteum	+	+	-	-
P. purpurrescens	+	+	+	-
P. restrictum	+	+	-	-
P. rubrum	+	+	-	+
Trichoderma viride	+	+	-	+
Varicosporina ramulosa	-	-	+	-
Verticillium luteo-album	+	+	-	+
Alternaria brassicola	+	+	-	-
A. cincerariae	-	+	+	-
A. citri	+	+	-	+
A. crassa	-	-	-	-
A. dennisii	-	-	+	-
A. humicola	+	+	-	-
A. petroselini	-	-	+	-
A. solani	-	-	+	-
A. triticicola	-	-	+	-
A. tenuissima	-	-	+	-
Bidenticula cannae	+	+	-	+
Bipolaris tetramera	-	+	-	-
Cercospora beticola	+	+	-	+
Cirrenalia tropicalis	-	-	-	+
Cladosporium apicale	+	+	-	+
C. britannicum	+	+	-	+
C. gallicola	+	+	-	-
C. herbarum	+	+	-	-
C. tenuissimum	+	+	-	+
C. uredinicola	+	+	-	-
Clavatspora bulbosa	-	-	-	+
Cochliobolus sativus	-	+	+	-

Curvularia andropogonis	-	-	-	-
C. geniculata	-	+	+	+
C. inaqualis	+	-	-	-
C. indica	+	-	+	-
C. lunata	+	+	-	+
C. pallescens	-	+	+	-
C. palmarum	+	+	-	+
C. richardiae	-	+	+	-
C. subulata	+	+	+	+
C. tritici	+	-	-	-
C. tuberculata	-	+	+	-
C. uncinata	-	+	-	-
Drechslera avenaea	-	+	-	-
D. indica	+	+	+	-
D. japonica	+	+	+	-
D. stenospila	+	+	-	-
D. tripogonis	-	+	-	-
H. oryzae	+	+	-	-
H. velutinum	-	-	-	-
Nigrospora sphaerica	+	+	-	+
Periconia laminella	-	-	-	-
Scolecobasidium gyrocarpi	-	+	+	-
Tetraploa aristata	-	-	+	-
Fusarium moniliforme	+	+	-	-
F. oxysporum	+	+	-	+
F. semitectum	+	+	+	+
F. subulatum	+	+	-	-
Ascochyta vulgaris	-	+	-	-
Phoma humicola	-	+	-	-
Total No.of Fungi	**87**	**98**	**40**	**66**

(+) – Present (–) – Absent

Table 4. Screening of enzymes from most dominant fungi isolated from Mangroves

Name of the fungi	Alpha amylase	Alkaline protease	*Cellulase*	Pectate lyase	Lipase	Xylanse	Phos-phatase	Laccase
Rhizopus nigricans	+	+	+	-	+	+	-	-
R. oryzae	+	+	-	+	+	-	+	-
R. stolonifer	+	+	+	-	+	-	+	+
Mucor sp.	+	+	+	-	+	+	+	-
Neurospora crassa	+	+	+	-	+	+	+	-
Aspergillus candidus	+	+	+	-	-	+	+	-
A. carbonarius	+	+	+	+	-	-	+	+
A. clavatus	+	+	+	+	+	+	+	+
A. conicus	+	+	+	+	-	-	+	-
A. erythrocephalus	+	+	-	-	-	-	+	-
A. flavus	+	+	+	+	-	+	+	+
A. fumigatus	+	+	+	-	-	+	-	-
A. funiculosis	+	+	-	-	-	+	+	-
A. luchensis	+	+	+	-	-	+	-	-
A. nidulans	+	+	-	+	+	-	-	+

A. niger	+	+	+	+	+	+	+	+
A. ochraceus	+	+	+	-	-	-	+	-
A. oryzae	+	+	+	+	+	-	-	+
A. sacchari	+	+	+	-	-	-	+	+
A. sulpuhreus	+	+	-	-	-	-	-	-
A. sydowi	+	+	+	-	-	+	+	+
A. terreus	+	+	-	-	-	-	-	+
A. terricola	+	+	-	-	-	+	-	+
A. ustus	+	+	-	-	-	-	+	+
A. versicolor	+	+	+	+	-	+	-	+
A. wentii	+	+	+	-	-	-	+	+
Pencillium citrinum	+	+	+	-	+	-	+	-
P. janthinellum	+	+	+	+	+	-	-	-
P. rubrum	+	+	+	-	-	-	-	+
Cladosporium britannicum	+	+	+	+	-	-	-	+
Fusarium semitectum	+	+	+	+	-	-	+	+
Total No.of Fungi	**31**	**31**	**23**	**12**	**11**	**13**	**19**	**17**

(+) - Presence of Zone formation (-) - Absence of Zone formation

Table 5. Enzyme activity of fungi isolated from mangroves (The values are represented in U/ml)

Name of the fungi	Alpha amylase	Alkaline protease	*Cellulase*	Pectate lyase	Lipase	Xylanase	Phosphatase		Laccase
							Acid	Alkaline	
Rhizopus nigricans	3.7605	3.0474	3.635	-	2.44	4.804	-	-	-
R .oryzae	1.7680	2.036	-	11.529	1.67	-	2.549	0.8147	-
R. stolonifer	4.3569	1.1906	2.241		1.318	-	1.708	1.1960	0.1738
Mucor sp.	2.5957	4.0633	0.8397	1.2153	2.982	3.712	1.109	1.122	-
Neurospora crassa	3.077	3.7352	1.812	-	0.4820	4.0178	0.9618	0.9537	-
Aspergillus candidus	1.9613	3.4550	0.8552	-	-	3.732	1.101	1.3786	-
A. carbonarius	2.1814	0.0606	0.7698	1.6470	-	-	0.8822	0.8606	0.0416
A. clavatus	2.422	5.0594	1.3407	1.3513	0.690	5.232	1.316	1.5723	0.0169
A. conicus	2.7975	6.4649	2.3700	3.0193	-	-	0.7725	1.0266	-
A. erythrocephalus	3.264	5.791	-	-	-	-	1.121	1.0495	-
A. flavus	1.6290	3.360	1.3906	0.6956	-	5.805	0.856	0.8875	0.0366
A. fumigatus	2.570	4.3794	3.2077	-	-	4.162	-	-	-
A. funiculosis	0.5940	6.8520	-	-	-	5.125	1.000	1.854	-
A. luchuensis	2.8507	1.5025	2.700	-	-	4.85	-	-	-
A. nidulans	2.602	2.8198	-	2.2857	0.6643	-	-	-	0.0189
A. niger	4.7752	2.1341	2.486	3.3557	1.341	3.688	1.366	1.850	0.0258
A. ochraceus	1.5614	2.6445	2.200	-	-	-	0.8612	0.7282	-
A. oryzae	1.0656	3.8408	2.477	-	1.021	-	-	-	0.0103
A. sacchari	3.037	2.689	0.7428	-	-	-	0.5329	1.2170	0.0608
A. sulpuhreus	4.153	6.104	-	-	-	-	-	-	-
A. sydowi	1.9776	3.3116	3.313	-	-	4.123	1.380	1.4375	0.0212
A. terreus	1.8522	4.9392	-	-	-	-	-	-	0.0207
A. terricola	2.863	5.7555	-	-	-	3.980	-	-	0.0504
A. ustus	1.9356	4.8613	-	-	-	-	0.8134	1.3045	0.0264
A. versicolor	2.0460	4.7346	3.991	1.999	-	5.424	-	-	0.0113
A. wentii	1.0427	6.419	3.1070	-	-	-	0.9214	1.2835	0.0151

Penicillium citrinum	2.1117	5.304	1.437	-	0.7638	-	1.115	1.4718	-
P. janthinellum	2.1061	5.482	2.951	1.8151	1.1933	-	-	-	-
P. rubrum	1.8506	3.3894	2.707	-	-	-	-	-	0.0861
Cladosporium britannicum	1.6480	2.4854	1.5983	-	-	-	-	-	0.0366
Fusarium semitectum	2.016	5.1991	11.460	1.085	-	-	1.6207	1.809	0.0149

Table 6. Estimation of protein, lipids, amino acids and rhamnolipids content of selected fungi

S.No	Name of the fungi	Protein (mg/g)	Lipids (%)	Amino acids (mg/g)	Rhamno Lipids (mg/g)
1	*Rhizopus nigricans*	1.2325	0.92	1.2587	0.1445
2	*R. oryzae*	0.9525	0.28	1.232	0.1445
3	*R. stolonifer*	1.5075	1.15	1.65	0.3545
4	*Mucor* sp.	1.6975	1.04	1.6062	0.4690
5	*Neurospora crassa*	1.5225	1.06	1.8275	0.3909
6	*Aspergillus candidus*	1.0525	0.95	1.4012	0.1854
7	*A. carbonarius*	0.945	0.47	1.16	0.1381
8	*A. clavatus*	1.0175	0.53	1.4187	0.1381
9	*A. conicus*	1.02	0.08	1.21	0.1636
10	*A. erythrocephalus*	1.2575	0.20	1.4112	0.1072
11	*A. flavus*	1.725	1.14	1.9862	0.5090
12	*A. fumigatus*	1.6325	1.07	1.866	0.52
13	*A. funiculosis*	1.13	0.36	1.2525	0.1254
14	*A. luchensis*	1.2275	0.55	1.5012	0.0836
15	*A. nidulans*	1.675	1.02	1.7362	0.52
16	*A. niger*	1.73	1.73	2.0025	0.2163
17	*A. ochraceus*	0.74	0.53	1.27	0.1563
18	*A. oryzae*	0.99	0.72	1.2412	0.1509
19	*A. sacchari*	1.2025	0.73	1.2362	0.1545
20	*A. sulphureus*	0.95	0.27	1.4862	0.1145
21	*A. sydowi*	0.725	0.27	1.2612	0.1381
22	*A. terreus*	1.625	1.22	1.9775	0.50
23	*A. terricola*	0.9625	0.24	1.24	0.1581
24	*A. ustus*	1.08	0.63	1.1262	0.1275
25	*A. versicolor*	0.7325	0.82	1.2262	0.1445
26	*A. wentii*	0.92	0.18	1.135	0.0963
27	*Penicillium citrinum*	1.5425	1.04	1.7362	0.3090
28	*P. janthinellum*	1.14	0.49	1.2475	0.1763
29	*P. rubrum*	1.5225	0.24	1.76	0.1445
30	*C. britannicum*	0.7925	0.50	1.3612	0.1872
31	*Fusarium semitectum*	1.5	1.13	1.7325	0.5327

Table – 7 Biodegradation of hydrocarbon – Diesel

Name of the fungi	1st Day	2nd Day	3rd Day	4th Day	5th Day	6th Day	7th Day
Aspergillus candidus	0.01	0.02	0.07	0.08	1.02	0.05	0.51
A. carbonarius	0.01	1.06	0.08	0.08	1.09	0.11	0.08
A.erythrocephalus	0.01	0.03	1.07	1.02	1.02	0.09	0.13
A. flavus	0.01	0.05	0.08	0.08	2.00	0.10	0.11
A. fumigatus	0.02	1.01	1.06	1.04	1.05	0.07	0.18
A. luchuensis	0.02	0.02	0.09	0.06	1.03	0.05	0.06
A. nidulans	0.01	1.01	0.08	1.00	1.04	0.06	0.13
A. niger	0.01	1.01	0.23	1.04	1.07	0.06	0.09
A. ochraceus	0.03	1.02	1.07	1.03	1.02	0.12	0.22
A. sulphureus	0.02	1.34	1.48	0.80	1.04	0.01	0.15
Pencillium citrinum	0.01	0.06	1.04	0.09	2.00	0.06	0.15
P. janthinellum	0.01	0.06	0.20	0.07	2.05	0.04	0.51
Rhizopus nigricans	1.2	0.54	0.83	0.73	0.88	0.08	0.18
R.oryzae	0.01	0.02	0.09	1.04	2.03	0.14	0.27
R.stolonifer	0.02	1.0	1.09	1.01	1.02	0.09	0.20
Cladosporium britannicum	0.01	1.03	1.02	1.06	1.06	0.26	0.14
Neurospora crassa	0.01	0.05	1.00	1.03	1.02	0.06	0.08
Mucor sp	0.01	1.0	1.08	0.05	1.08	0.09	0.11
F. semitectum	0.02	0.03	0.07	1.01	1.09	0.14	0.15

Table – 8Biodegradation of hydrocarbon - Petrol.

Name of the fungi	1st Day	2nd Day	3rd Day	4th Day	5th Day	6th Day	7th Day
Aspergillus candidus	0.03	0.21	0.09	0.10	0.11	0.09	0.06
A. carbonarius	0.01	0.03	0.11	0.07	0.08	0.05	0.06
A.erythrocephalus	0.01	0.06	0.06	0.03	0.11	0.15	0.09
A. flavus	0.03	0.04	0.08	0.07	0.08	0.11	0.10
A. fumigatus	0.01	0.02	0.09	0.05	0.09	0.06	0.09
A. luchuensis	0.02	0.02	0.10	0.05	0.10	0.08	0.05
A. nidulans	0.01	0.06	0.09	0.11	0.09	0.12	0.11
A. niger	0.03	0.02	0.12	0.04	0.10	0.08	0.06
A. ochraceus	0.01	0.02	0.14	0.05	0.13	0.10	0.08
A. sulphureus	0.02	0.03	0.02	0.03	0.13	0.11	0.09
Pencillium citrinum	0.04	0.04	0.05	0.09	0.09	0.09	0.07
P. janthinellum	0.16	0.03	0.32	0.22	0.34	0.24	0.19
Rhizopus nigricans	0.01	0.06	0.16	0.07	0.12	0.13	0.15
R.oryzae	0.01	0.10	0.10	0.14	0.17	0.10	0.11
R.stolonifer	0.01	0.10	0.09	0.08	0.26	0.12	0.08
Cladosporum britannicum	0.03	0.02	0.13	0.13	0.14	0.14	0.08
Neurospora crassa	0.05	0.20	0.11	0.13	0.20	0.13	0.10
Mucor sp	0.06	0.11	0.12	0.10	0.11	0.12	0.08
Fusarium semitectum	0.01	0.02	0.07	0.11	0.16	0.15	0.12

Table – 9Biodegradation of hydrocarbon – Crude oil.

Name of the fungi	1st Day	2nd Day	3rd Day	4th Day	5th Day	6th Day	7th Day
A.candidus	0.01	0.04	0.02	0.31	0.19	0.09	0.10
A. carbonarius	0.06	1.05	1.07	1.09	0.39	0.23	0.15
A.erythrocephalus	0.01	0.05	1.04	0.21	0.24	0.19	0.13
A. flavus	0.01	0.04	1.02	1.01	0.34	0.09	0.10
A. fumigatus	0.03	0.04	1.01	1.25	0.40	0.18	0.19
A. luchuensis	0.01	0.02	1.04	1.02	0.20	0.20	0.12
A. nidulans	0.01	1.03	1.09	1.25	0.24	0.15	0.17
A. niger	0.05	0.08	0.08	0.24	0.20	0.14	0.14
A. ochraceus	0.01	0.07	0.09	0.22	0.20.	0.16	0.19
A. sulphureus	0.04	1.00	1.04	0.20	0.19	0.06	0.17
Pencillium citrinum	0.01	1.02	0.08	1.06	0.24	0.14	0.18
P. janthinellum	0.01	1.03	0.06	0.19	0.19	0.11	0.08
Rhizopus nigricans	0.02	1.01	0.05	0.28	0.23	0.13	0.12
R.oryzae	0.04	1.06	0.07	0.20	0.25	0.17	0.17
R.stolonifer	0.02	0.07	2.00	0.31	0.48	0.21	0.21
Cladosporium britannicum	0.03	1.07	1.01	0.36	0.29	0.20	0.17
Neurospora crassa	0.02	1.04	1.05	0.21	0.29	0.15	0.12
Mucor sp	0.01	1.05	1.01	0.28	0.30	0.11	0.13
Fusarium semitectum	0.02	0.08	0.09	0.20	0.18	0.15	0.14

Table –10Biodegradation of hydrocarbon - kerosine.

Name of the fungi	1st Day	2nd Day	3rd Day	4th Day	5th Day	6th Day	7th Day
Aspergillus candidus	0.04	0.06	0.10	0.12	0.17	0.09	0.13
A. carbonarius	0.06	0.10	0.10	0.18	0.16	0.10	0.12
A.erythrocephalus	0.05	0.07	0.08	0.08	0.16	0.09	0.20
A. flavus	0.02	0.08	0.10	0.09	0.11	0.04	0.13
A. fumigatus	0.04	0.04	0.06	0.29	0.21	0.09	0.07
A. luchuensis	0.02	0.04	0.08	0.14	0.16	0.06	0.06
A. nidulans	0.05	0.09	0.13	0.12	0.21	0.17	0.16
A. niger	0.04	0.11	0.08	0.16	0.20	0.08	0.11
A. ochraceus	0.04	0.10	0.14	0.11	0.14	0.05	0.09
A. sulphureus	0.08	0.13	0.15	0.17	0.15	0.11	0.20
Pencillium citrinum	0.10	0.07	0.07	0.24	0.19	0.07	0.15
P. janthinellum	0.29	0.34	0.50	0.56	0.02	0.05	0.07
Rhizopus nigricans	0.04	0.06	0.08	0.12	0.17	0.04	0.10
R.oryzae	0.02	0.03	0.10	0.03	0.23	0.18	0.18
R.stolonifer	0.08	0.06	0.11	0.13	0.18	0.13	0.14
Cladosporium britannicum	0.05	0.05	0.09	0.18	0.08	0.11	0.16
Neurospora crassa	0.03	0.05	0.08	0.19	0.23	0.10	0.13
Mucor sp	0.01	0.04	0.07	0.12	0.20	0.12	0.15
Fusarium semitectum	0.08	0.11	0.17	0.18	0.19	0.10	0.20

Conclusion

From this investigation, we have concluded that the fungal biodiversity in marine ecosystem, *Aspergillus* and *Penicillium* was the common fungal genera among the isolated from the study period. Fungi play an important role in decomposition of natural substrates in marine ecosystem. The fungi isolated from marine systems are mainly used in hydrocarbon degradation of aliphatic and aromatic compounds, enzyme technology, biochemical, agricultural, pharmaceutical, molecular biology and other applied research fields.

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