

Diversity of Microfungi in Marine Sediments from the Gulf of Thailand and Andaman Sea and The *In Vitro* Antagonistic Activity Against Plant Pathogenic Fungi

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Abstract

A total of 50 fungal isolates comprising 8 genera 10 species were found in sediment from various island in Trat Province in the Gulf of Thailand and Krabi Province in Andaman Sea, and these were *Aspergillus flavus*, *A. fumigatus*, *A. niger*, *A. terreus*, *Aspergillus* spp., *Cladosporium cladosporioides*, *Emericella nidulans*, *Eupenicillium parvum*, *Eurotium amstelodami*, *Eurotium* spp., *Neosartorya* sp., *Penicillium* spp. and *Talaromyces flavus*. *Penicillium* spp. was the dominant species found in most locations comprising 21 isolates, followed by *Aspergillus* spp. (18), *Eurotium* spp. (4) *Cladosporium cladosporioides* (3), and one isolate each of *Emericella nidulans*, *Eupenicillium parvum*, *Neosartorya* sp. and *Talaromyces flavus*. Five isolates of marine-derived fungi were selected for *in vitro* antagonistic activity tests including *Penicillium* sp.1 (KUFC 10001), *Eurotium amstelodami* (KUFC 10011), *Eupenicillium parvum* (KUFC 10018), *Neosartorya* sp. (KUFC 10037) and *Talaromyces flavus* (KUFC 10046). The results indicated that *Eupenicillium parvum* inhibited 92.3% mycelial growth of *Phytophthora palmivora*, whereas *Neosartorya* sp. and *Talaromyces flavus* inhibited 83.9% and 83.3% mycelial growth of *Pyricularia oryzae* and *Alternaria brassicicola*, respectively. *Talaromyces flavus* inhibited 62-81% mycelial growth of *Colletotrichum gloeosporioides*, *Curvularia lunata*, *Fusarium oxysporum*, *Helminthosporium oryzae*, *Phytophthora palmivora* and *Pyricularia oryzae*. But five species of marine-derived fungi failed to inhibit mycelial growth of two basidiomycota anamorphs, *Rhizoctonia oryzae* and *Sclerotium rolfsii*.

Keywords: marine-derived fungi, marine sediment, Andaman sea, gulf of Thailand, plant pathogenic fungi, antagonistic test

Introduction

Kohlmeyer and Kohlmeyer (1979) stated that obligate marine fungi are those that grow and sporulate in a marine or estuarine habitat, while facultative marine fungi are those from freshwater or terrestrial environment which are able to grow and sporulate in the marine environment. Fungi play an active role in the degradation of organism debris present in marine environment and marine fungi have been discovered in all oceanic habitats, including coastal and oceanic waters and sediments.

Morrison-Gardiner (2002) stated that ecosystem fertility is dependent on microbial activity, and therefore fungi play a role in the heterotrophic conversion of reef biomass to nutrients. Only 1,500 taxa of marine fungi have been identified (Kirk et al., 2008), compared with the thousand species of terrestrial fungi described. The marine derived fungi are an excellent source of novel bioactive compounds potentially useful in medicine and agricultural applications.

Park et al. (2005) reported biologically active metabolites from the marine-derived fungus

Chromocleista sp. isolated from a deep-water sediment sample from the gulf of Mexico. Li et al. (2011) reported two Chloctanspirones A and B, that are novel chlorinated polyketides with an unprecedented carbon skeleton from the marine sedimentary derived fungus *Penicillium terrestre*. These compounds showed activity against both HL-60, A-549 cells. Eamvijarn et al. (2013) reported new bioactive meroditerpenes and indol alkaloids from the soil fungus *Neosartorya fischeri* and other marine-derived fungi, *Neosartorya laciniosa* and *Neosartorya tsunodae* from the gulf of Thailand. These compounds showed *in vitro* inhibitory activity on the MCF-7 (breast adenocarcinoma), NCI-H460 (non small cell lung cancer) and A375-C5 (melanoma) cell lines by the protein binding dye SRB method.

There have been several reports on the occurrence and distribution of fungi from marine sediments in Arabian sea, Australian ocean and Indian ocean (Soumya et al., 2013; Morrison-Gardiner, 2002; Raghukumar et al., 2003; Damare et al., 2005), but there no record on marine- derived fungi from Andaman sea which is one of the world's most dynamic and productive regions of oceans driven by strong reversals of monsoon winds. Therefore this report shows the occurrence of fungi in this area of the marine environment and discusses the general bioactivities of these organisms.

Materials and Methods

Fungal Isolation and Identification

Marine sediment samples were collected from Mu Koh Lanta National Park and

Mu Koh Phi Phi National Park, Krabi Province in Andaman Sea ; Koh Chang and Koh Yak-Lek, Trat Province in the gulf of Thailand (Table 1). Marine sediments were collected by SCUBA diving directly from the sea floor using a trowel. Each sample was placed wet into a sterile plastic bag and maintained in an ice box before transport to the laboratory. For fungal isolation, the soil plate method and potato dextrose agar (PDA) supplemented with 70% sea water were used (Ebel, 2007). They were incubated at 28°C for 3-5 days and the hyphal tips were transferred onto PDA slant and maintained as pure culture for identification.

Slides were prepared with sterile distilled water, lactophenol and Shear's as mounting media. Identification of the fungal isolates was based on macroscopic characteristics such as colony growth pattern, color, texture, etc. Microscopic characteristics such as spore formation, conidia, ascospore ornamentation, etc. and other characters were examined stereo- and light microscopes.

In vitro Antagonistic Tests of Marine derived Fungi and Plant Pathogenic Fungi

Five isolates of marine derived fungi from marine sediment were selected for testing their antagonistic activity against nine species of plant pathogenic fungi (Table 2). They were cultivated as dual cultures on PDA for 14 days at 28°C. The young mycelium from the colony margin of marine derived fungi and the particular plant pathogenic fungus were cut with sterile cork borer (0.8 cm diam) and placed on PDA, 7 cm apart. All Petri dishes were incubated at room temperature (28°C) for 14 days. The inhibition levels were calculated by using the formula: $(G_1 - G_2) / G_1 \times 100$. G_1 indicates the colony radius of plant pathogenic fungi in the control and G_2 indicated colony radius of plant pathogenic fungi in dual culture test (Intana et al., 2003; Kamsorn, 2012). Each treatment was performed on 2 replicates.

Results and Discussion

Diversity of Marine-derived Fungi

Fifty isolates of marine-derived fungi comprising 8 genera and 9 known species were found, including *Aspergillus flavus*, *A. fumigatus*, *A. niger*, *A. terreus*, *Aspergillus* spp., *Cladosporium cladosporioides*, *Emericella nidulans*, *Eupenicillium parvum*, *Eurotium amstelodami*, *Eurotium* spp., *Neosartorya* sp., *Penicillium* spp. and *Talaromyces flavus* (Table 3). *Penicillium* spp. was the dominant genus and 21 isolates were recorded, followed by *Aspergillus* spp. (18 isolates) and *Eurotium* spp. (4 isolates). However, it is interesting to note that one isolate each of *Emericella nidulans*, *Eupenicillium parvum*, *Eurotium amstelodami*, *Neosartorya* sp. and *Talaromyces flavus* were also found (Figures 1-4).

Table 1 Location, coordinates and dated of collection.

No.	Location	Coordinate	Dated
1	Koh Pai, Mu Koh Phi Phi National Park, Krabi Province	7° 48' 49.58" N and 98° 47' 54.99" S	20/04/56
2	Losama Bay, Kho Phi Phi Lay, Mu Koh Phi Phi National Park, Krabi Province	7° 40' 29.10" N and 98° 46' 03.65" S	21/04/56
3	Koh Ta-lu, Mu Koh Phi Phi National Park, Krabi Province	7° 56' 59.94" N and 98° 47' 32.98" S	21/04/56
4	Koh Rok-nai Mu Koh Lanta National Park, Krabi Province	7° 12' 22.55" N and 99° 03' 57.31" S	03/05/56
5	Koh Ha Mu Koh Lanta National Park, Krabi Province	7° 25' 22.79" N and 98° 53' 29.75" S	04/05/56
6	Deep marine sediment 40 m, Koh Ha, Mu Koh Lanta National Park, Krabi Province	7° 25' 27.31" N and 98° 53' 41.48" S	04/05/56
7	Koh Chang, Trat Province	11° 54' 18.13" N and 102° 19' 03.70" E	17/05/57
8	Koh Yak-Lek, Trat Province	11° 48' 59.00" N and 102° 12' 56.58" E	17/05/57

Table 2 Nine species of plant pathogenic fungi from various diseased plants used for antagonistic activity test.

Plant pathogenic fungi	Host plant	Diseases
<i>Alternaria brassicicola</i>	<i>Brassica alboglabra</i> (chinese kale)	Leaf spot
<i>Colletotrichum gloeosporioides</i>	<i>Capsicum frutescens</i> (chili)	Anthraxnose
<i>Curvularia lunata</i>	<i>Oryza sativa</i> (rice)	Leaf spot
<i>Fusarium oxysporum</i> f.sp. <i>cubense</i>	<i>Musa sapientum</i> (banana)	Fusarium wilt
<i>Helminthosporium oryzae</i>	<i>Oryza sativa</i> (rice)	Leaf blight
<i>Phytophthora palmivora</i>	<i>Durio zibethinus</i> (durian)	Root rot
<i>Pyricularia oryzae</i>	<i>Oryza sativa</i> (rice)	Leaf blight
<i>Rhizoctonia oryzae</i>	<i>Oryza sativa</i> (rice)	Sheath blight
<i>Sclerotium rolfsii</i>	<i>Solanum tuberosum</i> (potato)	Stem rot

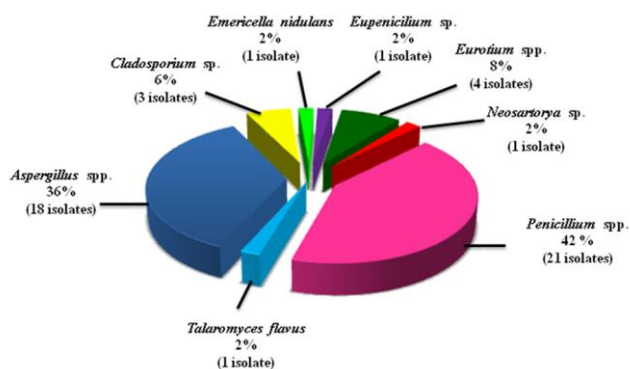
**Figure 1** Generic composition of marine-derived fungi isolated from marine sediments in the gulf of Thailand and Andaman sea.

Table 3 and Figures 2 indicated that *Penicillium* spp. were found from all locations, except Losama Bay, Koh Phi Phi National Park, Krabi Province. Higher numbers of *Penicillium* spp. were recorded at Koh Yak-Lek (5 isolates) and Koh Chang (3 isolates) in Trat Province, whereas *Penicillium* and *Aspergillus* were commonly found on all locations nearly *Talaromyces flavus*. High numbers of marine derived fungi were found at Koh Yak-Lek, Trat Province comprising 5 isolates of *Penicillium*, 6 isolates of *Aspergillus*, 2 isolates of *Cladosporium* and one isolate each of *Neosartorya* and *Talaromyces*. *Penicillium* spp. presented at high frequency (5 isolates) at deep marine sediment 40 m. Koh Ha, Mu Koh Lanta National Park, Krabi Province.

Table 3 Marine-derived fungi isolated from marine sediment at various locations in Trat and Krabi provinces.

Genus species	KUFC ^{1/}	Location ^{2/}	Genus species	KUFC ^{1/}	Location ^{2/}
<i>Aspergillus flavus</i>	10006	LbKb	<i>Eurotium</i> sp.2	10020	DpKb
<i>Aspergillus flavus</i>	10009	KtKb	<i>Eurotium</i> sp.3	10027	DpKb
<i>Aspergillus flavus</i>	10017	KhKb	<i>Neosartorya</i> sp.	10037	KyTr
<i>Aspergillus fumigatus</i>	10041	KyT	<i>Penicillium</i> sp.1	10001	KpKb
<i>Aspergillus fumigatus</i>	10042	KyTr	<i>Penicillium</i> sp.2	10002	KpKb
<i>Aspergillus fumigatus</i>	10043	KyTr	<i>Penicillium</i> sp.3	10003	KpKb
<i>Aspergillus fumigatus</i>	10045	KyTr	<i>Penicillium</i> sp.4	10008	KtKb
<i>Aspergillus niger</i>	10014	KrKb	<i>Penicillium</i> sp.5	10010	KtKb
<i>Aspergillus niger</i>	10035	KcT	<i>Penicillium</i> sp.6	10012	KrKb
<i>Aspergillus terreus</i>	10032	LbKb	<i>Penicillium</i> sp.7	10013	KrKb
<i>Aspergillus terreus</i>	10033	KcTr	<i>Penicillium</i> sp.8	10015	KhKb
<i>Aspergillus terreus</i>	10034	KcTr	<i>Penicillium</i> sp.9	10021	DpKb
<i>Aspergillus</i> sp.1	10005	KcTr	<i>Penicillium</i> sp.10	10023	DpK
<i>Aspergillus</i> sp.2	10019	DpKb	<i>Penicillium</i> sp.11	10024	DpKb
<i>Aspergillus</i> sp.3	10022	DpKb	<i>Penicillium</i> sp.12	10025	DpKb
<i>Aspergillus</i> sp.4	10048	KyTr	<i>Penicillium</i> sp.13	10026	DpKb
<i>Aspergillus</i> sp.5	10050	KyTr	<i>Penicillium</i> sp.14	10029	KcTr
<i>Aspergillus</i> sp.6	10007	KtK	<i>Penicillium</i> sp.15	10030	KcTr
<i>Cladosporium cladosporioides</i>	10028	DpKb	<i>Penicillium</i> sp.16	10031	KcTr
<i>Cladosporium cladosporioides</i>	10044	KyTr	<i>Penicillium</i> sp.17	10036	KyTr
<i>Cladosporium cladosporioides</i>	10049	KyTr	<i>Penicillium</i> sp.18	10038	KyTr
<i>Emericella nidulans</i>	10004	LbKb	<i>Penicillium</i> sp.19	10039	KyTr
<i>Eupenicillium parvum</i>	10018	KhKb	<i>Penicillium</i> sp.20	10040	KyTr
<i>Eurotium amstelodami</i>	10011	KtKb	<i>Penicillium</i> sp.21	10047	KyTr
<i>Eurotium</i> sp.1	10016	KhKb	<i>Talaromyces flavus</i>	10046	KyTr

^{1/} KUFC = Kasetsart University Fungal Collection

^{2/} Location KpKb = Koh Pai, Mu Koh Phi Phi National Park, Krabi Province, LbKb = Losama Bay, Kho Phi Phi Lay, Mu Koh Phi Phi National Park, Krabi Province, KtKb = Koh Ta-lu, Mu Koh Phi Phi National Park, Krabi Province, KrKb = Koh Rok-nai Mu Koh Lanta National Park, Krabi Province, KhKb = Koh Ha Mu Koh Lanta National Park, Krabi Province, DpKb = Deep marine sediment 40 m, Koh Ha, Mu Koh Lanta National Park, Krabi Province, KcTr = Koh Chang, Trat Province, KyTr = Koh Yak-Lek, Trat Province

Eupenicillium parvum (Raper & Fennell) Stolk & D.B. Scott, 1967

Reference: Guarro et al. (2012)

Specimens examined: Thailand. Krabi: Koh Ha, Mu Koh Lanta National Park. Andaman Sea, marine sediment, May 4, 2013, KUFC 10018.

Colonies on PDA growing slowly, reaching 2.0-2.3 cm diam. in 7 days at 28°C. Mycelium white, appearing red brown due to exudate. Cleistothecia abundant, submerged in mycelium, 50-200 µm. Asci borne singly, ellipsoidal, 6-7 µm in long axis. Ascospores ellipsoidal, very small, 2.0-2.2 µm diam. with roughened or spinose walls and two widely spaced longitudinal flanges.

Eurotium amstelodami Mangin, 1909

Reference: Guarro et al. (2012)

Specimens examined: Thailand. Krabi: Koh Ta-lu, Mu Koh Phi Phi National Park. Andaman Sea, marine sediment, April 21, 2013, KUFC 10011.

Colonies on PDA reaching 2.2-3.0 cm diam. in 7 days at 28°C. Mycelium yellow to dull yellow-grey. Conidial heads deep olive-green. Ascospores with irregularly papillate valves and broad ridges, 4.0-4.8 × 3.2-3.6 µm. Conidia subglobose to ellipsoidal, with end commonly flattened, finely papillate, mostly 4.5-5.0 × 3.5-4.0 µm, uninucleate (Figure 3D-3G).

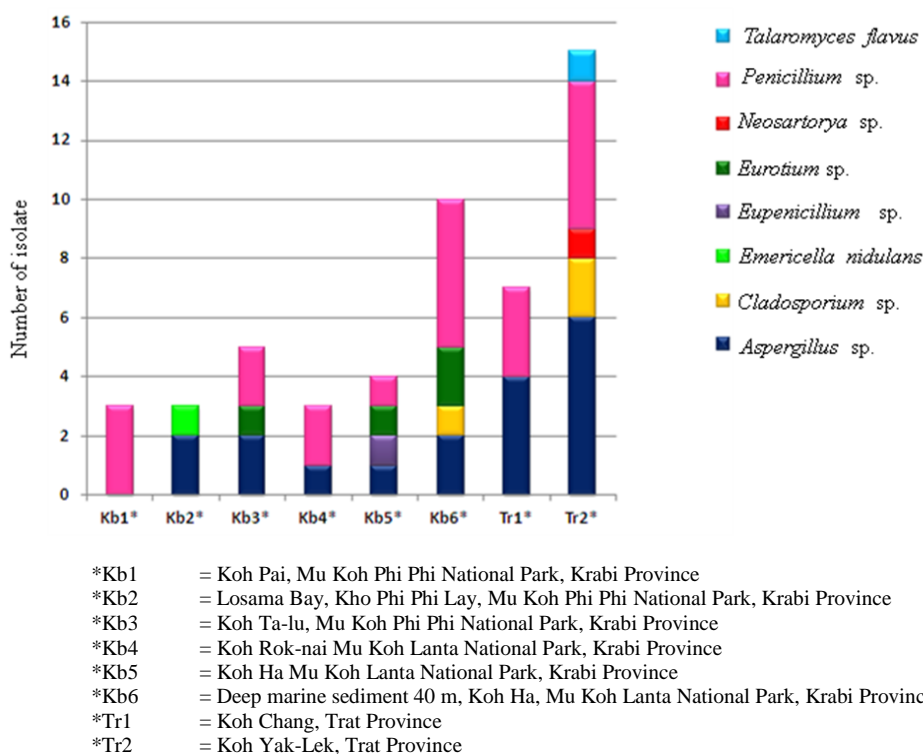


Figure 2 Occurrence of marine derived fungi isolated from marine sediments in Trat and Krabi provinces in the gulf of Thailand and Andaman sea.

Neosartorya sp. Malloch & Cain, 1972

Reference: Guarro et al. (2012)

Specimens examined: Thailand. Trat: Koh Yak-Lek. Gulf of Thailand, marine sediment, May 17, 2014, KUFC 10037.

Colonies on PDA reaching 3.0-5.0 cm diam. in 7 days at 28°C.

Ascomata superficial, pink to red, globose to subglobose, 100-190 µm. Asci 8 spored, globose to subglobose, 12.5-14.5×12.0-14.0 µm diam. Ascospores lenticular, spore body 5.0-5.5 × 5.0-5.5 µm provided with two wide equatorial crest measuring 0.5-1.0 µm wide (Figure 3H-3J).

Penicillium sp.1 Link ex Fr., 1821

Reference: Guarro et al. (2012)

Specimens examined: Thailand. Krabi: Koh Pai, Mu Koh Phi Phi National Park. Andaman Sea, marine sediment, April 20, 2013, KUFC 10001.

Colonies on PDA reaching 4.0-5.0 cm diam. in 7 days at 28°C.

Mycelium white with red pigment. Conidiophore 80-150 × 2-3 µm, smooth-walled, Monoverticillate, Phialides flask-shaped, 10-12 ×

2.0-2.5 µm. Conidia globose, smooth-walled, 2.5-3.0 µm in diam (Figure 3A-3C).

Talaromyces flavus (Klocker) Stolck and Samson, 1972

Reference: Stolck and Samson (1983)

Specimens examined: Thailand. Trat: Koh Yak-Lek. Gulf of Thailand, marine sediment, May 17, 2014, KUFC 10046.

Colonies on PDA reaching 3.5-4.5 cm diam. in 7 days at 28°C. Cleistothecia of tightly interwoven mycelium, bright yellow, about 200-450 µm diam., closely packed, maturing within 10-14 days. Ascospores yellow, ellipsoidal, 2.5-3.0 µm long, with spinose walls. Conidiophores borne from aerial hyphae, stipes 20-80 µm long, bearing terminal biverticillate or less commonly monoverticillate. Phialides acerose, 10-16 µm long. Conidia ellipsoidal to fusiform, 2.5-3.5 µm long, with smooth to spinulose walls.

Soumya et al. (2013) reported the occurrence of fungal species from 95 sediment samples in Arabian Sea using spread plate method on Rose Bengal agar medium supplemented with

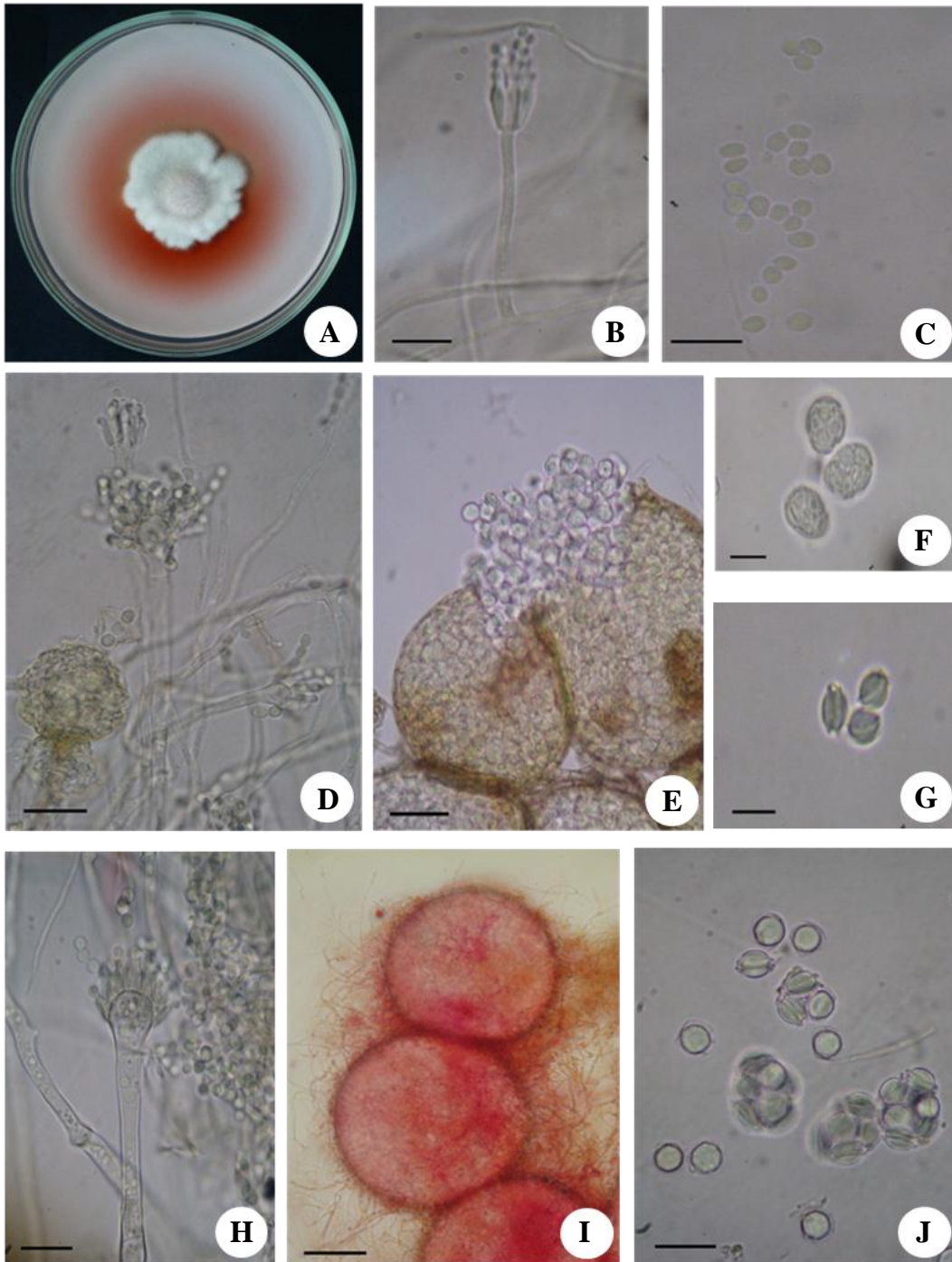


Figure 3 A-C. *Penicillium* sp.1 (KUFC 10001): A. Colony on PDA; B. Conidiophore, phialides and conidia; C. Conidia; D-G. *Eurotium amstelodami* (KUFC 10011): D. Conidiophores, phialides and conidia; E-G. Cleistothecia, asci and ascospores; H-J. *Neosartorya* sp. (KUFC 10037): H. Conidiophore, phialides and conidia; I. Cleistothecia; J. Asci and ascospores. (Scale bars: B, D, H = 5 μ m; C, E-G, I, J = 2 μ m)

choramphenicol (100 mg L⁻¹). They found 302 fungal isolates, comprising 27 different species. *Aspergillus* spp. was the dominant species (37%), followed by *Penicillium* sp. and *Cladosporium*. In contrast with our research, *Penicillium* was the

dominant fungal species and 21 isolates were recorded. Other investigators reported that *Aspergillus* was the dominant species in marine sediments for example; Raghukumar et al. (2003) recorded cultivated non-sporulating fungi, and

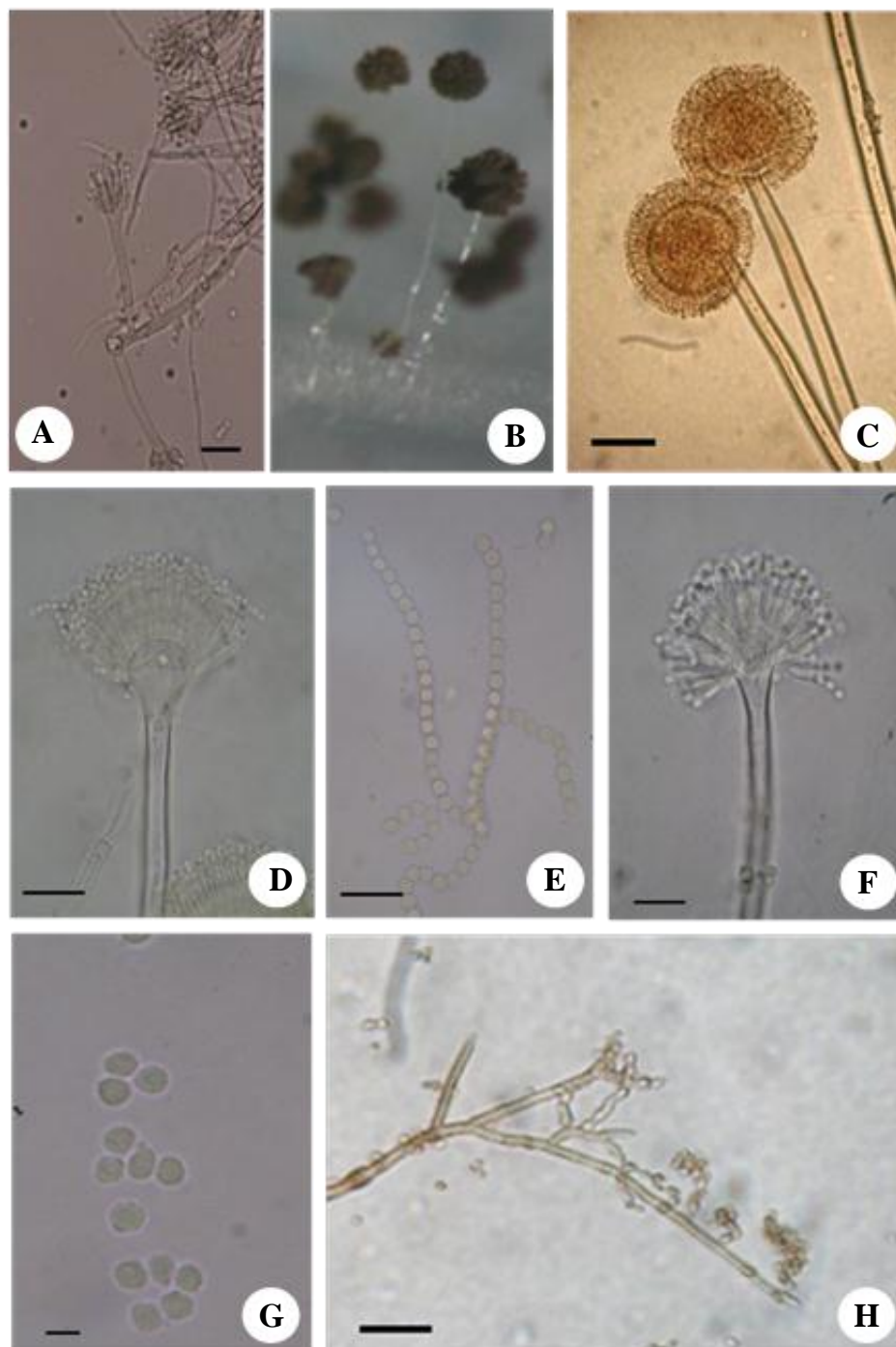


Figure 4 A. *Aspergillus fumigatus* (KUFC 10041): conidial heads and conidiophores; B-C. *Aspergillus niger* (KUFC 10014): B. Conidial head under stereomicroscope; C. Conidial head and conidiophore; D-E. *Aspergillus terreus* (KUFC 10032): D. Conidial head and conidiophore; E. Conidia; F-G. *Aspergillus* sp.4 (KUFC 10048): F. Conidial head and conidiophore; G. Conidia; H. *Cladosporium cladosporioides* (KUFC 10028): conidiophores and conidia. (Scale bars: A, D-F, H = 2 μ m; C, G = 1 μ m).

Aspergillus sydowii from the paleobes from a deep-sea sediment at a depth of 5,904 m from the Chagos trench in the Indian ocean. Damare *et al.* (2005) found that species of *Aspergillus* and non-sporulating fungi were most common in deep-sea

sediments from 5,000 m depth in the central Indian Basin using a variety of isolation techniques. They also stated that terrestrial species of fungi transported to the deep sea.

In Vitro Antagonistic Effect of Marine Fungi against Plant Pathogenic Fungi

Figure 5 show five isolates of marine derived fungi were selected for antagonistic activity test including *Penicillium* sp.1 (KUFC 10001), *Eurotium amstelodami* (KUFC 10011), *Eupenicillium parvum* (KUFC 10018), *Neosartorya* sp. (KUFC 10037) and *Talaromyces flavus* (KUFC 10046). *In vitro* antagonistic activity test was conducted using 5 isolates of them against 9 species of plant pathogenic fungi incubated for 14 days by dual culture test.

Table 4 and Figure 5 indicated that *Eupenicillium parvum* inhibited 92.3% mycelial growth of *P. palmivora*, followed by *Neosartorya* sp. and *Talaromyces flavus* inhibited 83.9% and 83.3% mycelial growth of *Pyricularia oryzae* and *Alternaria brassicicola*, respectively. In addition, *T. flavus* could inhibit 62-81% mycelial growth of *C. gloeosporioides*, *C. lunata*,

F. oxysporum, *H. oryzae*, *P. palmivora* and *P. oryzae*. However, five species of selected marine-derived fungi did not inhibit mycelial growth of two basidiomycota anamorphs, *Rhizoctonia oryzae* and *Sclerotium rolfsii*.

Eamvijan (2013) reported *N. fischeri* isolated from soil inhibited 53.9%-58.3% of radial growth of *Fusarium oxysporum*, *Alternaria brassicicola*, *Colletotrichum gloeosporioides* and *Curvularia oryzae*. Moreover, *N. tatenoi* provided of 62.2 and 57.1% growth inhibition of *Phytophthora palmivora* and *Pythium aphanidermatum*. Buaruang et al. (2010) reported a marine-derived fungus, *Neosartorya paulistensis* from marine sponge (*Chondrilla australiensis*) collected from coral reef at Mu Koh

Lan, Chonburi Province, in the Gulf of Thailand. However, *Neosartorya* spp. from a marine organism in coral reefs showed effectively control of mycelial growth of *Alternaria brassicicola*, *Colletotrichum gloeosporioides*, *Curvularia oryzae*, *Fusarium oxysporum*, *Lasiodiplodia theobromae*, *Phytophthora palmivora* and *Pythium aphanidermatum* but could not control *Rhizoctonia oryzae* and *Sclerotium rolfsii*.

Conclusions

Fifty isolates of marine derived fungi comprising 8 genera and 9 species were found in marine sediment from the Gulf of Thailand and Andaman Sea. Most common genera of microfungi were *Penicillium* spp. and *Aspergillus* spp. Species diversity and the percent of occurrence were higher in Trat as compare with Krabi. *Talaromyces flavus* was only found in Trat, whereas *Emericella nidulans*, *Eurotium amsterodami* and *Eurotium* spp. were found in Krabi. For antagonistic activity tests, *Eupenicillium parvum* inhibited 92.3% mycelial growth of *Phytophthora palmivora*, whereas *Neosartorya* sp. and *Talaromyces flavus* inhibited 83.9% and 83.3% mycelial growth of *Pyricularia oryzae* and *Alternaria brassicicola*, respectively. *Talaromyces flavus* inhibited 62-81% mycelial growth of *Colletotrichum gloeosporioides*, *Curvularia lunata*, *Fusarium oxysporum*, *Helminthosporium oryzae*, *Phytophthora palmivora* and *Pyricularia oryzae*. But five species of marine-derived fungi failed to inhibit mycelial growth of two basidiomycota anamorphs, *Rhizoctonia oryzae* and *Sclerotium rolfsii*.

Table 4 Percent inhibition on mycelial growth of nine plant pathogenic fungi by marine derived fungi cultivated on PDA at 28 °C for 14 days.

Plant pathogenic fungi	Mycelial growth inhibition of plant pathogenic fungi <i>in vitro</i> (%)				
	<i>Penicillium</i> sp.1	<i>Eurotium amstelodami</i>	<i>Eupenicillium parvum</i>	<i>Neosartorya</i> sp.	<i>Talaromyces flavus</i>
<i>Alternaria brassicicola</i>	56.7	47.7	76.7	63.3	83.3
<i>Colletotrichum gloeosporioides</i>	41.4	13.8	51.7	43.1	62.1
<i>Curvularia lunata</i>	52.9	35.7	68.6	51.4	75.7
<i>Fusarium oxysporum</i>	67.1	32.8	59.7	52.2	68.7
<i>Helminthosporium oryzae</i>	57.1	35.7	61.4	58.6	72.9
<i>Phytophthora palmivora</i>	60	50.7	92.3	75.4	81.5
<i>Pyricularia oryzae</i>	62.9	38.7	74.2	83.9	74.2
<i>Rhizoctonia oryzae</i> ^{1/}	0	0	0	0	0
<i>Sclerotium rolfsii</i> ^{1/}	0	0	0	0	0

^{1/} plant pathogenic fungi overgrew the colony of marine fungi.

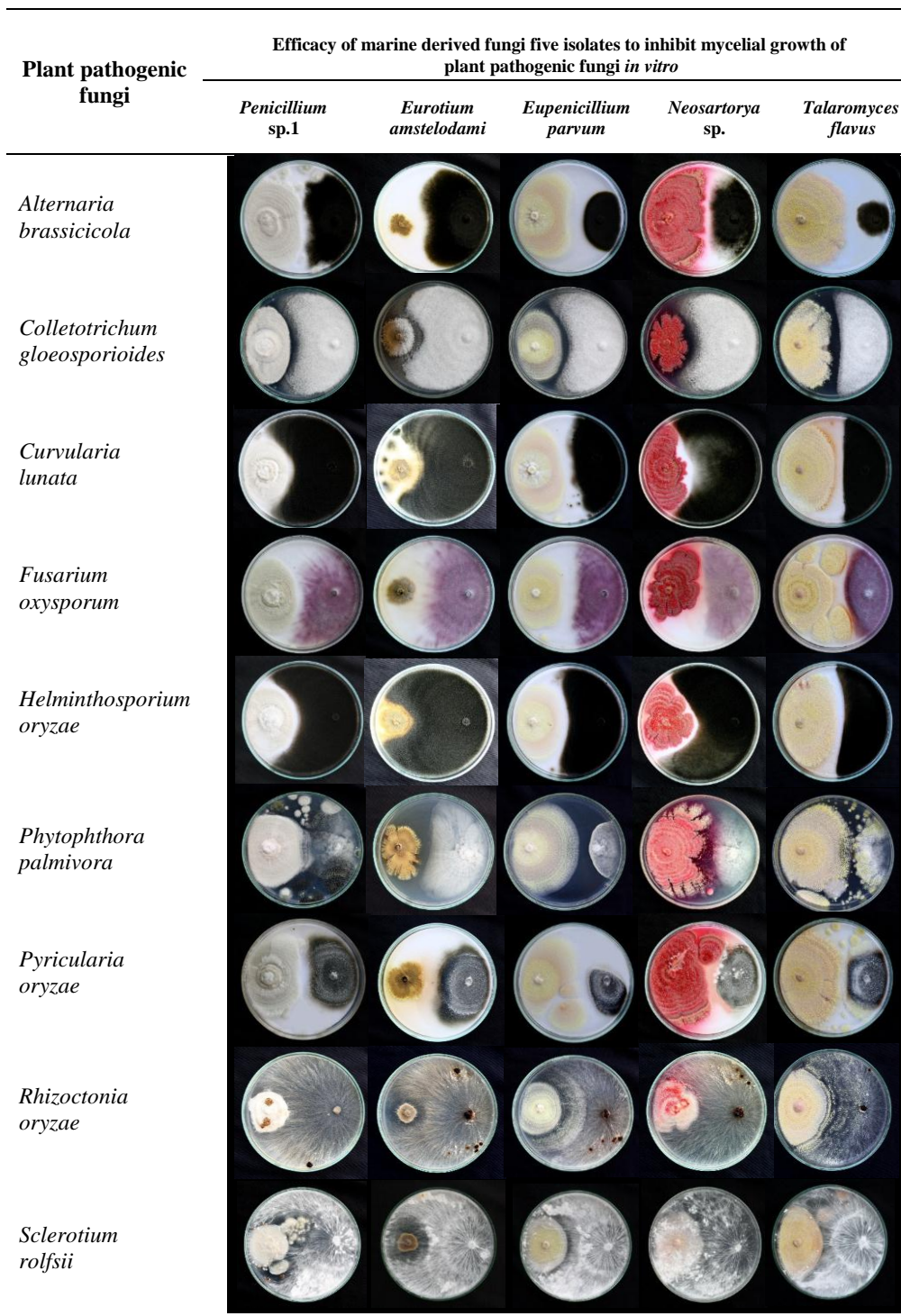


Figure 5 Antagonistic activity tests of five isolates of marine derived fungi against nine species of plant pathogenic fungi incubated as dual culture on PDA, 28 °C for 14 days (marine fungi on the left, plant pathogen on the right).

Acknowledgements

The authors would like to express their appreciation to the Graduate School, Kasetsart University for the Graduate Scholarship for the Fiscal Year 2010 for KT. Grateful thanks are extended to the Plant Genetic Conservation Project

under the Royal Initiative of HRH Princess Maha Chakri Sirindhorn and the Naval Special Warfare Command, the Royal Thai Fleet, the Royal Thai Navy for their support in collecting the marine sediment samples. We thank Mr. Jamrearn Buaruang for his assistance in collecting the marine

sediment samples at Mu Koh Phi Phi National Park, Krabi Province, Koh Chang and Koh Yak-Lek, Trat Province. Prof. Dr. Gary Strobel, Department of Plant Sciences, Montana State University, Bozeman, Mt, USA is acknowledged for his valuable comments, suggestions and reviewing the manuscript.

References

- Buaruang, J., L. Manoch, T. Dethoup, O. Piasai and A. Kijjoa. 2010. Sponge-derived fungi from coral reefs in the gulf of Thailand and Andaman sea and antagonistic activity tests against plant fungi, p. 74. In abstracts book the 5th Thai Mycological Conference, 7 December 2010. Bangkok, Thailand.
- Damare, S., C. Raghukumar and S. Raghukumar. 2006. Fungi in deep-sea sediments of the Central Indian Basin. *Deep-Sea Research I* 53: 14-27.
- Eamvijarn, A. 2013. *Neosartorya* species: Diversity, Morphology, Phylogeny, Antagonistic Tests against Plant Pathogenic Fungi and Secondary Metabolites of *N. pseudofischeri*. Ph.D. Thesis, Kasetsart University.
- Ebel, R. 2007. Bioactive natural products from marine-derived fungal strains, pp. 8. In Abstract of the Workshop and Seminar on Chemistry Biological Activities and Biodiversity of Marine Organisms, 6-8 Nov. 2007, Institute of Marine Science, Burapha University, Chonburi, Thailand
- Guarro, J., J. Gené, A.M. Stchigel and M.J. Figueras. 2012. Atlas of Soil Ascomycetes. CBS-KNAW Fungal Biodiversity Center, Utrecht, The Netherlands.
- Hyde, K.D., E.B.G. Jones, E. Leanauml, S.B. Pointing, A.D. Poonyth and L.L.P. Vrijmoed. 1998. Role of fungi in marine ecosystems. *Biodiversity and Conservation* 7: 1147-1161.
- Intana, W., C. Chamswarnng, W. Intanoo, C. Hongprayoon and K. Sivasithamparam. 2003. Use of mutant strains for improved efficacy of *Trichoderma harzianum* for controlling cucumber damping-off. *Thai Journal of Agricultural Science* 36: 429-439.
- Kamsorn, W. 2012. Diversity of *Emericella* Species from Soil and *In Vitro* Efficacy Against Plant Pathogenic Fungi. MS. Thesis, Kasetsart University.
- Kirk, P.M., P.F. Cannon, D.W. Minter and J.A. Stalpers. 2008. *Dictionary of the Fungi* 10th edition.
- Li, D., L. Chen, T. Zhu, T. Kurtan, A. Mandi, Z. Zhao, J. Li and Q. Gu. 2011. Chloctanspiroones A and B, novel chlorinated polyketides with an unprecedented skeleton, from marine sediment derived fungus *Penicillium terrestre*. *Tetrahedron*. 67: 7913-7918.
- Manoch L., O. Piasai, T. Dethoup, J. Kokaew, A. Eamvijarn and S. Piriyaiprin. 2010. Identification of *Eurotium* species (*Aspergillus glaucus*) using scanning electron microscope, pp. 85. Proceedings of the 27th Annual Conference of the Microscopy Society of Thailand, 20-22 January 2010.
- Manoch, L., O. Piasai, T. Dethoup, Kokaew A. Eamvijarn, M. Sudsanguan, W. Limthanawanit, S. Piriyaiprin and S. Klinpoo. 2010. Diversity of *Emericella*, *Eurotium* and *Neosartorya* from soil, pp. 635-642. the Proceeding of 48th Kasetsart University Annual Conference (Plant Sciences), 3-5 February 2010, Kasetsart University, Bangkok.
- Manoch, L., O. Piasai, T. Dethoup, J. Kokaew, A. Eamvijarn, S. Piriyaiprin, Y. Paopun, P. Poochina and P. Umrung . 2009. Morphological studies of slime mold, some noteworthy Sordariaceae and synnemata fungi. *Journal of Microscopy Society of Thailand* 23: 25-29.
- Manoch, L. O. Jeamjitt, T. Dethoup, J. Kokaew, A. Eamvijarn, N. Visarathanonth and C. Chamswarnng. 2008. Biological control of plant pathogenic fungi using *Talaromyces flavus*, *Sordaria fimicola* and some endophytic fungi, pp. 101. The American Phytopathological Society Centennial Meeting 2008, July 26-30, 2008, Minneapolis, Minnesota.
- Morrison-Gardiner, S. 2002. Dominant fungi from Australian coral reef. *Fungal Diversity* 9: 105-121.
- Park, Y.C., P. S.P. Gunasekera, J.V. Lopez, P.J. McCarthy and A.E. Wright. 2006. Metabolites from the Marine-Derived Fungus *Chromocleista* sp. Isolated from a Deep-Water Sediment Sample Collected in the Gulf of Mexico. *J. Nat. Prod.* 69: 580-584.
- Raghukumar, C., S. Raghukumar, G. Sheelu, S.M. Gupta, B.N. Nath and B.R. Rao. 2004. Buried in time: culturable fungi in a deep-sea sediment core from the Chagos Trench, Indian Ocean. *Deep-Sea Research* 1: 1759-1768.
- Soumya, K.S., J.C. Jacob, N.S. Correya, S.L. Smitha, K.D. Ramya, P.R.A. Kumar, M. Thomas and R. Philip. 2013. Filamentous fungal isolates from the continental shelf and slope sediments of Arabian Sea. *International Journal of Research in Marine Sciences* 2: 26-31.
- Stolk, A.C. and R.A. Samson. 1972. The Genus *Talaromyces*: Studies on *Talaromyces* and Related Genera II. CBS, Baarn, Netherlands.
- Sumathi, J.C. and C. Raghukumar. 2009. Anaerobic denitrification in fungi from the coastal marine sediments off Goa, India. *Mycol. Res.* 113: 100-109.
- Yeemin, T., M. Sutthacheep and R. Pettongma. 2006. Coral reef restoration projects in Thailand. *Ocean and Coastal Management* 49: 562-575.

Manuscript received 23 May 2014, accepted 29 November 2014