DISSERTATION

DECOMPOSITION RATES AND ASSOCIATED DEGRADATION FUNGI ON MANGROVE LEAF LITTERS OF *Rhizophora apiculata* AND *Avicennia alba* AT THACHINE ESTUARY, SAMUT SAKHON PROVINCE

SUKHAN KONGAMOL

GRADUATE SCHOOL, KASETSART UNIVERSITY
2001

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โครงการ BRT ชั้น 15 อาคารมหานครยิบซั่ม
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NAME : Miss Sukhan Kongamol

THIS THESIS HAS BEEN CONSIDERED AS HIGH DISTINCTION AND ACCEPTED BY

Sanit Aksornkoae ..... THESIS ADVISOR

(Professor Sanit Aksornkoae, Ph.D.)

A-Chalermpaw ..... COMMITTEE MEMBER

(Mr.Aniwat Chalermpongse, M.S.)

Leka Manoch ..... COMMITTEE MEMBER

(Assoc.Prof.Leka Manoch, Ph.D.)

S. Boonyawat ..... DEPARTMENT HEAD

(Assoc.Prof.Samakkee Boonyawat, Ph.D.)

APPROVED BY THE GRADUATE SCHOOL ON 26 April 2001

Tasnee Attanandana ..... DEAN

(Prof.Tasnee Attanandana, D.Agr.)

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The objectives of this study were to determine the litters falls, nutrients, decomposition rates, associated degradation fungi on mangrove leaf litters of *Rhizophora apiculata* and *Avicennia alba* and enzyme activities of degrading fungi at Thachine estuary, Samut Sakhon province during December 1997 to January 1999. The study sites included 1) natural mangrove forest site I on the west coast of estuary 2) natural mangrove forest site II on the east coast of estuary and 3) mangrove plantation. The results showed that the average litter falls in natural mangrove forest and mangrove plantation were approximately 1,656 and 1,943 kg/ rai/year with total nutrients gained from litter production about 118.5 g/rai/year and 139.2 g/rai/year respectively. The decomposition of *R. apiculata* and *A. alba* leaves both in natural mangrove forest and mangrove plantation were completely decomposed within 5-6 months except the *A. alba* leaf in mangrove plantation to be completely decomposed faster within only 3-5 months. The study of mangrove leaf degradation fungi on *R. apiculata* and *A. alba* leaves collected in both natural mangrove forests and mangrove plantation was determined by direct and indirect methods. In all study areas, there were totally 49 species of 19 genera of fungi found on leaves of *R. apiculata* and *A. alba* respectively. The common genera of fungi were *Trichoderma, Aspergillus, Penicillium*, and *Fusarium*. The species of fungi on leaf of *A. alba* in natural forest colonized by 34 species and mangrove plantation by 20 species. The species of fungi on leaf of *R. apiculata* in natural forest showed 23 species and mangrove plantation for 13 species. It was also found that the species of fungi colonized on leaves of both species in natural mangrove forest showed greater than the mangrove plantation. The study on enzyme activities of leaf component decomposition on cellulose, xylan, and lignin by 12 species of fungi in 6 genera; *Trichoderma, Aspergillus, Pestalotiopsis, Penicillium, Geotrichum* and *Rhizoctonia* indicated that *Trochoderma* was the best in degrading the leaf composition into glucose and followed by *Aspergillus, Pestalotiopsis, Penicillium, Geotrichum and Rhizoctonia* respectively. It was also found that *A. alba* leaf was decomposed faster than *R. apiculata*. Leaf component decomposition were mostly depending on the age of fungi, species and salinity. The brown rot cultivated for 14-21 days and white rot for 7 days in corn meal agar (CMA) at salinity 15 ppt were the best condition in decomposing leaf components. The results of this investigation suggest a new finding on decomposition, associated degrading fungi on litter falls and enzyme activities of degrading fungi on *R. apiculata* and *A. alba* leaves in mangrove ecosystem for Thailand.

Sukhan Kongamol — Student's signature

Sanit Aksornkoae — Thesis Advisor's signature

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Decomposition Rates and Associated Degradation Fungi on Mangrove Leaf Litters of *Rhizophora apiculata* and *Avicennia alba* at Thachine Estuary, Samut Sakhon Province

INTRODUCTION

Mangrove resources, especially in the mouth of the river at Thachine estury, Samut Sakhon, Thailand, are very important to coastal ecosystems. They play a very important role in human life such as fuel, food, and coastal environment. There is very little information dealing with decomposition rates, nutrient flows, associated species and enzyme activities of fungi in degrading leaf mangrove litters both in Thailand and the global levels. This study will provide more information for understanding about mangrove ecosystem in Thailand particularly at the river mouth, and the important role of fungi in mangrove ecosystem. The study of the decomposition rates, nutrient flows, associated species and enzyme activities of fungi to degrade leaf litters would be a good database information for Thailand and world wide in applying for sustainable management and conservation of mangrove resources in coastal areas. Very few studies have been, so far, attempted to carry out research on species and enzyme activities of the estuary fungi decomposition on leaf litters. This knowledge based information is very important for utilization forestry, agriculture and pharmaceatical products such as extracting antibiotics and antagonistic compounds in the estuarine mangrove ecosystem.

Mangrove forests are the brackish water plant communities covering the world total areas of approximately 18.1 million hectares or 113.4 million rai. They distribute along with 3 major low-lying tropical and subtropical coastlines of the world: 1) Tropical Asia, Australia and Oceania with areas of about 8.4 million hectares (52.5 million rai) or 46.4% of world mangroves 2) Tropical America about 6.3 million hectares (39.6 million rai) or 34.9 %; and 3) Tropical Africa of about 3.4 million hectares (21.3 million rai) or 18.7% respectively (Aksornkoae, 1998). The majority of global mangrove forests is mainly found in the tropical Indo-Pacific region.

At present, Thailand covers with the total areas of mangrove forests, about 0.17 million hectares or 1.05 million rai (Charuppat and Charuppat, 1997). Mangroves have been found to decline over 50 % of the overall areas of country since 1960. The distribution of mangrove forest lies on the eastern region from Cha Choeng Sao, Rayong, Chanthaburi and Trat; the central region from Samut Prakan to Prachuap Khiri Khan. These two regions contain mangrove forest areas of about 120,000 rais or 14.8%. In the southern region, the eastern peninsula or the Gulf of Thailand from Chumphon to Pattani and the Andaman coastline from Ranong to Satun, the mangrove forests are found about 930,000 rais or 85.2% of the total areas (Aksornkoae, 1998). Most of the remaining mangrove forest in Thailand can be found on the Andaman coastline while the mangrove areas along the coastline of the Gulf of Thailand are very limited and most areas were mainly converted into shrimp ponds. Only narrow strips can be found along the coastline.

Mangroves are a very important ecosystems with high productivity and very valuable coastal resources. They play a very important role for human life as a source of fuel, food, ecological protected areas along the coastlines, and also the economy of the country. Moreover, they have long been recognized as a very important part in supporting marine life such as shrimps, crabs, shells, fishes and other benthic fauna in the estuarine and coastal waters.

Regarding with mangrove forest ecosystem at Thachine estuary, Samut Sakhon province, where the present investigation is carried out, the forest exists approximately only 0.55 million rai. The mangrove in this area plays a very important role in maintaining the equilibrium and conserving coastal resources of Samut Sakhon and neighbouring provinces. They also protect soil erosion, and windbreak along the coastline caused by severe storms and strong currents. The mangrove forests in this area also play an important role in sheltering and spawning ground of various aquatic animals. Due to great destruction of mangrove forest ecosystem along the coastlines in this province, therefore the coastal ecosystems were drastically demaged. Moreover, the fertility and productivity of Thachine mangrove community are also jeopardized.

Fungi play a very important part in providing nutrients in mangrove ecosystems by decomposing leaf litters. The nutrient production in the mangrove ecosystem is mainly derived from leaf litter falls about 80% (Odum, 1975) which are actually decomposed and utilized as food sources and energy for life existence of the surrounding organisms. The production of mangrove leaf litter falls exceeded 1.49 tons/rai/year in Chanthaburi mangrove, Eastern Thailand reported by Aksornkoae and Khemnark (1984) and the decomposition rate was estimated about 46% of the total leaf falls. After the microbial decomposition caused by bacteria and fungi, the nutrients could be released into the surrounding soils and water as a beginning of the food web for marine animals and also for plant growth.

Falling leaves of mangrove plants may eventually be washed up from the forests. These leaves will accumulate in great numbers and on seashore or some of them will float in rafts into the sea. Old leaves may also drop into the bottom of the sea, even far away from the original source. Mangrove trees can shed considerable amount of leaves each year and can be decomposed by bacteria and fungi, then contribute to the detritus production of estuarine. The detritus will finally be released into the soils and water which will be used by mangrove plants, animals and microorganisms to survive and exist (Boonruang, 1978).

The decomposition process of leaf litters by fungi can be discussed in various manners. Extracellular enzyme produced by bacteria and fungi will decompose leaf litters (cellulose, lignin and tannin) and breakdown into small molecules of inorganic and organic substances, then return into the mangrove ecosystem as a sustainable nutrient pool. Kohlmeyer (1971) and very few studies have attempted to determine fungi but rared in decomposition and associated fungi on leaf litters in the mangrove ecosystems in Thailand.

This study was aimed to find out the litter fall production, associated degradation fungi, decomposition rates and activities of fungi at natural mangrove forest and plantation mangrove in Thachine estuary, Samut Sakhon province.

OBJECTIVES

This investigation was carried out in the mangrove ecosystem at Thachine estuary, Samut Sakhon province and the main objectives were as follows:

1. To study the litter production, decomposition rates and nutrients derived from litters in the mangrove ecosystem.

2. To identifiy the species and abundance of fungi on the leaves of *Rhizophora apiculata* and *Avicennia alba* in the mangrove ecosystem.

3. To study the role of fungi in decomposing leaf components regarding to different ages and salinity including fungal growth development on various leaf components.

LITERATURE REVIEWS

Mangrove Situation in Thachine Estuary, Samut Sakhon

The study was located in the mangrove forests at Thachine estuary, Samut Sakhon province. The mangroves area is situated between 13° N and between 100° E. The mangrove formerly, used to cover an area of approximately 100,000 rai but until 1993 the area decreased to 34,899 rai. The mangrove forest in 1996 increased to 36,687 rai. The mangrove forest in this area can be found only along the coastline (Charuppat and Charuppat, 1997).

There are about 26 plants species found in this mangrove forest. The most dominant species are *Avicennia alba, A. marina* and *Sonneratia caseolaris. Rhizophora apiculata* is mainly composed of immature mangrove species (1-2 years). There is also mangrove plantation (Poovachiranon, 1982) which established in the new mud flat with the total area of about 1,800 rai.

Leaf Litter Production in Mangrove Forest

Litter production in mangroves was widely undertaken. Litter was ussually collected by using litter baskets. Litter falls in various countries were considerably different from place to place as shown in Table 1. Litter fall rates were depending upon plant species, stand density, biomass of different parts of the tree, and also the seasonal conditions of flowering and fruit falling. It was found that litter falls was indicated the highest amout during the dry season (Lugo and Snedaker, 1973; Woodroffe, 1982). It was also found that litter production in the mangrove forest provided at least equal to or higher than that in upland forest. Thaiusa *et al.*, (1978) reported litter falls of about 8.13 tons/ha/year in teak forest and 5.0, 6.88 and 10.63 tons/ha/year in mixed deciduous forest, hill evergreen forest and evergreen forest, respectively.

Table 1 Litter Falls of Mangroves in Various Countries

Species	Location	Litter fall (tons/ha/year)	References
Mixed Species	Chantaburi, Thailand	9.31	Aksornkoae & Khemnark, 1984
Mixed Species	Ranong, Thailand	8.88	Aksornkoae *et al.*,1987
Mixed Species	Phang-nga Bay, Thailand	5.50	Aksornkoae, 1994
R. apiculata	Phuket, Thailand	6.69	Christensen, 1978
R. apiculata	Phuket, Thailand	3.44	Poovachiranonand & Chansang, 1982
Mixed, *Rhizophora* Dominant spp.	Malasia	19.88	Ong *et al.*, 1980
Rhizophora (15 yr.)	Malaysia	10.00	Ong *et al.*, 1984
Rhizophora	Malaysia	15.81	Sasekumar and Loi, 1983
Sonneratia	Malaysia	14.00	Sasekumar and Loi, 1983
Mixed Species	Indonesia	8.5	Brotonnegoro and Abdulkadir, 1979
Mixed *A. offcinalis* & *C.decandra* Dominant	Phillippines	5.19	Technical staff, Philippes Nation Mangrove Committee, 1979
C. decandra Dominant			
R. apiculata	Australia	10.88	Duke *at al.*, 1981
R. stylosa	Australia	9.31	Duke *at al.*, 1981
Ceriops tagal	Australia	7.19	Duke *at al.*, 1981
A. ovata	Australia	7.88	Duke *at al.*, 1981
A. marina	Australia	5.81	Goulter and allaway, 1979
A. marina	New Zealand	3.69-8.13	Woodroffe, 1982
Mixed Species	Fiji	11.00	Lal *et al.*, 1983
R. mangle	Florida, USA	8.81	Herald, 1971
A. germinans	Florida, USA	6.50	Lugo and Snedaker, 1973

Source : Aksornkoae (1993).

Decomposition of Mangrove Leaf Litters

Several research papers reported that the mangrove leaf litters required different times in decomposing. Table 2 showed the litter decomposition rates of mangroves in various countries. Different mangroves leaf species showed different duration to decompose which were possibly due to variable environmental conditions such as soil oxygen, soil fauna, air temperature, currents, depths of shores, salinity, tidal range and substrates etc. It was found that the decomposition rates would be higher in brackish water than in fresh water (Herald, 1971) or in seawater (Boonruang, 1978). The litter decomposition and biological-physical factors were closely correlated. Fungi and bacteria were played the most important activities in litter decomposers. Crabs were also plays important for decomposition particalarly, in breaking down the litters into small pieces to be more easily decomposed by fungi and bacteria. Tidal flush and tidal current also helped in breaking down the litter to small pieces. In addition, only a few studies reported on the changes in chemical composition of leaves during decomposition. Cundell *et al.* (1979) reported that during the first 70 days of immersion, the carbon content of *R. mangle* leaves decreased from 46.2 to 36.2% while the nitrogen content increased from 0.51 to 0.89% respectively.

Table 2 Litter Decomposition Rates of Mangroves in Various Countries

Species	Location	Decomposition Rate	Reference
Mixed Species	Chantaburi, Thailand	50% of previous dry weight in 1 year	Aksornkoae and Khemnark, 1982
Mixed Species	Raong, Thailand	41.3% of previous dry weight in 1 year	Aksornkoae *et al.*, 1987
Avicennia marina	Phuket, Thailand	50% of previous dry weight in 3 week	Boonruang, 1987
Avicennia spp.	Phuket, Thailand	50% of previous dry weight in 4 weeks	Poovachiranonand & Chansang, 1982
R. apiculata	Phuket, Thailand	40% of previous dry weight in 4 weeks	Poovachiranonand & Chansang, 1982
R. apiculata	Phuket, Thailand	50% of previous dry weight in 6 weeks	Boonruang, 1987
Mixed Species	Phang-nga, Thailand	50% of previous dry weight in 6 weeks	Angsupanich and Aksornkoae, 1994
R. apiculata	Malaysia	70.8% of previous dry weight in 20 days	Ong *et al.*, 1980
Bruguiera spp.	Indonesia	88.6% of previous dry weight in 20 days	Ong *et al.*, 1980
Mixed Species	Indonesia	100% of previous dry weight in 100 days	Brotonegoro and Abdulkadir, 1979
Mixed, *A. officinalis* *C. dedandra* dominant	Philippines	82% of previous dry weight in 1 year	Philippines National Mangrove Committee, 1979
A. marina	Australia	50% of previous dry weight in 8 weeks	Goulter and Allaway, 1979
A. marina	New Zealand	50% of previous dry weight in 6-8 weeks	Woodroff, 1982
R. mangle	Florida, USA	50% of previous dry weight in 45 days	Herald, 1971

Source : Aksornkoae (1993).

Nutrients Recycling via Litter Decomposition

A large number of nutrients can be returned to the soil through decomposition of litter falls. The total amount of nitrogen, phosphorus, potassium, calcium, magnesium from litter decomposition in the mangroves of Ranong province was found to be as high as 306.3 kg/ha/year (Aksornkoae *et al.*, 1987). In Chantaburi, the total was 268.2 kg/ha/year (Aksornkoae and Khemnark, 1984). In Malaysia, Khoo and Chin (1984) reported 243.2 kg of nutrient/ha/year from litter decomposition which was lower than in Thailand. Moreover, the values for mangrove forests were higher than those reported for the evergreen hill forest by Naprakorb and Chukao (1977) as 145.0 kg of nutrient/ha/year. Details on nutrients from litter decomposition in various locations were indicated in Table 3.

Table 3 Nutrients from Litter Decompositions in Mangroves of Different Areas

Nutrients	Nutrients from Litter Decomposition (kg/ha/year)		
	Ranong[1]	Chantaburi[2]	Malaysia[3]
Nitrogen	55.6	69.4	46.9
Phosphorus	4.4	9.4	5.0
Potassium	52.5	58.1	25.6
Calcium	113.8	53.1	99.4
Magnesium	24.4	26.9	34.4
Sodium	55.6	51.3	31.9
Total	306.3	268.2	243.2

Sources :

1) Aksornkoae *et al.*, (1987) 2) Aksornkoae and Khemnark (1984)

3) Khoo and Chin (1984)

Species and Characteristics of Fungal Abundance in Mangrove Estuary

In view of the importance of mangrove leaves as sources of detritus, it was of great interest to investigate the role of microorganisms in breaking down of leaf litters. Fell and Master (1973, 1975) and Fell *et al.* (1975) examined the activities of lower and higher fungi in the degradation of *R. mangle* leaves. During the first week of submergence, the lower fungi *Phytophthora* spp. And *Pythium* spp. were prevalent and a few Hyphomycetes were reported. Within the second and third weeks the first obligate marine fungi, *Lulworthia* spp. and *Zalerion varium* were observed, while at the end of this period in weeks most of the lower fungi had disappeared. However, the total of 53 genera of fungi including lower and higher fungi were found in this study (Fell and Master, 1973). Cribb and Cribb (1956) studied from the fungal species Queensland mangrove forests in Australia and found many species of marine fungi, including *Phialophorophora littoralis* Linder (Deuteromycotina), *Gnomonia longirostris* Cribb& Cribb, *G. marina* Cribb & Cribb, *Holosarpheia guadricornuta* Cribb & Cribb, *Lulworthia longispora* Cribb & Cribb, *Metasphaeria australiensis* Cribb & Cribb and *Ophiobolus autraliensis* Cribb & Cribb (Ascomycotina) from *Avicennia marina.* In Hawaii Island, Kohlmeyer & Kohlmeyer (1979) reported 43 species of marine fungi on *Rhizophora mangle* leaves; 23 Ascomycotina, 17 Deuteromycotina, 2 Basidiomycotina respectively.

Kuthabutheen (1984) isolated 50 fungal species from *Rhizophora stylosa* and *Avicennia marina* leaves in Malaysia. Most of them were saprophyte fungi such as *Penicillium* spp., *Aspergillus* spp., *Fusarium* spp. etc., whereas the others were obligate marine fungi such as *Lulworthia* spp., *Dictyosporium* spp. etc.

Hyde and Jones (1988) reported 90 species of estuarine fungi in USA (65 Ascomycotina, 23 Deuteromycotina, 2 Basidiomycotina) from 26 species mangrove plants. (Appendix Table 3). In Thailand, Hyde *et al* (1990) studied intertidal marine fungi at Ranong mangrove forest (Appendix Table 4). They found 76 fungal species from 650 samples of different tree components. Ito and Nakagiri (1997) studied fungi on root, soil

and mud in Okinawa, Japan and reported 29, 43, 61 fungal species from each habitat respectively. Among them included *Savoryella lignicola* Jones & Eaton, *Aigialus grandis* Kohlm. & Schatz, *Dactylospora haliotrepha* (Kohlm, & E. Kohlm) *Halosarpheia abonnis* Kohlm and *Massarina velataspora* Hyde & Borse (Appendix Table 5- 6). Ito *et al.* (2001) studied fungi in mangrove soil at Ranong, Thailand and reported 44 fungal species. Included among them were *Aspergillus clavatus, A. niger, A. terreus, Eupenicillium, Penicillium* sp., *Trichoderma harziamun, T. pseudokoningii* and *Paecilomyces variotii* ect (Appendix Table 7).

Fungal Isolation

Warcup (1960) stated that "for the study on decomposition rate, leaf litters at the mouth of the river in mangrove forests were placed into litters bags and laid on the soil surface. Firstly, the soil mycologist was working literally "in the dark" because soil was opaque. Secondly, the fructications whereby fungi were identified into genera and species were neither regularly nor commonly seen on mycelia actually within the soil. In order to identify a soil fungus with certainty, therefore, it was usually necessary to "isolate" it, and to grow it in pure culture under such conditions that it would produce its characteristic fructifications. Soil mycologists had employed either or both of two methods of study, neither of which was satisfactory by itself, a) to observe fungal mycelium, which could be seen but not usually identified, by direct microscopical observation of soil, b) to isolate and identify species of fungi in culture from unknown propagules in the soil. A vegetational ecologist would be placed in position of comparable difficulty only if he was compelled to collect all his samples of plants in complete darkness, with the slight concession that he might be permitted to view his area of vegetation in late winter when flowers and fruits would be difficult to find".

Various techniques had been devised to overcome these difficulties. During the last 10 years, there had been a considerable increase in the number of papers published in soil mycology. One of the most promising developments had been a combination by Warcup (1960) of the cultural and direct observation methods, whereby a mycologist could now determine the nature of the fungal propagule from which had come the species of fungus that he had isolated and identified in culture.

Direct Observation

A direct method of a somewhat different kind for determination of the amount of fungal mycelium in the soil at any time was devised by Richard *et al.* (1970). They made up a weighed amount of soil in suspension in melted but cooled agar, and from this prepared files of known thickness with the aid of a haemocytometer slide. When set, the films were removed, dried, stained and mounted for microscopical observation upon another slide; the total length of fungal hyphae was measured, and expressed in terms of the original weight of soil. Various other methods for direct microscopical examination of the soil had together with strong direct illumination to examine faces of soil *in situ*, outside in the field. He also used a resin for impregnation of undisturbed blocks of soil; when the resin had set, sections were cut for examination. More recently, hard-setting resins had been used for soil impregnation; section were then prepared by grinding down, as was done for examination of geological sections (Richard *et al.*, 1970).

The usefulness of these direct methods had been somewhat circumscribed by their limitations, though they had given information that could have been obtained in no other way. They would continue, no doubt, to be employed as a check upon conclusions derived from culural methods, but their chief value in the future might well be in functional combination with cultural methods, as would be discribed later.

Indirect Observation

For the dilution plate method, Warcup (1960) reported that " This method was originally developed by soil bacteriologists, for whom it was merely a special application of their well established dilution plate procedure for the isolation of single species of bacteria in pure culture. The dilution plate suffered from several disadvantages. Frist of all there was a general disadvantage, common to all such cultural method, that no single culture medium was suitable for the development of more than a small minority amongst species of soil fungi; this statement applied equally well to bacteria and actinomyces. Among species of soil fungi that were rarely found on soil dilution plate, only a small proportion failed to appear because the culture medium was nutritionally inadequate. Some species were not represented because their population numbers were too low by comparison with those of the common species; the probability that a viable propagule of an uncommon species might be included in a sample plated from the highest dilution was not nil, but it may be extremely low. Many species were quite common in soil, however, also remained largely unrepresented on the dilution plate; the reason for this was that development of their propagules was inhibited at early stage by the competition of faster growing fungi, and so these more slowly growing fungi are unable to form visible colonies. Species of the higher Basidiomycetes, which were common in soil but grow rather slowly, were rarely found on soil dilution plates.

The secound disadvantage of the soil dilution plate was also common for isolation of bacteria and actinomyces, but it operated more significantly on the isolation of fungi. This disadvantage arised directly out of the procedure for diluting the original suspension of soil. Even before a sample of soil suspension had been completely pipetted off to make a dilution in fresh shake medium, most of the heavier part of the soil had already sunk to the bottom of the shaking vessel; this part would include the larger mineral particles, together with those soil crumbs that had not been disaggregated by the shaking procedure, and the heavier organic fragment. The soil dilution plate was a reasonably

satisfactory method for the counting of numbers of soil bacteria, because these were unicellular microorganisms; it was also adequare for actinomycetes, because their hyphae multiply very readily into individual hyphal cell. But for fungi, the count of "numbers" was rendered almost meaningless by the somatic dichotomy of these organisms into vegetative hyphae and spores."

Soil Plate Technique (Warcup, 1960)

This was designed by Warcup (1960) in order to reduce some of the particular disadvantages from which the soil dilution plate suffered. By Warcup method, small samples (0.005- 0.015 g) of soil were taken with the flattened blade of a sterilized nichrome inoculating needle, which was then used to crush and disperse the soil aggregates in the bottom of a sterile petri dish; a little sterile water was added to assist in the dispersion of soil that did not break up easily. Melted and cooled agar (8-10 ml) was then poured into the dish and manipulated before setting so as to secure as completely as possible a dispersion of the soil particles.

The Warcup soil plate had been widely used; much of its popularity was due to the fact that a series of soil plates was much less tedious to prepare than was a series of soil dilution plates. By incorporation of the whole of the soil with the agar, the method permitted isolation of fungi that were rejected with the soil residue by the dilution plate method, and so the soil plate had at least the potentiality of isolating a wider range of species than that obtained from the dilution plate. The soil plate method reduced, though it did not eliminate, the advantage obtained by heavily sporing fungi. Inter colony competition, on the other hand, was certainly more severe than on a dilution plate giving not more than 25 colonies, and here the soil plate was at a disadvantage. Warcup provided a comparative survey of the result obtained with this and other methods.

Measurement of Activities of Mangrove Fungi

A wide range of techniques and approaches were available for the study of fungal activity in mangrove ecosystems. The individual fungi under laboratory condition and biochemical studies could be discussed as follows.

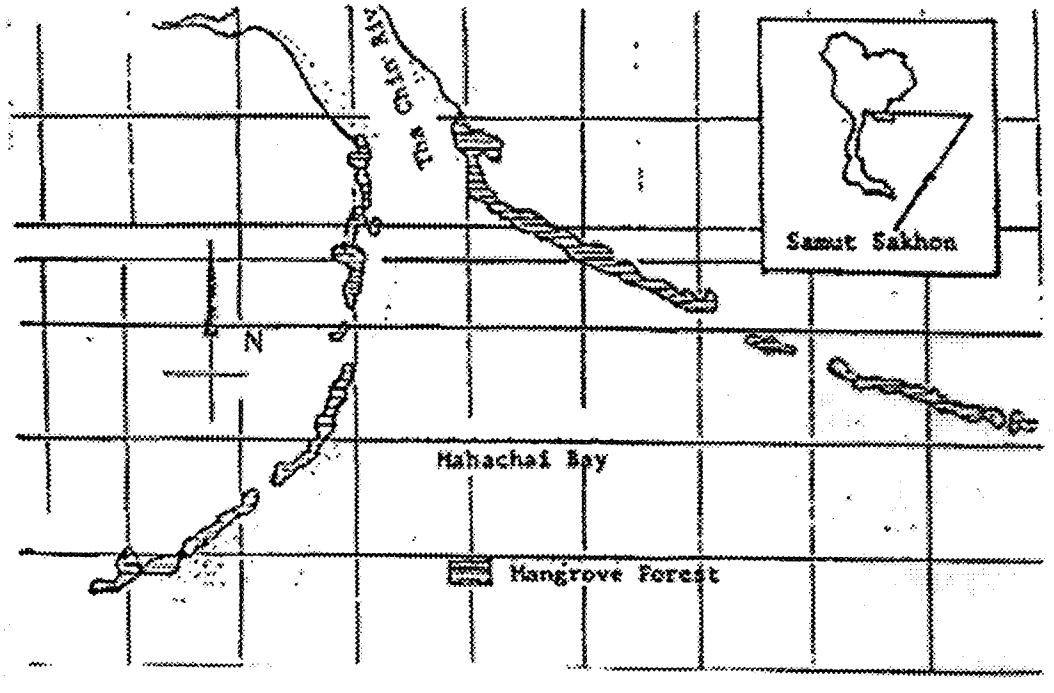
Weight loss tests were carried out by using yeast extract seawater with wood samples of *Pinus sylvestris* L. and *Fagus sylvatica* heartwood in various dimensions by Jones (1971). He found that it took more than one year for many fungal species to process decomposition. Leightley and Eaton (1979) studied specific species of fungi, namely *Nia vibrissa*, a marine white rot fungus attack wood and they found that white rot fungus could penetrate into cell wall and brown rot fungus could penetrate later into parenchyma cell. In addition, they also examined the species of fungi capable of decomposing cellulose and lignin by using chemical test.

In a similar study, Mouzouras (1986) used chemical test to determine enzyme laccase and tryrosinase in degrading lignin by fungi: *Digitatispora marina* and *Halocyphina villsa*. But Rautela and Cowling (1966) studied enzyme cellulase and xylanase to degrade cellulose and hemicellulose with emphasis on different concentration levels.

MATERIALS AND METHODS

Study Sites

The study area was located in mangrove forest at Tachine estuary, Samut Sakhon province. Three sites were selected as illustrated in Figure 1. Site 1). Mangrove plantation forest, Site 2). Natural mangrove forest I on the west coast of the estuary and Site 3). Natural mangrove forest II on the eastcoast of the estuary (Figure 1). The areas were flushed daily by the tide. The salinity of the seawater flushing the mangroves was about 25 ppt in the wet season and 35 ppt in the dry season. The substratum was an organic-rich mud. The mangrove forests in this area were mainly distributed along the coastline with a narrow strip ranging from 50-500 m wides. *Avicennia* spp. were a dominant species with *Rhiziphora spp.* scattering througout the forest.



1 = mangrove plantation 2 = natural mangrove forest site I

3 = natural mangrove forest site II

Figure 1 Study Sites in Natural Mangrove Forest and Mangrove Plantation, at Thachine Estuary, Samut Sakhon Province

Mangrove Forest Area in Thachine Estuary

The study was located in the mangrove forests at Thachine estuary, Samut Sakhon province. The mangrove area is situated between 13° N and between 100° E. The mangrove formerly, used to cover an area of approximately 100,000 rai but until 1993 the area decreased to 34,899 rai. The mangrove forest in 1996 increased to 36,687 rai. The mangrove forest in this area can be found only along the coastline (Charuppat and Charuppat, 1997).

Plant Vegetation in Thachine Estuary

There are about 26 plants species found in this mangrove forest. The most dominant species are *Avicennia alba, A. marina* and *Sonneratia caseolaris*. *Rhizophora apiculata* is mainly composed of immature mangrove species (1-2 years). There is also mangrove plantation (Poovachiranon and Chansang, 1982) which established in the new mud flat with the total area of about 1,800 rai.

Physical Factors

The soil in mangrove plantation was identified as clay, clay loam and silt clay which also found the same properties as in natural mangrove forests I and II. However in the three areas it could be summarized that the soil properties showed pH 7.4-7.5, 15-28 ppt salinity, temperature between 30-35°C, rain fall 1400 mm/year.

Places of Studies:

1) Thachine estuary, Samut Sakhon Province
2) Department of Forest Biology, Faculty of Forestry, Kasetsart University
3) Department of Plant Pathology, Faculty of Agriculture, Kasetsart University
4) Chemistry Research Institute, Rajamongala Institute of Technology
5) Agricultural Chemistry Division, Department of Agriculture, Ministry of Agriculture and Cooperatives

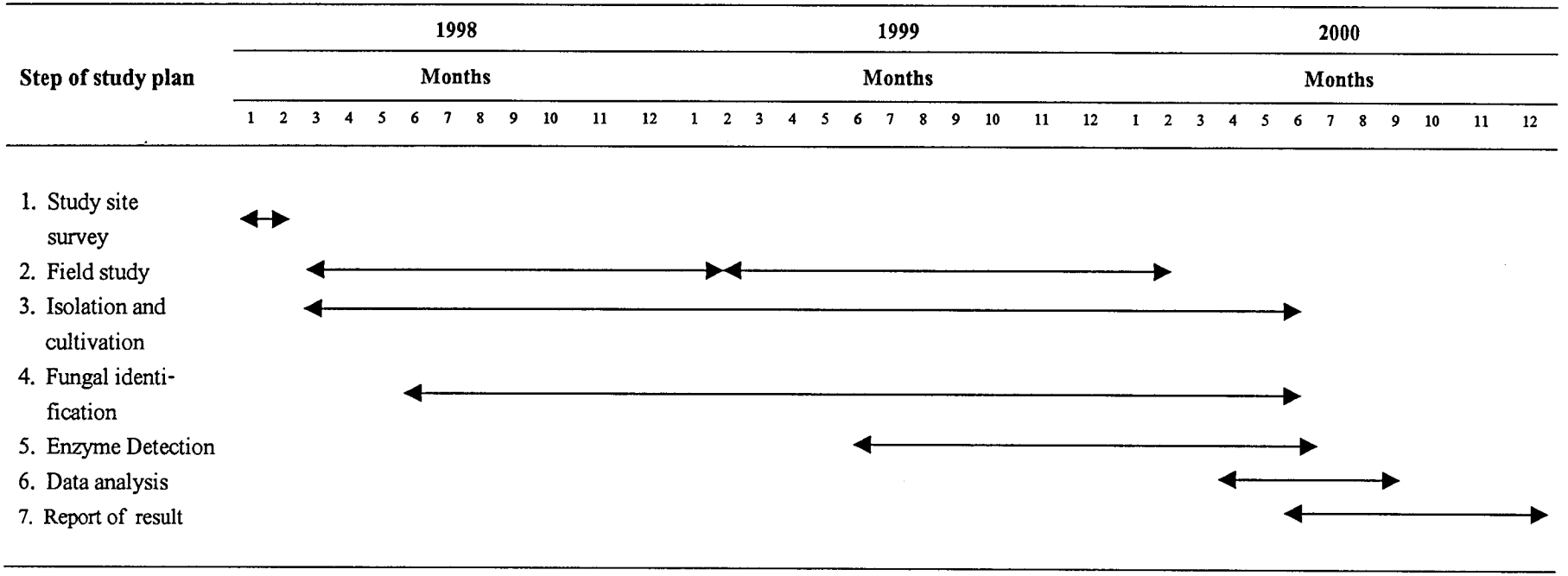
Duration of Study (Table 4):	Started :	January 1998
	Ended:	December 2000
	Total Period :	36 months

Experimental Designing (Hassard, 1991)

The typical experiment consists of a group of subjects, each of which was exposed to a particular experimental condition. The objective of the experiment was to determine whether various experimental conditions differ in their influence on the experimental subjects or not. In the conclusion of the experiment, this hypothesis was tested by using the appropriate statistical technique to analyze the experimental evidence. If the experiment had been well designed the analysis and interpretation of the results generated should be relatively straightforward. The real skills of experimentation were involved when the experiment was being planned, and the mistakes at this stage would totally destroy the following weeks or months of effort (Hassard, 1991).

In order to obtain a decisive measure of machine capability, we must "block" on the extraneous factor by placing the observations in homogeneous groups based on years of experience. Thus, the observations were classified by both blocks and treatments. The purpose of blocking was to decrease the variation within a treatment (Hassard, 1991). This experimental design was called a Complete Randomized Block Design (CRBD). In this study there were two treatments (at the river bank and 50 meter away from the river bank), three blocks were natural forests site I, II and mangrove plantation, 4 replicates. The data were statistically analyzed in computer by using SPSS.

Table 4 Study Plan of Decomposition Rates and Associated Degradation Fungi on Mangrove Leaf Litters of *Rhizophora apiculata* and *Avicennia alba* at Thachine Estuary Samut Sakhon Province during 36 Months from 1998 to 2000



Leaf Litter Production and Decomposition

Leaf Litter Production

Leaf litter production was monthly collected. Baskets for collecting litter, each measured by 1 x 1 m with nylon screen and wooden frame, were placed at the forest margin and at 20 meters interval along straight line transects in three representative sites and distributed throughout the mangrove area (Figure 2 A). The nylon baskets were elevated to avoid water-logging at high tide. Litter trapped in the baskets was monthly collected for a one year period. Each sample was dried to constant weight at 70°C for 24 hours, and then analyzed for the nitrogen, phosphorus, potassium, calcium, and magnesium. Nitrogen content was determined by Kjeldahl method, phosphorus by Bray II, potassium was extracted by NH 4 Oac, calcium and magnesium content were measured by using Absorption Spectrophotometer at the laboratory of Agricultural Chemistry Division, Department of Agriculture, Ministry of Agriculture and Cooperatives.

Litter production was estimated by collecting litters in the baskets. Litter baskets were made of 0.02 mm mesh size nylon screen attached by 1 x 1 m of 2 wooden frames. Thirty baskets were distributed at three study sites. Baskets were tied above the seawater at high tide. The material was sorted into leaves, branches, flowers and fruits, then oven-dried to a constant weight at 105°C for 48 hours.

Leaf litter Decomposition (Figure 2 B)

Leaf litter decomposition rates were determined from leaf litters collected and placed by using nylon-mesh, prepared by 40 x 60 cm. Twelve such nylon-meshes, each containing 400 g of air-dried litter sample, were placed along each of the straight transect lines at the forest margin (0-40 m), and between 50-100 m from the river bank. This meaned that there was a total of 24 nylon-meshes per one replicate. In order to protect the litter samples from being afloated or washed away by the tide, the nylon-meshes were

tied up with ropes to the wooden frames. (Figure 2 B). The nylon-mesh frames were placed on the forest floor or at soil surface in order to simulate natural condition. From each site, one nylon-mesh containing litter sample was collected once a month. The amount of litter remaining in each nylon-mesh was air-dried, weighed and oven dried at 105°C for 48 hours. Then the amount of litter loss through decomposition for each month was calculated by substracting the initial weight of the litter contained in the nylon-mesh by that of the remaining litter.

Figure 2 A : Nylon Screen and Wooden Frame for Litter Falls;

B : Nylon Bags for Leaf Litter Decomposition

Fungal Isolation from Leaf Litter

Leaf Litter Preparation

Mangrove leaves were collected from the trees which were not damaged by insects. Immediately after the collection, the leaves were kept at low temperature and transported back to the laboratory. Totally 12 bags of the leaves of each species were weighed at 400 g/bag while still fresh into a size of 40 x 60 cm nylon bag with 0.02 mm mesh size. Then they were covered with sterile plastic bags and kept at low temperature before placing at the study sites.

Totally 12 bags of each leaf litter species were placed on the soil surface at the forest margin (between 0-40 m), and between 60-100 m from the river bank. They were placed in the mangrove forest for a period of one year. On the 15th day or in the middle of each month, one bag of each species, *Avicennia alba* and *Rhizophora apiculata* were taken randomly for fungal isolation.

Fungal Isolation

Two methods of isolation, direct and indirect methods were used in this investigation.

Direct Isolation (Richard *et al.*, 1970)

Materials colltected from the study sites were incubated at room condition in a plastic box, and providing with moist chamber. After 7-14 days incubation period, the fruiting body of the fungi were transferred with a fine needle to a microscopic slide, a drop of water was added to expose the spores, carefully squeezed under a cover glass and examined under compound (light) microscope. For a taxonomic purpose, each fungal species was taken for photographs; its characteristics were recorded as the aid for identification.

Indirect Isolation

1) Dilution Plate method (Amodification of Manoch, 1989; Manoch and Piriyaprin, 1993)

Leaves from the bags were prepared in suspension by mixing with sterile seawater in a blender: (1 g wet weight in 20 ml sterile seawater). Prepared serial dilution of suspension in sterile seawater 15 ppt salinity. Spreaded 1 ml portion of suitable dilution on the surface of a modified Glucose Ammonium Nitrate Agar (GAN) in seawater at 15 ppt salinity (Manoch, 1989; Gochenaur, 1964). The petri dishes were incubated at room temperature in the dark for 2-3 days. Fungal colonies appearing on the plates were transferred onto Potato Dextrose Agar (PDA) slant in 1 % seawater, by using a transfer needle. After initial isolations were completed, plates were examined at various intervals over 2 week period to obtain slow-growing forms. Pure culture of fungi were incubated on PDA slant in direct light at room temperature for 2 weeks. The total numbers of isolates of each entity were recorded. Each tube represented a presumed fungal species. All isolates not discarded at this time were kept for further studies and stored in slant PDA at room temperature.

2) Soil Plate Method (Manoch, 1989; Manoch and Piriyaprin, 1993)

A small amount of soils (0.0005-0.015 g) was placed into a sterilized petri dish. Ten ml of modified GAN was added and the petri dish was gently rotated to disperse the leaf particle. They were incubated in darkness at room temperature for 2-3 days. The following proceduce were as above.

3) Baiting Technique (Agate *et al.*, 1988)

Five pieces of 1 x 1 cm mangrove leaves and sterile hemp seeds were placed in a petri dish with sterile brackish water of 15 ppt. In anather experiment, 15 cc of mud water was placed with hemp seed baits in sterile brackish water in a petri dish. The plates

were incubated at room temperature for 7-14 days. Hemp seeds were washed with brackish water at 15 ppt salinity for 5-6 times and colonized fungi were transfered on PDA providing with 0.003 g/ ml streptomycin in a petri dish. After free from contamination, hyphal tips were transferred onto PDA slant and kept on pure culture for identification.

Determination of Soil Chemical Properties

Samples of soil were collected from the 3 study sites. Two kilograms of soil sample were collected from each site. They were analyzed for the chemical properties such as soil pH, organic matter, total nitrogen, available P, K, Ca, Mg, Cation Exchange Capacity (CEC) and soil texture at Agricultural Chemistry Division, Department of Agriculture, Ministry of Agriculture and Cooperatives.

Soil Fungal Population

Soil samples of 3 study sites were collected from soil surface (15 cm depth) of 10 samples per season (rainy and summer seasons). The soil samples were brought to the laboratory to estimate the population of total fungal species by using soil plate techniques.

Fungal Identification

Identification was based on morphological features observed by plate cultures on modified suitable media providing with 15 ppt seawater and observation was made under stereo and compound microscopes. Imperfect fungi developed best on malt agar and PDA, whereas the ascosporic stages did better on cornmeal agar and V-8 agar. The cultures were incubated under light at room temperature for 5-14 days. Cultural features were usually recorded and microscopic features were studied. Morphological characteristics were described based on direct microscopic examination of undisturbed colony surfaces and followed by the study on slide preparation or slide culture mounted with lactophenol. Measurement of spores and other structures were made on water mounts. In describing colony color, a mycological color chart was used.

The important references used for fungal identification in this study were Hawsksworth *et al.* (1995), Sparrow (1960), Ellis (1971), Kohlmeyer (1971), Fell and Master (1973) Domsch *et al.* (1993), Baron (1968), Carmichael *et al.* (1980), Raper and Fennell (1961) Raper and Thom (1965), Ramirez (1982), and Hawksworth (1979).

Fungal Preservation

Pure cultures of all identified fungal species were maintained in the refrigerator at 10° C liquid paraffin, sterile seawater at Biodiversity Research and Training Program, Bangkok and Rajamongala Institute of Technology, Pathum Thani province for further study on enzyme activities.

Activities of Dominant Fungi under Laboratory Condition

The total of 12 dominant fungal species of the genera *Trichoderma, Aspergillus, Penicillium, Pestalotiopsis, Geotrichum* and *Rhizoctonia* were used to study enzyme activity of brown rot and white rot by cultivating them on cellulose and xylan agar media on CMA in a petri dish. The determination of activities of dominant fungi was carried out at laboratory, Forest Biology Department, Faculty of Forestry, Kasetsart University and Chemistry Research Institute, Rajamongala Institute of Technology.

Determining Brown or White Rot Fungi Degrading Lignin

Twenty fungal species of the genera *Trichoderma, Aspergillus, Penicilliun, Pestalotiopsis, Geotrichum, Rhizoctonia,* etc. (Table 18) were inoculated on corn- meal agar plates (CMA) containing gallic acid at different concentrations: 0.125, 0.25, 0.5 and 1%. They were incubated at room temperture (28- 30°C) for 7, 14, 21, 35 days. Observation of white rot fungi were investigated by deep brown color on the reverse side of the colony in contrast to the normal color of pale yellow for the brown rot fungi. Otherwise 2-3 drops of 0.1% gallic acid dissolved in 95% ethanol at the margin of mycelium on CMA incubated for 14 days. Color changes of mycelium to pale pink or pale orange were recorded (Leightley and Eaton, 1979).

Growth Rates of Fungi on the Different Cellulose and Xylan Concentrations on CMA at 15 and 30 ppt Salinities of Seawater

Twelve species of six genera: *Trichoderma, Aspergillus, Penicilliun, Pestalotiopsis, Geotrichum,* and *Rhizoctonia* were investigated for extracellular enzyme production. They were cultivated on CMA containing cellulose powder or xylan at different concentrations: 0.1, 0.2, 0.5 % at 15 and 30 ppt salinity of seawater. Incubations of the plates were made at room temperature for 7, 14 and 21 days. Growth rates of the colony by measurement in centimeter were observed within three weeks (Rautela and Cowling, 1966).

Methods for Investigation on Decomposition of Cellulose Powder, Filter Paper, Xylan, Lignin, *R. apiculata* Leaves and *A. alba* Leaves in Terms of Glucose Detection by 12 Fungal Crude Enzyme from Different Ages at 15 and 30 ppt Salinities.

The same set of fungi (6 genera, 12 species) were cultivated on CMA at 15 and 30 ppt salinities for 7, 14, 21, and 28 days at room temperature. The mycelium were extracted by sea water of 15 ppt at the ratio of fungal mycelium: sea water = 1 : 10 by weight, centrifuged at 1000 rpms. The supernatant from this extraction was used as crude enzyme solution for testing of fungal enzymatic activities. The method of Mondels and Sternberg (1976) was employed for cellulose decomposition. Various cellulose subtrates such as cellulose powder, fiter paper, *R. apiculata* and *A. alba* leaves were used for 0.01 g and 0.5 ml crude fungal enzyme and 0.5 ml of phosphate buffer 0.02 M were adjusted at pH 6.0 in test tube, cellulose substrate was added. They were incubated in water bath at 56°C for one and a half hours one ml of 3, 5 dinitrosalicylic acid was added and boiled in water bath at 100°C for 10 minutes. Then the solution was diluted to 20 ml by 18 ml seawater of 15 ppt salinity. Measured with Spectophotometer UV 16001 at wave range 550 nm, and calculated glucose concentration with standard curve in the Spectophotometer UV 16001. The activity of enzyme xylanase was tested by using the method of Kitprechavanich *et al.,* (1984). The xylan and lignin were used for 0.01 g and 0.5 ml crude fungal enzyme and 0.5 ml acetate buffer adjusted pH at 5.5 were put in test tube, xylan substrate was added. They were incubated in water bath at 65°C for one and a half hours. One ml of 3, 5

dinitrosalicylic acid was added and boiled in water bath at 100°C for 10 minutes. Then the solution was diluted to 20 ml by 18 ml seawater of 15 ppt salinity, measured with Spectophotometer UV 16001 at wave range 550 nm, and calculated glucose concentration with standard curve in the Spectophotometer UV 16001.

Methods of Data Analysis

Calculated similarity index or community coefficient of number of species of fungi from Sorencen formular in 1948 (Pelz and Luebbers, 1998) as follow

Similarity index = $2W/A + B$

W = number of fungi in two areas

A = number of fungi in area A

B = number of fungi in area B

Biodiversity index (1949) from biodiversity index of Simpson (Pelz and Luebbers, 1998)

Biodiversity index of Simpson = $1 - \Sigma (Pi)\,2$

Pi = change of each species of fungi

After qualitative analysis was completed, assumption in the analysis of association and multi-way analysis of number of fungi from equation in biostatistics (Hassard, 1991) were conducted.

RESULTS AND DISCUSSION

Leaf Litter Production in Natural Mangrove Forest and Mangrove Plantation

Natural Mangrove Forest

Litter production by different tree components in natural mangrove forest at Thachine estuary, Samut Sakhon throughout one year investigation was presented in Table 5. The highest litter production was exhibited for 786.21 kg/rai at 60-80 meters distance from sea margin. It ranged approximately 209.4 kg/rai/month. Litter production about 76.3 kg/rai/month was observed during Febaury to July. The annual total litter falls obtained for 1,656 kg/rai/year. Most litter falls were composed of 54 % leaves. Branches, fruits, flowers and others were weighed at 4.63, 28.52, 8.26 and 4.16%, respectively as indicated in Table 6.

Mangrove Plantation

The litter production in mangrove plantation investigated throughout one year was shown in Table 7. The highest litter production was indicated between September at 60–80 meters distance from sea margin. It ranged about 221 kg/rai/month. Litter production for 105.5 kg/rai/month was observed between Febuary to July. The total litter production was 1943 kg/rai/year. Litter falls were mainly composed of 54.2% leaves whereas branches, fruits, flowers and others weighed at 5.37, 28.95, 7.83 and 3.64% respectively as revealed in Table 8.

It was found that litter falls at mangrove plantation demonstrated more than natural mangrove forest due to 1) density of trees in mangrove plantation was counted at 250 trees/rai while natural mangrove forest was 200 trees/rai, 2) species of plants in mangrove plantation mainly composed of *A. alba* of 5 years old but in natural mangrove forest composed of mixed mangrove plants of more than 5 years old.

However it was found that the litter production in mangrove of Samut Sakhorn was illustrated more higher than that in the Ranong mangrove forest about 1,420.0 kg/rai/ year (Aksornkoae *et al.*, 1987) and Chantaburi mangrove forest about 1,490.0 kg/rai/year (Aksornkoae and Khemnark, 1984). The leaf litter has played an important source for minerlization because leaf litters are usually decomposed easier than branch and fruit litters. Though the importance of branch could not be underestimated, which took a longer time to decompose and remineralise (Sasekumar and Loi, 1983). It could be said that Thachine estuary had a high nutrient turnover rate due to its high leaf litter composition. And the various areas had been different litter production due to they had varied dominant species such as *Avicennia alba, Avicennia marina and Rhizophora apiculata*, and density of plant communities.

Table 5 Litters Falls in Different Distance from Sea Margin of Natural Mangrove Forest within One Year at Thachine Estuary; Samut Sakhon Province

Disstance from Sea Margin (m)	Litter Fall Based on Dry Weight (kg/rai)												Total	Average/ Month
	Jan.	Feb.	Mar.	April	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.		
0-20	229.65	121.34	116.22	51.02	143.30	66.93	109.02	319.33	99.31	153.01	115.50	295.09	1,819.73	151.68
20-40	25.78	15.01	20.78	19.78	56.70	33.18	57.60	217.89	21.52	15.01	25.50	42.51	551.18	45.93
40-60	140.34	90.45	112.80	61.58	120.53	71.61	100.62	316.54	393.98	52.50	55.06	148.98	1,667.94	138.99
60-80	187.79	63.90	39.09	29.22	73.07	102.73	103.71	678.06	786.21	108.00	84.00	131.14	2,346.91	195.58
80-100	157.65	102.90	94.11	56.50	92.10	78.58	90.34	134.40	432.00	117.01	94.50	175.89	1,625.95	135.50
100-120	110.02	70.50	47.31	22.50	48.70	53.78	55.89	307.02	496.54	198.00	25.50	110.22	1,543.12	128.59
120-140	221.42	99.30	112.46	45.81	89.07	66.51	135.25	149.44	511.46	225.01	202.21	280.62	2,138.58	178.21
140-160	159.15	59.25	119.82	51.70	75.02	111.22	91.38	232.42	114.21	84.75	195.01	182.91	1,476.83	123.07
160-180	180.13	80.26	123.78	73.50	150.93	97.50	89.31	248.08	582.62	220.50	126.75	360.69	2,334.05	194.50
180-200	88.67	53.55	56.91	52.38	58.85	53.62	73.02	49.65	283.04	84.00	103.50	107.31	1,064.51	88.71
Total	1,460.59	756.45	843.25	463.95	908.27	735.60	906.16	2,653.01	3,720.85	1,257.78	1,027.54	1,835.36	-	-
Average	146.06	75.64	84.32	46.40	90.83	73.56	90.62	265.30	372.08	125.78	102.75	183.54	1,656.88	138.07

Table 6 Litter Production of Mixed Mangrove Species during January to December 1998 at Thachine Estuary in National Mangrove Forest, Samut Sakhon Province

Month	Litter Falls Based on Dry Weight (kg/rai)					
	Leaves	Branches	Fruits	Flowers	Others	Total
Jan.	134.12	8.45	-	-	3.49	146.06
Feb.	67.73	6.30	-	-	1.69	75.65
Mar.	69.41	9.08	-	5.83	-	84.32
Apr.	33.50	2.99	-	9.89	-	46.39
May	41.44	10.51	1.00	37.86	-	90.81
Jun.	25.22	6.63	2.20	39.52	-	73.57
Jul.	37.32	3.46	6.25	43.68	-	90.61
Aug.	81.59	6.19	123.40	-	54.1	265.31
Sept.	86.90	9.43	275.75	-	-	372.08
Oct.	57.01	8.32	60.45	-	-	125.78
Nov.	89.25	5.25	3.00	-	5.25	102.75
Dec.	178.03	0.15	0.47	-	4.49	183.14
Total	901.55	76.77	472.42	136.76	68.98	1,656.47
%	54.43	4.63	28.52	8.26	4.16	100.00

Table 7 Litters Falls in Different Distances from Sea Margin of Mangrove Plantation Forest within One Year at Thachine Estuary; Sumut Sakhon Province

Disstance from Sea Margin (m)	Litter Fall Based on Dry Weight (kg/rai)													Average/ Month
	Jan.	Feb.	Mar.	Apri.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Total	
0-20	155.74	99.47	102.70	83.69	136.35	73.33	77.61	155.13	334.68	104.79	110.97	139.04	1,573.68	136.15
20-40	302.79	116.15	144.56	96.89	233.24	100.76	87.79	241.86	567.94	190.11	119.87	295.57	2,497.53	208.12
40-60	190.32	96.94	141.59	83.31	147.47	109.33	89.08	223.47	275.17	105.97	160.38	181.68	1,804.71	150.39
60-80	238.31	128.06	137.49	79.57	156.25	81.40	116.54	191.66	297.46	192.93	168.91	242.76	2,031.04	169.25
80-100	168.76	110.06	96.77	65.01	131.04	71.54	66.93	298.86	514.13	176.05	62.22	139.04	19,00.41	158.36
100-120	195.68	130.31	125.02	76.27	158.14	88.94	88.46	190.31	473.81	125.43	97.84	178.28	1,928.49	160.70
120-140	192.37	105.94	91.63	69.26	166.25	104.02	96.74	510.59	695.17	131.05	93.16	151.15	2,407.33	200.61
140-160	187.91	122.53	137.70	89.44	175.93	86.45	94.91	293.26	450.01	97.31	80.68	161.33	1,977.46	164.78
160-180	116.11	75.38	80.16	62.29	136.03	60.56	67.97	244.23	235.85	81.68	62.22	96.72	1,319.03	109.91
180-200	243.37	137.82	139.88	8.84	190.13	81.58	120.38	303.58	265.86	147.93	110.97	249.86	2,000.20	166.68
Total	1,991.36	1,122.68	1,197.50	714.57	1,630.83	857.91	906.41	2,652.95	4,110.08	1,353.25	1,067.22	1,834.6	19,439.88	1,619.95
Average	199.13	112.26	119.75	71.45	163.08	85.79	90.64	265.29	411.00	135.32	106.7	183.46	1,943.99	161.99

Table 8 Litter Production of Mixed Mangrove Species during January to December 1998 at Thachine Estuary in Mangrove Plantation, Samut Sakhon Province

Month	Litter falls based on dry weight (kg/rai)					
	Leaves	Branches	Fruits	Flowers	Others	Total
Jan.	160.57	10.99	23.85	-	4.00	199.41
Feb.	100.11	8.51	1.63	-	2.40	112.65
Mar.	94.08	12.02	3.01	7.18	-	116.29
Apr.	51.97	3.44	8.78	15.80	-	79.95
May	63.37	28.72	11.79	47.85	-	151.73
Jun.	34.17	8.37	5.20	37.78	-	85.52
Juy.	37.32	3.46	6.15	43.68	-	90.61
Aug.	81.59	6.19	123.40	-	54.13	265.31
Sept.	106.37	9.05	315.03	-	-	430.45
Oct.	57.00	8.33	60.45	-	-	125.78
Nov.	89.25	5.25	3.00	-	5.25	102.75
Dec.	178.03	0.15	0.47	-	4.89	183.54
Total	1,053.83	104.48	562.72	152.29	70.67	1,943.99
%	54.21	5.37	28.95	7.83	3.64	100

Decomposition Rates of Leaf Litter in Natural Mangrove Forest and Mangrove Plantation

Decomposition rates were investigated from December 1997 to January 1999 in natural mangrove forest site I on the west coast of the estuary, natural mangrove forest site II on the east coast of the estuary and mangrove plantation. The leaf litter loss through decomposition on the soil surface in different sites were variable (Table 9). The litter loss rates in natural mangrove forest site I and II at the forest margin or river bank area and in the mangrove plantation were shown approximately 2-5% higher than the loss in those areas at 50 meters from the river bank. The *A. alba* and *R. apiculata* leaf litters in natural mangrove forest site I and II at the river bank and at 50 meters away from the river bank were completely decomposeed in 5-6 months except *A. alba* in the mangrove plantation at the river bank and at 50 meters away from river bank were completely decomposed in 3-5 months. The rapid decay (90%) of both litter had been found within 2-3 months, and thereafter, the rate gradually decreased. In the mangrove plantation forest, *Rhizophora apiculata* and *Avicinnia alba* leaf litters were decomposed faster than those in the natural mangrove.

The initial dry weight of the litter decreased by half within 20 days. Decomposition rates of *A. alba* and *R. apiculata* as shown in Figure 3 and 4 at Thachine estuary were indicated differently from those reported in Phuket mangrove within 21 days (Boonruang, 1978), in Florida 45 days (Heald, 1971) and in New Zealand 45- 60 days (Woodroffe, 1982). This was due to the differentes of physical factors and biological activities. Relatively, in terms of percentage the weight loss of the dry leaves in Thachine estuary was higher than the loss at Ranong mangrove (Aksornkoae *et al.*,1991). The leaf decomposition of *Avicennia* was revealed higher than *Rhizophora* (Angsupanich *et al.*, 1989; Robertson, 1988).

Past reports showed that autolysis leaching by microbial action quickly released by decomposed fractions of leaf litter as soluble organic materials remaining some refractory material behind (Cundell *et al.*, 1979; Reice *et al.*, 1984; and Angsupanich *et al.*, 1989). Then the refractory materials gradually decayed later. Although the microbial activity in general which decomposed organic compound to inorganic compound, was an important process but the chemical and physical processes also accelerated the decay rate.

This investigation showed that the litters in the natural mangrove forest and the mangrove plantation still remained on the soil surface for serveral months or years before they completely decayed and the residues were finally incorporated into mineral soils. Under certain circumstances, in mangrove communities where litter production was high and the decay rate was fast, the litters transformed into detritus, mixed into soils in several centimetres depths. At Thachine estuary, Samut Sakhon large amount of litter falls of mixed species was produced into the forest floor annually (Table 5and 7) which was similar to the situation appearing at Samut Songkram (Chukamdee, 1998).

The decomposition rates of leaf litters and the mineral-soil incorporation process were depending on physical conditions and plant species. The leaf litter of *A. alba* decayed faster and took about 3 months to become a humus while the leaf litter of *R. apiculata* decayed slowly within 6 months. Generally, the leaf litter containing less fiber and less cellulose, decomposed rapidly than leaves with more fibers and lignin like *R. apiculata* (Mikola,1954).

The decomposition rate of leaf litter into humus was mainly depending on 4 factors. 1.) benthic organisms, such as earthworms, crabs and mocroorganisms, which were the most important factors in decaying fragment of leaves, promoted gradual reduction of litter size, and speeding decomposition by microoranisms especially fungi, which broke down of the leaf tissues. 2.). The second factor involved mesh size of leaf- containing bags. Increasing the mesh size of bags showed insignificantly increases the rate of weight loss of leaves, which disappeared equally fast from all bags irrespective of mesh size.

(Heath, Arnold and Edwords, 1966). 3.) The growth of fungi on leaf litter also producedimportant reciprocal effects for the benefit of soil animals. Fungal respiration lowered the C: N ratio and polyphenols oxidized and transformed to innocuous substances. Fungal hyphae which increased the protein content of the litter, and cellulose and lignin that could not be digested by most soil animals were transformed into digestible fungal carbohydrates. As a result, the litter became more palatable and more nutritious for the soil animals. 4.) Reduction in the rate of litter decomposition was presumably due to the reduction in diversity of species (Newsham *et al.*, 1992; Malik, 1979).

Table 9 Decomposition Percentage of *Rhizophora apiculata* and *Avicennia alba* Leaf at Thachine Estuary, Samut Sakhon province

Species	Month/ Year	Decomposition (%) at forest margin			Decomposition (%) at 50 meters from river bank		
		Natural forest I	Natural forest II	Mangrove plantation	Natural forest I	Natural forest II	Mangrove Plantation
R. apiculata	Dec, 97	66.66	63.70	71.76	50.68	45.96	57.04
	Jan, 98	86.87	91.30	87.36	82.18	78.06	85.53
	Feb, 98	89.14	91.77	94.77	87.02	86.35	92.56
	Mar, 98	96.06	99.62	98.77	91.71	96.63	98.90
	Apri, 98	97.32	100	98.57	96.01	100	99.75
	May, 98	99.00	100	100	98.20	100	100
A. alba	Dec, 97	27.52	14.09	39.20	13.90	12.00	37.20
	Jan, 98	55.53	72.92	73.05	45.00	41.09	69.05
	Feb, 98	78.71	82.35	89.69	59.68	82.00	83.50
	Mar, 98	83.60	90.59	91.50	73.81	86.82	88.14
	Apri, 98	93.79	98.01	100	89.70	96.52	98.24
	May, 98	98.52	100	100	92.50	100	100
R. apiculata	Jul, 98	40.72	36.96	68.53	38.58	51.22	65.44
	Aug, 98	61.03	64.12	77.68	58.42	63.58	72.85
	Sep, 98	96.42	95.89	98.71	97.17	97.47	98.65
	Oct, 98	99.12	96.77	97.43	98.55	96.22	99.16
	Nov, 98	97.83	97.28	99.02	97.96	99.22	98.58
	Oct,98	98.70	99.18	99.42	99.37	99.75	98.68
	Jan,99	100	100	100	100	100	100
A. alba	Jul, 98	83.58	96.19	85.51	78.81	75.1	76.73
	Aug, 98	90.27	86.28	95.39	88.03	81.72	91.36
	Sep, 98	99.23	97.96	100	99.22	99.11	100
	Oct, 98	96.25	99.23	100	97.03	99.13	100
	Nov, 98	99.63	99.69	100	99.07	99.50	100
	Dec, 98	98.63	100	100	99.65	100	100
	Jan, 99	100	100	100	100	100	100

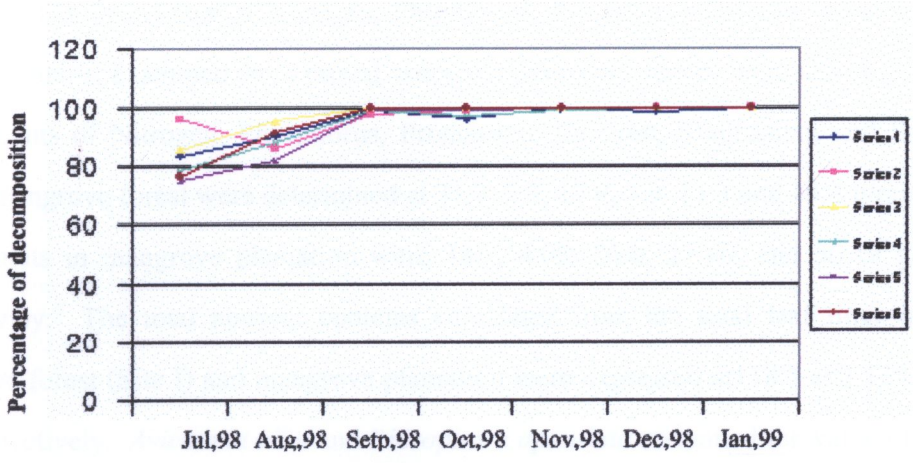


Figure 3 Decomposition Rates of *A. alba* at Thachine Estuary

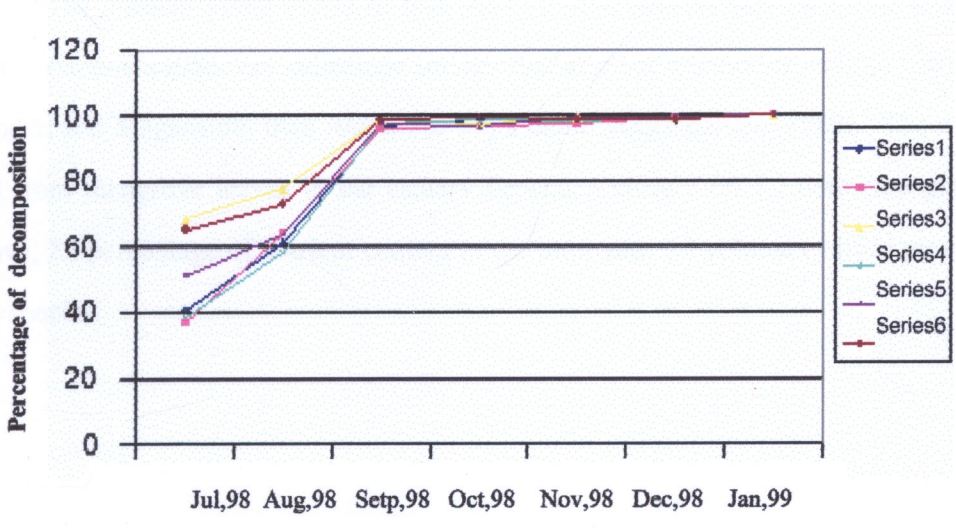


Figure 4 Decomposition Rates of *R. apiculata* at Thachine Estuary

Note

Series 1 = Natural forest I at forest margin
Series 2 = Natural forest II at forest margin
Series 3 = Mangrove plantation forest at forest margin
Series 4 = Natural forest I at 50 meters away from river bank
Series 5 = Natural forest II at 50 meters away from river bank
Series 6 = Mangrove plantation forest at 50 meters away from river bank

Nutrients from Litter Falls

The percentage of Nitrogen, Phosphorus, Protassium, Calcium, Magnasium and Sodium contents examined from mixed senescent mangrove leaves were shown in Table 9. The amounts of Nitrogen, Phosphorus, Protassium, Calcium, Magnasium and Sodium in natural mangrove forest were determined at 31.7, 2.3, 17.9, 3.9, 13.3 and 49.4 g/rai/year and the amounts in mangrove plantation were 38.3, 4.08, 20.0, 21.40, and 50.12 g/rai/year, respectively. The total nutrient contents calculated from the total leaf litter in natural mangrove forest (Site I) and mangrove plantation were expressed at118.5 and 139.02 g/rai/ year respectively. *Avicennia alba* and *Rhizophora apiculata* contained the value of nitrogen of 1.824% and 1.048% respectively, the lowest amounts of the phosphorus contents were measured at 0.0123 % and 0.041% respectively as shown in Table 10.

The nutrient composition of leaf litter of each species was exhibited somewhat different. *Avicennia alba* was indicateda smaller leaf size but it contained a high percentage of Nitrogen and Magnesium than *Rhizophor aapiculata* (Angsupanich, 1989). The nutrient sources from mangrove leaves in the estuary depended closely on 1.) dominant plants in mangrove, 2.) percentage of nutrient content in the litter and 3.) volume of litter production of each species.

Table 10 Nutrients Derived from Litter Falls in 1998 at Thachine Estuary, Samut Sakhon Province

Nutrients	Nutrient from Litter Falls			
	Mixed Leaves (g/rai/year)		*R. apiculata* (%)	*A. alba* (%)
	Natural Forest	Mangrove Plantation		
Nitrogen (N)	31.70	38.3	1.048	1.824
Phosphorus (P)	2.30	4.08	0.071	0.0123
Protassium (K)	17.90	20.0	0.850	0.750
Calcium (Ca)	3.90	5.10	1.047	0.580
Magnesium (Mg)	13.30	21.40	0.477	0.622
Sodium (Na)	49.45	0.12	-	-
Total	118.5	139.02		

Species of Fungi Isolated from Leaf Litters

Fungi isolated from *R. apiculata* and *A. alba* leaves in natural mangrove forest site I on the west coast of the estuary, natural mangrove forest site II on the east coast of the estuary and mangrove plantation at the river bank and at 50 meters away from the river bank detected by direct and indirect methods could be classified into 49 species of 19 genera, including 2 genera of Zygomycota, and 16 genera of Deuteromycota and 1 genus of Ascomycota as shown in Table 11 and 12 respectively. The important genera were *Trichoderma, Aspergillus, Penicillium* and *Fusarium*. The number of fungi colonized on *R. apiculata* and *A. alba* leaves were identified into 30 and 36 species respectively (Table 13 and 14). Specific fungi were found only on *R. apiculata* such as *Drechslera* sp., *Rhizoctonia* sp. and *Phoma* sp.(Figure 5). The species of fungi on *A. alba* leaves in natural mangrove forest (site I and II) at the river bank and at 50 meters away from the river bank

were identified into 22 and 12 species respectively. In the mangrove plantation at the river bank and at 50 meters away from the river bank, the fungal species were found 13 and 7 species respectively (Table 14). The species of fungi on the *R. apiculata* leaves in natural mangrove forest (site I and II) at the river bank and at 50 meters away from the river bank were shown 12 and 11 species respectively. In the mangrove plantation at the river bank and at 50 meters away from the river bank the fungal species were found for 9 and 4 species respectively (Table 13). A higher distribution of fungi mostly found at the forest margin or the river bank than at 50 meters away from the river bank. The number of fungal species on both leaves in natural mangrove forest site I on the west coast of the estuary was revealed higher than those in the natural mangrove forest site II on the east coast of the estuary because of more flat mud which provided for suitable nutrients.

Similar trend of fungal species decomposing leaf litters on soil surface at Thachine estuary, Samut Sakhon province, had been recorded in mangrove soil in Hawai, USA (Kohlmeyer, 1979; Benny, 1972); in Malaysia (Kuthabuteen, 1984) and in Ranong, Thailand (Ito, 2001) and Nagakari *et al.* (2001). In addition, the number of fungal species were not indicated much different from those at Tachine estuary. However, researchers in those countries did not record and indicate the number of the fungi species on *A. apiculata* and *A. alba* leaf litters on surfaces soil at the river bank and at 50 meters away from the river bank.

Previously there were some studies on estuarine fungi only substrates like on mud soil, root, branch, and bark of mangrove plants but the fungi on leaf decomposition had never been studied. The esturine fungi mostly were found terestrial fungi and marine fungi. Most of marine fungi have appendaged spores in the Phylum Ascomycota but terestrial fungi do not.

Normally when the leaf litter falls on surface soil, it would be quickly colonized by soil fungi. After leaves were buried and transfered into deeper soil layers, soil microfungi such as *Penicillium, Humicola, Trichoderma, Fusarium,* and *Gliocladium* were ubiquitous in distribution (Table 11 and 12). However, species of these genera were known to be widely distributed in different soils. All of them continued active growing on resident populations in soils and were so called "Autononous" species of the soil. Many fungi metabolized litter phenolic compounds, and especially important species among them were *Penicilium* and other species. This species is generally tolerant to phenols in culture. They also utilized tannin as a sole carbon source (Cowley and Whittingham.1961; Lewis and Starkey, 1969; Grant, 1976; Dix, 1979). Most Antonomous soil fungi also hydrolysed polysaccharides. Because *Trichoderma, Penicillium* species and others caused weight loss of leaf litter in monocultures after long incubation periods, and some of the commonest antonomous soil fungi associated with leaf litter appeared only a minor part in its direct decomposition (Hering, 1967; De-Boois, 1976). However, it had been shown that these fungal populations illustrated an important indirect role in leaf litter decomposition. Generally soil fungi, including *Penicillium* and *Fusarium* species, could synergistically increase decay rates on leaf litter when co-culture with leaf litters decomposer (Dix and Simpson, 1984).

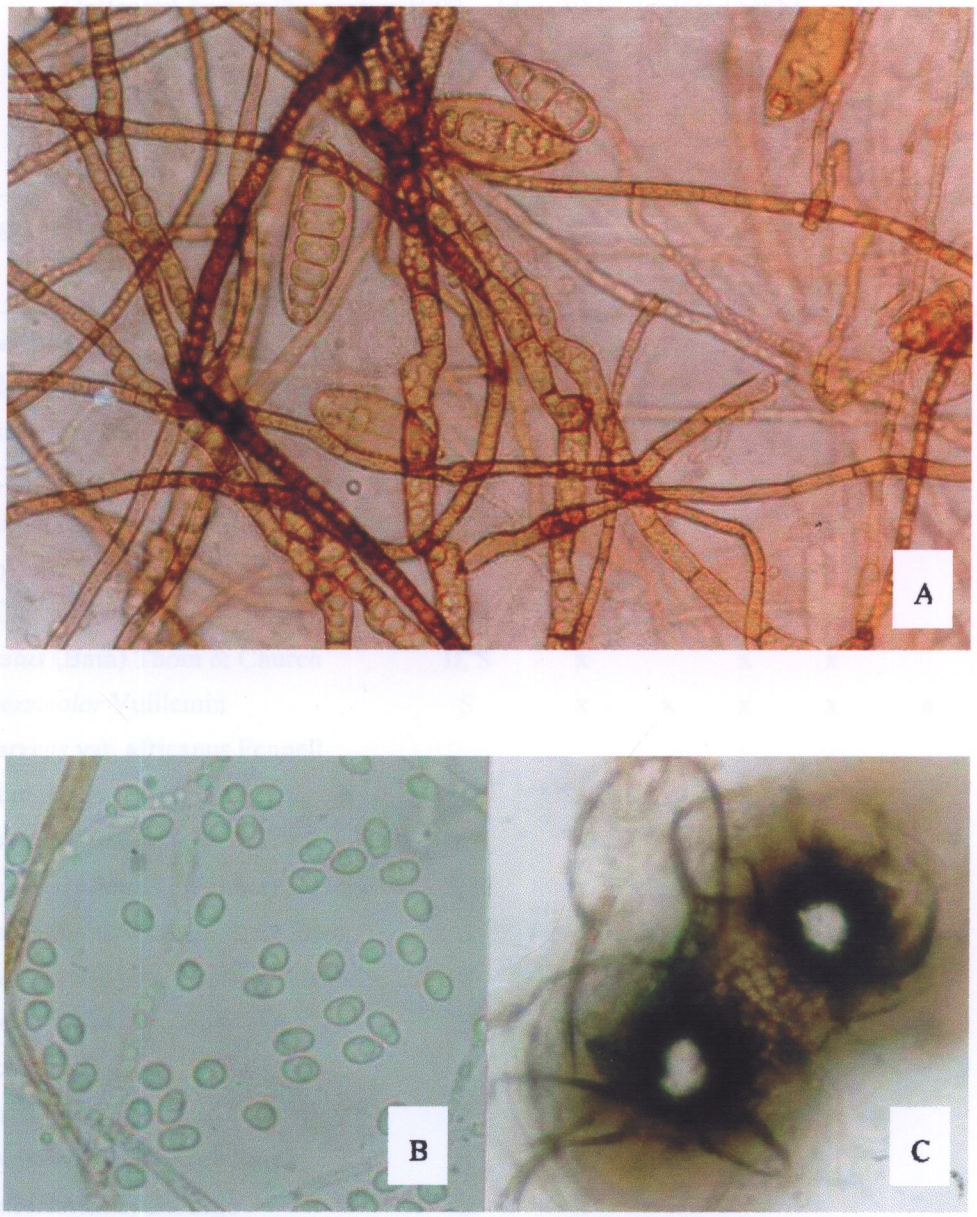


Figure 5 Species of Fungi on *R. apiculata* Leaf Litters, A. *Drechslera* sp. : Condia; B, C. *Phoma lingams* : Conidia and Pycnidia, 1000 x

Table 11 Species of Fungi Associatd with *R. apiculata* and *A. alba* Leaf Litters in Collected during December 1997 – May 1998, Isolated by Moist Chamber (M), Baiting (B), Soil Plate (S) and Dilution Plate (D) methods.

Remark : x = present fungi

Fungal Species	Isolation Method	Month					
		Dec.	Jan.	Feb.	Mar.	Apr.	May
Aspergillus fumigatus Fres.	D, S	x	x	x	x	x	x
A. flavus Link	S,B,M	x	x				
A. lutescens Bainier ex Thom & Church	S	x			x	x	
A. niger van Tieghem	D, S	x	x	x	x	x	x
A. sydowi (Bain and Sart.) Thom & Church	S	x	x				
A. ustus (Bain) Thom & Church	D, S	x		x	x		
A. versicolor Vuillemin	S	x	x	x	x	x	x
A. terreus var. africanus Fennell and Raper	S	x	x	x	x	x	x
A. wentii Wehmer	D, S	x	x	x	x	x	
Curvularia lunata (Wakker) Boedijn	S, B	x					
Emericella nidulans Link ex Fries	S			x		x	
Fusarium illudens (Peck) Wolleaw.	S	x					
F. poae (Peck) Wolleaw	S	x		x			x
Mucor sp. 1	S	x					
Penicillium adametziix Zaleski	S			x			
P. paraherqueii Abe ex Smith	S	x		x			
P. sublateritium Biourge	S	x					
Phoma lingams.	S	x					
Rhizoctonia sp.	D, S, B	x	x	x	x	x	x
Trichoderma harzianum Rifai aggr.	D, S	x	x	x			
T. koningii Oud. Aggr.	S	x	x	x			
T. polysporum (Link ex Bers.) Rifai aggr.	S	x					
T. pseudokoningii Rifai	D, S	x					
Total		21	10	13	8	8	5

Table 12 Species of Fungi Associated with *R. apiculata* and *A. alba* Leaf Litters in Collected during July 1998 - January 1999, Isolated by Moist Chamber (M), Baiting (B), Soil Plate (S) and Dilution Plate (D) Methods

Remark : x = present fungi

Fungal Species	Isolation Method	Month					
		Jul.	Aug.	Sept.	Oct.	Nov.	Dec.
Acremonium murorum	S			x			
Aspergillus aeneus	S	x					x
A. alutacens	S	x	x				
A. candidus	S					x	
A. flavipes	S	x					
A. flavus	S		x			x	x
A. funigatus	D,S	x	x	x	x	x	x
A. lutescens	S		x			x	x
A. niger	D, S	x	x	x	x	x	x
A. ornatus	S						x
A. sydowi	S		x				
A. sparus	S	x	x				
A. terreus	S	x	x	x	x	x	x
A. ustus	D, S	x					
A. versicolor	S			x			
A. wentii	D, S	x	x	x	x	x	
Curvularia geniculatus	S	x				x	x
Curvularia lunata	S				x		
Cylindrocarpon destructans	S	x					
C. magnasia	S	x					
Drechslera sp.	D	x					
Emericella nidulans	S		x				
Fusarium miliniforme	S	x					
F. illudens	S					x	
Fusarium sp.	S				x		
F. poae	S					x	x
Geotrichum sp.	D						x
Humicola sp.	S			x			
Mucor sp. 1	S	x	x				
Mucor sp. 2	D, S	x	x				

Table 12 (contd.)

Fungal Species	Isolation Method	Month					
		Jul.	Aug.	Sept.	Oct.	Nov.	Dec.
Penicillium adametziix	S		x				
P. erythrocephalus	D		x				x
P. paraherqueii	S				x	x	x
P. ranigenum	S				x		
P. sublateritium	S		x				x
P. velutinum	S						
Phoma lingams	S				x		
Pestalotiopsis guipinii	S	x			x		
Rhizoctonia sp.	D, S	x	x			x	x
Scopulariopsis sp.	S				x		
Trichoderma aureoviride	D					x	x
T. hamatum	S						x
T. harzianum	D, S				x	x	x
T. koningii	S	x				x	x
T. pilulitrum	S					x	
T. polysporum	S						x
T. pseudokoningii	D, S					x	
T. viride	D					x	x
Verticillium sp.	D		x				
Total		19	17	7	12	18	20

Table 13 Species of Fungi Associated with *R. apiculata* Leaf Litters in Natural Mangrove Forest and Mangrove Plantation at Tachine Estuary, Samut Sakhon Province

Remark : x = present fungi

Fingal Species	Forest Margin or River Bank			50 Meters Away from River Bank		
	Natural Forest I	Natural Forest II	Plantation Forest	Natural Forest I	Natural Forest II	Plantation Forest
Aspergillus flavipes			x			
A. flavus	x			x	x	x
A. lutescens					x	
A. niger		x		x	x	x
A. niger		x		x	x	x
A. sparus			x			
A. ustus					x	
A. versicolor			x			
A. wentii		x	x		x	
Curvularia lunata			x	x		
Cylindrocarpon destructans	x					
C. magnosia				x		
Emericella nidulans	x					
Drechslera sp.	x	x				
Fusarium muliniforma			x			
Geotrichum sp.	x					
Humicola sp.					x	
Mucor sp.			x			
Phoma lingams				x		
Penicillium erythrocephalus				x		
P. paraherqueii	x		x	x		
P. velutinum	x	x				
Rhizoctonia sp.	x	x				x
Stephylotrichum sp.			x			
Trichoderma aureoviride		x				
T. piluliform	x	x				
T. pseudokoningii						x
Total	8	8	9	7	6	4

Table 14 Species of Fungi Associated with *A. alba* Leaf Litters in Natural Mangrove Forest and Mangrove Plantation at Thachine Estuary, Samut Sakhon Province

Remark : x= pesent fungi

Fingal Species	Forest Margin or River Bank			50 Meters Away from River Bank		
	Natural Forest I	Natural Forest II	Plantation Forest	Natural Forest I	Natural Forest II	Plantation Forest
Acremonium murorum	x		x			
Aspergillus candidus						x
A. flavus	x	x		x		
A. flavipes	x					
A. lutescens			x		x	
A. niger	x	x	x	x	x	x
A. ornatus			x			
A. sparus			x			
A. sydowi		x				
A. terreus				x		
A. ustus	x	x		x		
A. versicolor	x	x				x
A. wentii		x				
Emericell nidulans	x					x
Cylindrocarpon magnosia	x					
Fusarium poae	x					
Humicola sp.				x		
Mucor sp. 1	x		x			
Mucor.sp. 2	x		x			
Pestlotiopsis guipinii		x				
Penicillium ademetzii	x					
P. paraherqueii					x	
P. ramigenum		x				
P. sublateritium				x		
Scopulatiopsis sp.		x				
Trichoderma aureoviride			x			
T. harzianum	x		x	x		x
T. koningii	x	x	x	x		x
T. longibracheatum			x			
T. polysporum	x		x	x		x
T. pseudokoningii	x	x				
T. viride	x		x	x		x
Total	17	11	13	19	4	7

Soil Chemical Properties

Soil chemical properties in the natural mangrove forest and the mangrove plantation were shown on Table 14. The soil in mangrove plantation was identified as clay; clay loam and silt clay which also found the same properties at the natural mangrove forest I and natural mangrove forest II. However in the three areas it could be sammarized that the soil properties showed pH 7.4-75, salinity condition revealed approximately 15-28 ppt, temperature between 30-35°C. Total cation exchange capacity (CEC) in particular was about 23.6, 26.8 and 28.0 meq/100 gms soil in the mangrove plantation, natural mangrove forest and natural mangrove forest II respectively. The organic matter of the surface soil values was expressed 6.01, 6.51 and 5.71% in mangrove plantation, natural mangrove forest I and II respectively (Table 15).

Table 15 Soil Chemical Properties in Natural Mangrove Forests and Mangrove Plantation at Thachine Estuasy, Samut Sakhon Province

Location	Chemical Soil Properties								
	Texture	pH	CEC Meq/ 100 g	Organic Matter (%)	N (%)	P (ppm)	K (ppm)	Ca (%)	Mg (%)
Natural Managrove Forest I	Clay Loam	7.4	26.28	6.51	1.12	87	1472	4086	4040
Natural Managrove Forest II	Silt Clay	7.4	28.0	5.71	1.52	75	1644	2898	4452
Mangrove Plantation	Clay	7.5	23.6	6.01	1.46	80	1636	5642	5789

Species of Soil Fungi

Soil fungi isolated using the soil plate method in summer and the rainy season were identified into 25 species. *Rhizoctonia sp.* and *Trichoderma viride* were found only in the rainy season, whereas *Aspergillus* sp., *Penicillium* sp. could be found in both seasons (Table 16 and 17). The number of the soil fungi distributed in natural mangrove forest (Site I and II) and mangrove plantation in the summer season at the forest margin or the river bank depicted higher than that 50 meters away from the river bank. There were 13 species at river bank and 5 species at 50 meter away from river bank. In natural mangrove species found 7 species and 3 species of fungi for the mangrove plantation. In rainy season, natural mangrove forest (Site I and II) at the river bank and at 50 meters away from river bank the soil fungi species were found for 11 species at the river bank and 7 species (50 meter away from river bank) for the former mangrove and 5 species for the latter mangrove types respectively. Similarity, the number of fungi on leaf litter in the west coast of the estuary, the number of fungi were found greater than that in the east coast of the estuary. *Aspergillus* sp. and *Penicillium* sp. were found in both seasons because this species showed well adaptation to physical factors such as temperature and salinity better than other fungal species (Benny and Baker, 1972). The number of species in natural mangrove forest was higher than that in the mangrove plantation. The reason was that in natural mangrove forest actually contained higher nutrients and suitable physical factors for fungal growth which were reported by Kohlmeyer, 1979.

Table 16 Species of Soil Fungi Found in Natural Mangrove Forests and Mangrove Plantation in Summer Using Soil Plate Method

Remark : x = present fungi

Fingal Species	Forest Margin or River Bank			50 Meters Away from River Bank		
	Natural Forest I	Natural Forest II	Plantation Forest	Natural Forest I	Natural Forest II	Plantation Forest
Aspergillus flavus	x					
A. flavipes					x	x
A. funigatus	x	x	x			x
A. niger	x	x	x	x	x	x
A. tarmarii	x	x	x			
A. versicolor		x	x	x		
Fusarium poae	x					
Gliocladium sp.	x					
Mucor sp.		x				
Phoma nebulasa					x	
P. lingams		x	x	x		
Penicillium sp.	x					
P. paraherqueii	x					
Trichoderma harzianum	x	x	x			
T. koningii	x					
T. pseudokoningii			x			
Total	10	7	7	3	3	3

Table 17 Species of Soil Fungi Found in Natural Mangrove Forest and Mangrove Plantation in Rainy Season Using Soil Plate Method

Remark : x = present fungi

Fingal Species	Forest Margin or River Bank			50 Meters Away from River Bank		
	Natural Forest I	Natural Forest II	Plantation Forest	Natural Forest I	Natural Forest II	Plantation Forest
Aspergillus fumigatus	x			x		
A. niger	x	x	x	x	x	x
A. terreus	x					
Fusarium muliniforme		x				
F. poae	x	x		x		x
Fusarium sp.			x			
Penicillium sp.					x	
P. paraherqueii				x		
P. purpurgenum	x					
P. lingams	x					
Rhizoctonia sp.	x		x		x	x
Trichoderma hamatum	x		x			x
T. harzianum						x
T. pseudokoningii	x		x	x		
T. viride	x	x				
Total	10	4	5	5	3	5

Activity of Dominant Fungi under Laboratory Condition

Brown and White Rot Fungi and Degrading Gallic Acid

The experiment on brown rot and white rot fungi showed that *Phoma lingams, P. bebutosa, Penicillium sublateritium,* and *P. purpurgenum* were depicted the efficient white rot fungi because these species had ability to change gallic acid in CMA media to deep brown and also changed mycelium colour to pink when droped with gallic acid which dissolved in 95% ethanol, whereas *Trichoderma* spp. and *Aspergillus* spp. were clearly exhibited brown rot fungi (Table 18, Figure 6). White rot fungi coud change the media to deep brown because the fungi excreted lignocellulase enzyme to digest lignin in gallic acid but brown rot fungi produced enzyme less than white rot fungi therefore it could not show ability to change the media color to dark brown (Leightley and Eaton, 1979).

Growth Rates of Fungi at Different Percentages of Cellulose on CMA Containing 15 and 30 ppt Salinity of Seawater

Examination of the growth rates of fungi at different percentages of cellulose and xylan showed that growth on CMA plus cellulose concentration 0.1-0.2 at the 15 ppt salinity; revealed better than other cellulose concentrations (Table 19-20). At 30 ppt salinity concentration, growth colony showed smaller than those on the salinity concentration of 15 ppt media in every fungus. The growth rates varied due to the limit of the enzyme activities of each fungus (Benny and Baker, 1972). Some fungi such as *T. viride, T. hamatum, T. koningii* and *Penicillium* sp could change colour of media to yellow, whereas *T. polysporum, T. pseudosporum, T. hazianum, A. ustus, A. niger,* and *Rhizoctonia* sp. could not change the media colour.

Table 18 Brown Rot (B) and White Rot (W) Fungi Cultured on CMA plus Lignin (gallic acid) at Different Concentrations

Fungal Species	Concentrations of Gallic Acid (%) on CMA				Brown	White
	0.1	0.2	0.5	1.0	Rot (B)	Rot (W)
Aspergillus lutescens	-	-	-	-	✓	
A. niger	-	-	-	-	✓	
A. ustus	-	-	-	-	✓	
Curvularia lunata	-	-	-	-	✓	
Fusarium poae	-	-	-	-	✓	
Geotrichum sp.	-	-	-	-	✓	
Penicillium purpurgenum	+	++	+++	++++		✓
P. sublateritium	+	++	+++	++++		✓
Penicillium sp.	-	-	-	-	✓	
Pestalotiopsis guiopinii	-	-	-	-	✓	
Phoma nebuiosa	+	++	+++	++++		✓
P. lingams	+	++	+++	++++		✓
Rhizactonia sp.	-	-	-	-	✓	
Scopuratiopsis sp.	-	-	-	-	✓	
Trichoderma hamatum	-	-	-	-	✓	
T. harziamum	-	-	-	-	✓	
T. koningii	-	-	-	-	✓	
T. polysporum	-	-	-	-	✓	
T. pseudosporum	-	-	-	-	✓	
T. viride	-	-	-	-	✓	
Total					16	4

Note
- \- not change color media
- \+ poor deep brown
- ++ fair deep brown
- +++ good deep brown
- ++++ excellent deep brown

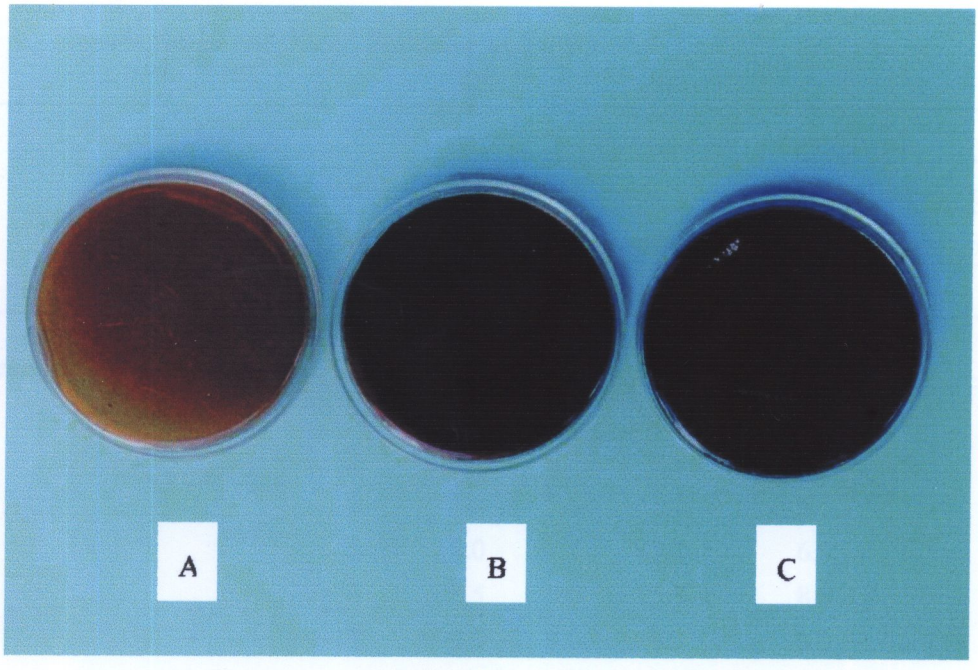


Figure 6 *Trichoderma viride,* a Brown Rot Fungus Decomposed Gallic Acid at Concentrations of 0.1 and 0.2% on CMA (B, C) as Compared with Plain CMA (A)

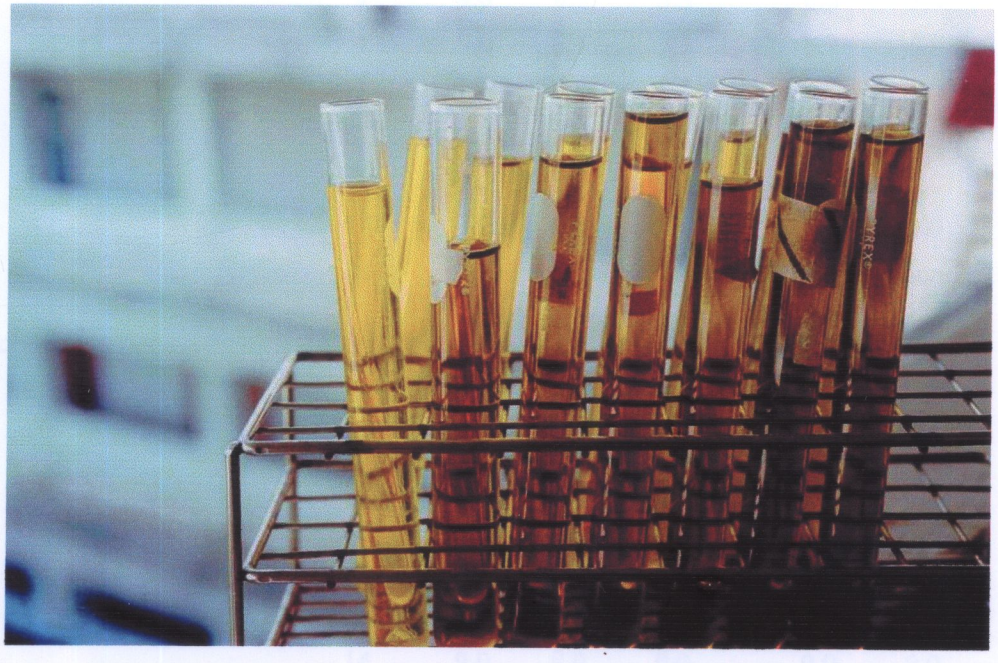


Figure 7 Glucose Production from Cellulose Powder, Filter Paper, Xylan, Lignin and Cellulose on *A. alba* and *R. apiculata* Leaves Degraded by *T. viride* at 15 ppt Salinity as Compare to the Control Bank

Table 19 Growth Rates of Fungi on CMA Containing Different Concentration of Cellulose Powder at 15 and 30 ppt Salinities of Seawater

Species	Time (days)	Growth Rate of Fungi (cm)					
		Salinily 15 ppt			Salinily 30 ppt		
		% Cellulose Powder			% Cellulose Powder		
		0.1	0.2	0.5	0.1	0.2	0.5
Trichoderma hamatum	1	1.7	1.3	0.4	0.7	0.5	0.2
	2	5.9	5.5	3.8	3.3	1.5	0.9
	3	7.5	4.3	4.0	5.0	4.7	2.0
	4	7.9	7.5	5.0	5.5	5.3	2.5
	5	8.0	7.7	5.2	6.5	6.2	3.7
	6	8.5	8.0	5.5	8.0	7.9	5.0
	7	9.0	9.0	5.7	9.0	8.5	6.5
	14	9.0	9.0	9.0	9.0	9.0	9.0
	21	Changed CMA to Yellownish Brown					
Trichoderma koningii	1	2.7	1.8	1.5	1.1	0.4	0.1
	2	6.3	5.2	4.5	3.6	2.2	0.2
	3	9.0	6.5	5.5	6.0	3.4	2.5
	4	9.0	8.5	7.5	8.2	5.8	5.5
	5	9.0	9.0	8.5	9.0	6.7	6.0
	6	9.0	9.0	9.0	9.0	7.0	7.0
	7	9.0	9.0	9.0	9.0	8.0	7.5
	14	9.0	9.0	9.0	9.0	9.0	9.0
	21	Changed CMA to Greenish Brown					
Trichoderma polysporum	1	3.1	2.9	2.6	1.2	0.7	0.6
	2	6.2	5.6	4.1	4.6	2.5	1.1
	3	9.0	9.0	8.5	7.0	3.5	2.7
	4	9.0	9.0	9.0	8.5	7.5	4.0
	5	9.0	9.0	9.0	9.0	6.9	4.6
	6	9.0	9.0	9.0	9.0	7.8	4.7
	7	9.0	9.0	9.0	9.0	8.2	5.0
	14	9.0	9.0	9.0	9.0	9.0	9.0
	21	No Changed CMA					

Table 19 (contd.)

Species	Time (days)	Growth Rate of Fungi (cm)					
		Salinily 15 ppt			Salinily 30 ppt		
		% Cellulose Powder			% Cellulose Powder		
		0.1	0.2	0.5	0.1	0.2	0.5
Trichoderma pseudokoningii	1	2.5	2.0	1.8	1.2	0.9	0.8
	2	5.6	5.0	4.5	3.7	2.0	1.0
	3	8.5	7.1	6.4	4.5	4.0	3.5
	4	9.0	8.2	7.5	7.5	6.8	5.9
	5	9.0	9.0	8.0	8.1	7.4	6.3
	6	9.0	9.0	9.0	8.5	8.0	6.8
	7	9.0	9.0	9.0	8.6	8.2	7.4
	14	9.0	9.0	9.0	9.0	9.0	9.0
	21	9.0	9.0	9.0	9.0	9.0	9.0
Trichoderma harzianum	1	2.7	2.6	2.5	1.6	0.6	0.1
	2	6.3	5.7	4.6	4.2	0.7	0.3
	3	9.0	9.0	8.5	6.5	2.8	2.7
	4	9.0	9.0	9.0	8.0	5.5	4.3
	5	9.0	9.0	9.0	9.0	7.0	6.5
	6	9.0	9.0	9.0	9.0	7.5	7.0
	7	9.0	9.0	9.0	9.0	8.5	8.0
	14	9.0	9.0	9.0	9.0	9.0	9.0
	21	No Changed CMA					
Trichoderma viride	1	3.1	2.8	2.5	2.1	0.9	0.5
	2	6.2	5.7	4.2	4.2	2.5	2.2
	3	9.0	8.5	8.0	7.0	3.5	2.7
	4	9.0	9.0	9.0	8.5	7.0	6.0
	5	9.0	9.0	9.0	9.0	7.5	6.1
	6	9.0	9.0	9.0	9.0	7.6	6.2
	7	9.0	9.0	9.0	9.0	8.0	6.5
	14	9.0	9.0	9.0	9.0	9.0	9.0
	21	Changed CMA to Yellow					

Table 19 (contd.)

Species	Time (days)	Growth Rate of Fungi (cm)					
		Salinily 15 ppt			Salinily 30 ppt		
		% Cellulose Powder			% Cellulose Powder		
		0.1	0.2	0.5	0.1	0.2	0.5
Aspergillus ustus	1	0.4	0.4	0.3	0.3	0.2	0.1
	2	1.2	1.1	0.9	0.9	0.5	0.4
	3	2.5	2.0	1.5	2.5	2.2	1.0
	4	4.0	3.1	2.7	3.5	3.0	1.0
	5	4.5	3.5	3.0	4.0	3.5	1.1
	6	4.7	4.0	3.5	4.3	3.7	1.2
	7	5.2	4.5	4.0	4.5	4.0	1.3
	14	9.0	9.0	9.0	8.2	7.0	5.0
	21	9.0	9.0	9.0	9.0	9.0	9.0
Aspergillus niger	1	1.5	1.0	0.8	0.6	0.5	0.3
	2	2.8	1.8	1.2	1.2	0.9	0.5
	3	4.5	3.0	2.1	3.4	2.5	2.0
	4	6.8	5.0	4.1	5.7	3.7	3.1
	5	8.5	6.1	5.9	7.5	4.5	3.9
	6	9.0	8.5	6.8	8.5	5.6	4.5
	7	9.0	8.5	6.8	9.0	7.5	6.1
	14	9.0	9.0	8.5	9.0	9.0	9.0
	21	9.0	9.0	9.0	9.0	9.0	9.0
Pestalotiopsis guipinii	1	2.2	2.0	1.7	1.5	1.2	1.1
	2	4.3	4.2	3.8	2.8	2.6	2.5
	3	5.5	5.0	4.7	4.5	3.5	3.1
	4	7.5	6.4	6.0	5.0	4.2	4.1
	5	8.5	8.0	7.5	6.0	5.5	5.0
	6	9.0	9.0	8.0	6.5	6.3	6.0
	7	9.0	9.0	9.0	9.0	9.0	6.2
	14	Produced Acervuli			No Produced Acervuli		
	21	9.0	9.0	9.0	9.0	9.0	9.0

Table 19 (contd.)

Species	Time (days)	Growth Rate of Fungi (cm)					
		Salinily 15 ppt			Salinily 30 ppt		
		% Cellulose Powder			% Cellulose Powder		
		0.1	0.2	0.5	0.1	0.2	0.5
Rhizoctonia sp.	1	1.1	0.7	0.5	0.7	0.3	0.2
	2	2.7	2.7	1.8	0.9	0.6	0.5
	3	3.5	3.0	2.5	1.8	1.5	1.1
	4	4.5	4.0	3.1	2.8	2.0	1.5
	5	6.0	4.5	3.5	3.0	2.1	2.0
	6	6.5	5.5	4.0	3.7	2.2	2.1
	7	7.0	6.0	5.1	3.2	2.4	2.3
	14	9.0	8.1	7.5	6.5	5.1	4.8
	21	9.0	9.0	9.0	9.0	9.0	9.0
Penicillum sp.	1	0.5	0.3	0.2	0.3	0.2	0.1
	2	0.6	0.5	0.5	0.6	0.4	0.4
	3	2.5	1.5	1.5	1.7	1.5	1.2
	4	3.0	2.5	2.0	2.0	1.5	1.2
	5	3.1	2.8	2.1	2.0	1.5	1.4
	6	3.2	3.0	2.5	2.0	1.5	1.5
	7	3.2	3.2	3.2	2.5	2.1	1.9
	14	3.2	3.2	3.2	3.2	3.2	3.2
	21	Changed CMA to Yellownish Green					
Geotrichum sp.	1	1.2	1.1	1.0	0.8	0.7	0.5
	2	2.7	2.5	2.2	1.5	1.4	1.3
	3	4.5	4.0	3.8	3.0	2.9	2.8
	4	5.5	4.5	3.9	5.0	3.1	3.0
	5	5.7	4.6	4.0	5.4	4.0	3.0
	6	5.8	4.8	4.3	5.4	5.0	4.0
	7	7.0	5.0	4.5	6.0	5.5	4.5
	14	9.0	9.0	9.0	8.5	8.5	8.5
	21	9.0	9.0	9.0	9.0	9.0	9.0

Table 20 Growth Rates of Fungi on CMA Containing Different Concentration of Xylan at 15 and 30 ppt Salinity of Seawater

Species	Times (days)	Growth Rates of Fungi (cm)					
		Salinity 15 ppt			Salinity 30 ppt		
		% Xylan			% Xylan		
		0.1	0.2	0.5	0.1	0.2	0.5
Trichoderma hamatum	1	1.2	0.6	0.2	0.6	0.4	0.3
	2	4.1	3.3	2.1	2.8	2.4	2.2
	3	5.1	4.2	3.0	2.9	2.6	2.3
	4	5.9	5.0	4.1	4.1	3.6	3.0
	5	6.5	6.0	5.4	5.5	5.0	3.9
	6	8.0	7.5	6.7	6.0	5.0	4.1
	7	9.0	8.5	7.6	7.5	6.2	5.2
	14	9.0	9.0	9.0	9.0	9.0	9.0
	21	9.0	9.0	9.0	9.0	9.0	9.0
Trichoderma koningii	1	2.0	1.6	1.4	0.2	0.1	0.1
	2	5.5	5.0	4.7	2.0	1.5	1.2
	3	7.5	7.2	7.0	2.1	1.7	1.3
	4	7.5	7.2	7.0	2.1	1.7	1.3
	5	7.5	7.2	7.0	2.1	1.7	1.3
	6	7.5	7.2	7.0	2.1	1.7	1.3
	7	7.5	7.2	7.0	2.1	1.7	1.3
	14			No Changed CMA			
	21	7.5	7.2	7.0	2.1	1.7	1.3
Trichoderma polysporum	1	2.7	2.5	2.4	0.2	0.1	0.1
	2	5.7	5.0	4.8	1.2	0.8	0.4
	3	8.2	7.9	7.5	2.5	1.7	1.0
	4	8.2	7.9	7.5	2.5	1.7	1.0
	5	8.2	7.9	7.5	2.5	1.7	1.0
	6	8.2	7.9	7.5	2.5	1.7	1.0
	7	8.2	7.9	7.5	2.5	1.7	1.0
	14			No Changed CMA			
	21	8.2	7.9	7.5	2.5	1.7	1.0

Table 20 (contd.)

Species	Times (days)	Growth Rates of Fungi (cm)					
		Salinity 15 ppt			Salinity 30 ppt		
		% Xylan			% Xylan		
		0.1	0.2	0.5	0.1	0.2	0.5
Trichoderma pseudokoningii	1	2.1	1.8	1.5	0.2	0.1	0.1
	2	5.2	5.0	4.5	1.5	1.1	1.0
	3	7.0	6.3	5.0	1.8	1.5	1.2
	4	7.2	6.3	5.0	1.8	1.5	1.2
	5	7.2	6.3	5.0	1.8	1.5	1.2
	6	7.2	6.3	5.0	1.8	1.5	1.2
	7	7.2	6.3	5.0	1.8	1.5	1.2
	14	7.2	6.3	5.0	1.8	1.5	1.2
	21	7.2	6.3	5.0	1.8	1.5	1.2
Trichoderma harzianum	1	1.8	1.3	1.1	0.2	0.1	0.1
	2	5.5	5.1	5.0	0.5	0.3	0.2
	3	8.5	7.5	7.2	1.0	0.9	0.5
	4	8.5	7.5	7.2	1.0	0.9	0.5
	5	8.5	7.5	7.2	1.0	0.9	0.5
	6	8.5	7.5	7.2	1.1	0.9	0.5
	7	8.5	.5	7.2	1.1	0.9	0.5
	14	8.5	7.5	7.2	1.1	0.9	0.5
	21	8.5	7.5	7.2	1.1	0.9	0.5
Trichoderma viride	1	2.5	2.0	1.8	0.2	0.1	0.1
	2	5.4	5.0	4.9	1.0	0.5	0.2
	3	7.8	7.5	7.2	2.0	1.2	0.8
	4	7.8	7.5	7.2	2.0	1.2	0.8
	5	7.8	7.5	7.2	2.0	1.2	0.8
	6	7.8	7.5	7.2	2.0	1.2	0.8
	7	7.8	7.5	7.2	2.0	1.2	0.8
	14	7.8	7.5	7.2	2.0	1.2	0.8
	21	7.8	7.5	7.2	2.0	1.2	0.8

Table 20 (contd.)

Species	Times (days)	Growth Rates of Fungi (cm)					
		Salinity 15 ppt			Salinity 30 ppt		
		% Xylan			% Xylan		
		0.1	0.2	0.5	0.1	0.2	0.5
Aspergillus ustus	1	0.2	0.1	0.05	0.2	0.1	0.05
	2	0.6	0.3	0.1	0.5	0.3	0.1
	3	1.2	1.1	0.9	0.8	0.6	0.3
	4	2.2	2.0	1.5	1.5	1.2	0.8
	5	3.0	2.7	2.5	2.0	1.7	1.2
	6	4.1	4.0	3.5	2.5	2.0	1.5
	7	5.5	5.0	4.0	4.5	3.9	2.8
	14	5.5	5.0	4.0	4.5	3.9	2.8
	21	5.5	5.0	4.0	4.5	3.9	2.8
Aspergillus niger	1	2.1	1.6	1.2	1.0	0.8	0.5
	2	3.5	2.6	1.5	2.4	2.0	1.1
	3	5.1	4.2	3.9	3.5	2.9	2.0
	4	7.5	6.1	5.5	4.2	3.4	2.9
	5	8.6	8.0	7.6	7.0	6.2	4.5
	6	9.0	8.5	8.0	8.0	7.5	7.2
	7	9.0	9.0	9.0	8.2	8.0	7.2
	14	9.0	9.0	9.0	8.2	8.0	7.2
	21	9.0	9.0	9.0	8.2	8.0	7.2
Pestalotiopsis guipinii	1	1.8	1.7	1.5	1.2	1.1	0.8
	2	3.5	3.3	3.0	2.7	2.5	1.5
	3	4.5	4.1	3.9	3.3	3.0	2.1
	4	5.5	5.2	5.0	4.0	3.5	2.9
	5	6.5	5.5	5.2	4.5	4.0	3.5
	6	8.5	8.0	7.5	6.0	5.5	4.4
	7	9.0	8.5	8.1	6.6	5.5	5.0
	14	9.0	9.0	9.0	8.5	8.5	8.5
	21	9.0	9.0	9.0	8.5	8.5	8.5

Table 20 (contd.)

Species	Times (days)	Growth Rates of Fungi (cm)					
		Salinity 15 ppt			Salinity 30 ppt		
		% Xylan			% Xylan		
		0.1	0.2	0.5	0.1	0.2	0.5
Rhizoctonia sp.	1	0.5	0.4	0.3	0.2	0.01	0.05
	2	1.5	1.0	0.9	0.6	0.3	0.1
	3	3.1	2.5	2.0	0.8	0.5	0.3
	4	3.1	2.5	2.0	0.8	0.5	0.3
	5	3.1	2.5	2.0	0.8	0.5	0.3
	6	3.1	2.5	2.0	0.8	0.5	0.3
	7	3.1	2.5	2.0	0.8	0.5	0.3
	14	3.1	2.5	2.0	0.8	0.5	0.3
	21	Changed CMA to Black					
Penicillium sp.	1	0.2	0.1	0.1	0.1	0.005	0
	2	0.4	0.3	0.2	0.5	0.1	0.1
	3	1.2	0.9	0.7	0.8	0.4	0.2
	4	3.2	2.7	2.1	2.5	2.0	1.4
	5	3.9	3.0	2.5	2.6	2.1	1.5
	6	4.2	3.5	3.0	2.9	2.1	1.7
	7	4.5	4.0	3.1	3.0	2.1	2.0
	14	4.5	4.0	3.1	3.0	2.1	2.0
	21	4.5	4.0	3.1	3.0	2.1	2.0
Geotrichum sp.	1	0.8	0.5	0.3	0.1	0.1	0
	2	1.8	1.4	1.1	0.5	0.2	0.1
	3	3.1	2.5	1.8	1.0	0.5	0.2
	4	3.9	2.8	2.0	2.1	1.7	1.0
	5	4.2	2.9	2.2	2.9	2.0	1.5
	6	4.2	2.9	2.2	2.9	2.0	1.5
	7	4.2	2.9	2.2	2.9	2.0	1.5
	14	4.2	2.9	2.2	2.9	2.0	1.5
	21	4.2	2.9	2.2	2.9	2.0	1.5

Methods for Investigation on Decomposition of Cellulose Powder, Filter Paper, Xylan, Lignin, *R. apiculata* Leaves and *A. alba* Leaves in Terms of Glucose Detected by 12 Fungal Crude Enzyme from Different Ages at 15 and 30 ppt Salinities

There are several groups of fungi, such as lower fungi (Zygomycota), higher fungi (Ascomycota, Deuteromycota.). The majority of these fungi were saprotroph (Kohlmeyer and Volkmann- Kohlmeyer, 1989). This experiment included 12 fungi in the genera *Trichoderma, Aspergillus, Penicillium, Geotrichum, Pestalotiopsis*, and *Rhizoctonia.* Most of the fungi, except *Penicillium* sp. were mostly verified as brown rot and could decompose leaf components such as cellulose, xylan, and lignin into glucose when cultured on CMA at salinity 15 ppt. While *Penicillium* sp. was a white rot fungus (Table 18).

Table 24 indicated that the fungal transformation of leaf components of *R. alba* into glucose was found best efficacy in the genera *Trichoderma,* followed by *Aspergillus, Penicillium, Geotrichum, Rhizoctonia* and *Pestalotiopsis* respectively. For *A. alba* leaf, it was found that *Trichoderma* was the best efficacy genera followed by *Rhizoctonia, Penicillium, Pestalotiopsis, Aspergillus,* and *Geotrichum.* In comparison with decomposition of *A. alba* and *R. apiculata* leaf litters, it was found that *A. alba* leaf litters were decomposed better than *R. apiculata* leaf litters. The reason was that *A. alba* leaf litters contained cellulose less than *R. apiculata* leaf litters, but by way of the decomposition *A. alba* leaf litters produced higher amounts of glucose concentration more than *R. apiculata* leaf litters (Table 21, 22). Table 21 to 22 also showed that fungal crude enzymes could decompose the leaf components at salinity concentration of 15 ppt faster than that salinity concentration of 30 ppt. Table 23 showed the activity of fungal crude enzyme capable of decomposing cellulose powder, xylan and lignin. Among them, *Trichoderma* spp. were the best effecacy genera.

The crude enzyme from 11 brown rot fungi incubated for 14-21 days in CMA at 15 ppt salinity decomposed leaf components faster than 30 ppt salinity when incubated in the same period of time. *Penicillium* sp. on the other hand, which was verified as white rot fungi, could decompose leaf components well when incubated for 7 days (Figure 8-19).

Within the estuary there were a range of chemical, physical and biological factors that controlled the distribution, activities and abundance of fungal inhabitants. The salinity in estuaries was recorded between 5-37 ppt. The pH of seawater was in the range of 7.5 to 8.4 which was the same data recorded by Aksornkoae (1999). The temperature of seawater was depended on the depth, the season and the time of days and also affected by some factors such as the upwelling of currents. All of these factors, the salinity, pH and temperature of the seawater would certainly influence the activity, abundance and distribution of fungi. The important environmental factors influenced the enzyme activity of the fungi in decomposing leaf litters were 1.) type of fungal species, 2.) type of leaf components, 3.) surface areas of leaf components, 4.) growth stages of fungi, and 5.) salinity concentration of media respectively (Figure 7 - 19).

Table 21 Decomposition of Cellulose Powder, Filter Paper, *Rhizophora apiculata* Leaf and *Avicennia alba* Leaf Litters, Xylan and Lignin in Terms of Glucose Detected by 12 Fungal Crude Enzyme from Different Ages at 15 ppt Salinity

Fungal species Producing Crude Enzyme	Age (days)	Amount of glucose (mg/ml) Cellulose paper	Filter paper	*R.apiculata* Leaf	*A. alba* Leaf	Xylan	Lignin
Trichoderma koningii	7	2389.4	1959.9	2356.4	2314.1	1975.64	2277.5
	14	2554.7	2098.8	2566.6	2880.4	1300.2	1322.2
	21	1744.4	1793.9	2870.2	2701.7	1683.4	1874.7
	28	1400.5	1106.3	2087.4	1673.3	1648.0	1557.1
Trichoderma polysporum	7	1539.4	963.64	1466.2	1505.3	1011.6	1365.8
	14	1244.6	731.31	800.76	1324.1	1034.4	1190.3
	21	2095.0	1866.5	2215.0	2269.9	2646.5	2414.5
	28	1655.6	1570.4	2143.0	2384.0	1704.8	2183.8
Trichoderma hamatum	7	231.92	228.13	761.61	793.81	207.29	1038.1
	14	944.07	538.12	1428.9	631.56	627.7	1051.8
	21	1278.1	1226.9	1709.3	1778.1	1060.2	1373.04
	28	655.5	581.01	1057.7	990.89	572.21	1041.3
Trichoderma pseudokoningii	7	582.94	303.26	589.10	815.91	657.44	702.27
	14	489.50	261.59	1091.2	588.63	1274.5	1250.3
	21	1805.2	1079.2	1720.6	1968.1	298.21	1047.0
	28	935.87	838.64	1231.3	1409.4	949.76	1327.3
Trichoderma harzianum	7	156.79	142.90	1290.1	821.59	155.52	1201.0
	14	536.67	328.60	1039.5	878.49	255.94	136.15
	21	1199.8	1186.5	1507.0	1309.6	948.0	1473.8
	28	708.58	570.95	859.47	1029.5	646.71	678.9
Trichoderma viride	7	163.73	140.37	1817.8	373.19	295.65	212.7
	14	1384.30	1189.81	1615.47	1988.27	1169.34	1827.2
	21	2278.1	645.45	1691.0	2110.8	1449.1	2357.7
	28	464.25	255.91	875.89	520.44	258.43	552.01
Aspergillus ustus	7	173.20	127.74	499.61	391.01	157.42	253.38
	14	1758.5	1190.3	1661.9	1507.2	745.2	1653.7
	21	407.43	306.41	567.16	1691.0	308.31	526.12
	28	511.60	248.33	952.28	969.96	257.8	344.93

Table 21 (contd.)

Fungal species Producing Crude Enzyme	Age (days)	Amount of glucose (mg/ml) Cellulose paper	Filter paper	*R.apiculata* Leaf	*A. alba* Leaf	Xylan	Lignin
Aspergillus niger	7	132.16	97.43	228.13	870.21	110.7	438.37
	14	2365.2	1883.5	2089.3	1981.4	1017.3	1838.7
	21	369.55	168.15	747.49	901.77	134.06	315.25
	28	252.12	145.42	635.34	610.72	187.72	372.71
Pestalotiopsis guipinii	7	199.89	164.41	144.48	199.10	180.09	161.82
	14	522.33	202.87	784.34	536.86	549.9	511.6
	21	717.42	305.78	1290.1	627.18	363.24	1120.8
	28	288.76	135.95	542.54	473.76	179.51	637.87
Rhizoctonia sp.	7	644.83	201.45	1053.8	902.44	408.69	639.05
	14	1107.6	1002.8	1600.0	1609.5	996.47	1036.9
	21	1529.3	1156.8	1803.3	673.23	1511.0	961.75
	28	2011.0	1740.2	2249.7	2478.9	1765.5	2446.7
Penicillium sp.	7	704.16	396.7	721.21	1251.2	238.86	598.0
	14	713.63	540.01	1046.4	993.32	629.66	706.06
	21	543.80	271.06	1336.1	1154.9	430.79	644.18
	28	397.33	426.37	975.64	894.20	426.37	872.10
Geotrichum sp.	7	108.9	55.77	283.1	213.84	42.8	183.9
	14	114.49	131.53	176.99	355.66	93.70	416.27
	21	864.52	438.37	657.44	928.92	709.84	1045.1
	28	152.05	128.37	358.18	496.45	223.71	313.99

Table 22 Decomposition of Cellulose Powder, Filter Paper, *Rhizophora apiculata* Leaf and *Avicennia alba* Leaf Litters, Xylan and Lignin in Terms of Glucose Detected by 12 Fungal Crude Enzyme from Different Ages at 30 ppt Salinity

Fungal species Producing Crude Enzyme	Age (days)	Amount of glucose (mg/ml) Cellulose paper	Filter paper	*R.apiculata* Leaf	*A. alba* Leaf	Xylan	Lignin
Trichoderma koningii	7	1756.6	1449.1	1778.7	1873.4	369.55	704.16
	14	1939.59	1464.01	2227.6	1663.2	456.58	1251.7
	21	1334.9	1153.0	1664.65	1689.0	1449.1	1674.5
	28	1323.5	1084.2	1600.0	1871.5	1173.3	1386.0
Trichoderma polysporum	7	663.12	412.48	1089.3	733.84	474.35	868.31
	14	682.06	224.34	1178.9	564.63	118.27	1051.4
	21	1634.8	1395.5	2608.9	1799.5	389.8	1979.5
	28	532.2	389.5	1063.2	632.1	132.4	1200.2
Trichoderma hamatum	7	187.72	135.32	611.99	589.26	109.43	534.33
	14	380.28	145.42	983.22	144.46	249.21	775.50
	21	1232.6	1108.9	2073.6	1795.8	1270.5	1416.3
	28	660.60	466.78	608.20	1023.0	453.52	598.10
Trichoderma pseudokoningii	7	150.47	136.58	564.0	612.2	125.22	1040.0
	14	779.92	312.73	776.14	1059.0	416.27	739.52
	21	1166.9	988.9	1611.41	1963.1	953.54	1080.4
	28	1067.2	944.07	1487.1	1386.6	916.93	1275.5
Trichoderma harzianum	7	110.63	115.58	791.80	465.66	142.92	683.64
	14	151.10	125.22	814.65	589.26	151.1	353.76
	21	1019.2	877.78	1048.2	1312.8	1066.6	665.02
	28	553.90	403.64	1267.3	796.97	452.89	663.76
Trichoderma viride	7	194.28	124.59	393.53	681.43	112.59	348.08
	14	1264.20	1142.92	1106.5	1486.3	1142.0	1156.8
	21	1458.0	2003.5	1605.1	2391.7	1816.6	1636.0
	28	444.05	317.15	1077.3	564.63	329.77	1164.4
Aspergillus ustus	7	168.15	109.43	232.55	656.80	118.27	427.1
	14	1279.27	947.07	758.46	605.67	512.34	1414.9
	21	377.76	163.73	668.18	563.37	310.83	414.37
	28	430.16	287.47	1040.0	760.35	238.23	279.27

Table 22 (contd.)

Fungal species Producing Crude Enzyme	Age (days)	Amount of glucose (mg/ml) Cellulose paper	Filter paper	*R.apiculata* Leaf	*A. alba* Leaf	Xylan	Lignin
Aspergillus niger	7	116.38	105.01	182.67	304.52	110.7	38.54
	14	740.15	399.85	747.09	783.71	301.99	620.82
	21	235.70	167.52	465.51	672.59	176.99	387.86
	28	242.02	135.16	339.24	428.26	151.73	583.57
Pestalotiopsis guipinii	7	157.9	100.7	121.41	188.10	122.85	155.36
	14	277.27	120.17	382.81	408.69	222.45	943.44
	21	497.79	205.4	343.03	668.81	257.17	411.22
	28	197.82	101.86	384.70	466.14	142.9	197.82
Rhizoctonia sp.	7	354.20	363.28	449.97	433.46	378.97	544.1
	14	1089.3	977.53	2150.6	1592.5	981.32	1601.3
	21	1352.6	1160.6	1350.0	1607.0	2501.0	1502.2
	28	1854.1	1500.9	1497.8	1268.0	1331.7	3333.7
Penicillium sp.	7	466.06	206.19	401.26	666.04	97.43	395.48
	14	598.10	392.91	718.68	887.25	473.09	628.4
	21	445.94	299.47	716.79	626.51	228.76	372.71
	28	209.82	154.26	434.58	552.01	290.63	357.55
Geotrichum sp.	7	88.90	79.27	32.8	257.6	22.28	110.1
	14	100.2	70.56	354.2	500.1	135.45	351.8
	21	680.17	322.2	603.78	449.10	466.78	829.17
	28	122.05	100.37	258.18	396.45	253.71	413.99

Table 23 Activities of Fungal Species Capable of Degrading Cellulose Powder, Xylan and Lignin

Activities	Components		
	Cellulose Powder	Xylan	Lignin
1	*Trichoderma viride*	*Trichoderma polysporum*	*Trichoderma polysporum*
2	*Trichoderma polysporum*	*Trichoderma koningii*	*Trichoderma viride*
3	*Trichoderma pseudokoningii*	*Rhizoctonia* sp.	*Trichoderma koningii*
4	*Trichoderma koningii*	*Trichoderma viride*	*Trichoderma harzianum*
5	*Rhizoctonia* sp.	*Trichoderma hamatum*	*Trichoderma hamatum*
6	*Trichoderma hamatum*	*Trichoderma harzianum*	*Pestalotiopsis guipinii*
7	*Trichodrma harzianum*	*Geotrichum* sp.	*Trichoderma pseudokoningii*
8	*Geotrichum* sp.	*Penicillium* sp.	*Geotrichum* sp.
9	*Pestalotiopsis guipinii*	*Pestalotiopsis guipinii*	*Rhizoctonia* sp.
10	*Penicillium* sp.	*Aspergillus ustus*	*Penicillium* sp.
11	*Aspergillius ustus*	*Trichoderma pseudokoningii*	*Aspergillus ustus*
12	*Aspergillus niger*	*Aspergillus niger*	*Aspergillus niger*

Table 24 Activities of Fungal Species Capable of Degrading Cellulose on *R. apiculata* and *A. alba* Leaves

Activities	*R. apiculata* Leaf	*A. alba* Leaf
1	*Trichoderma koningii*	*Trichoderma koningii*
2	*Trichoderma polysporum*	*Trichoderma polysporum*
3	*Trichoderma viride*	*Trichoderma viride*
4	*Trichoderma pseudokoningii*	*Trichoderma pseudokoningii*
5	*Rhizoctonia* sp.	*Trichoderma hamatum*
6	*Trichoderma hamatum*	*Aspergillius ustus*
7	*Penicillium* sp.	*Trichoderma harzianum*
8	*Trichoderma harzianum*	*Penicillium* sp.
9	*Pestalotiopsis guipinii*	*Geotrichum* sp.
10	*Aspergillus niger*	*Aspergillus niger*
11	*Geotrichum* sp.	*Rhizoctonia* sp.
12	*Aspergillius ustus*	*Pestalotiopsis guipinii*

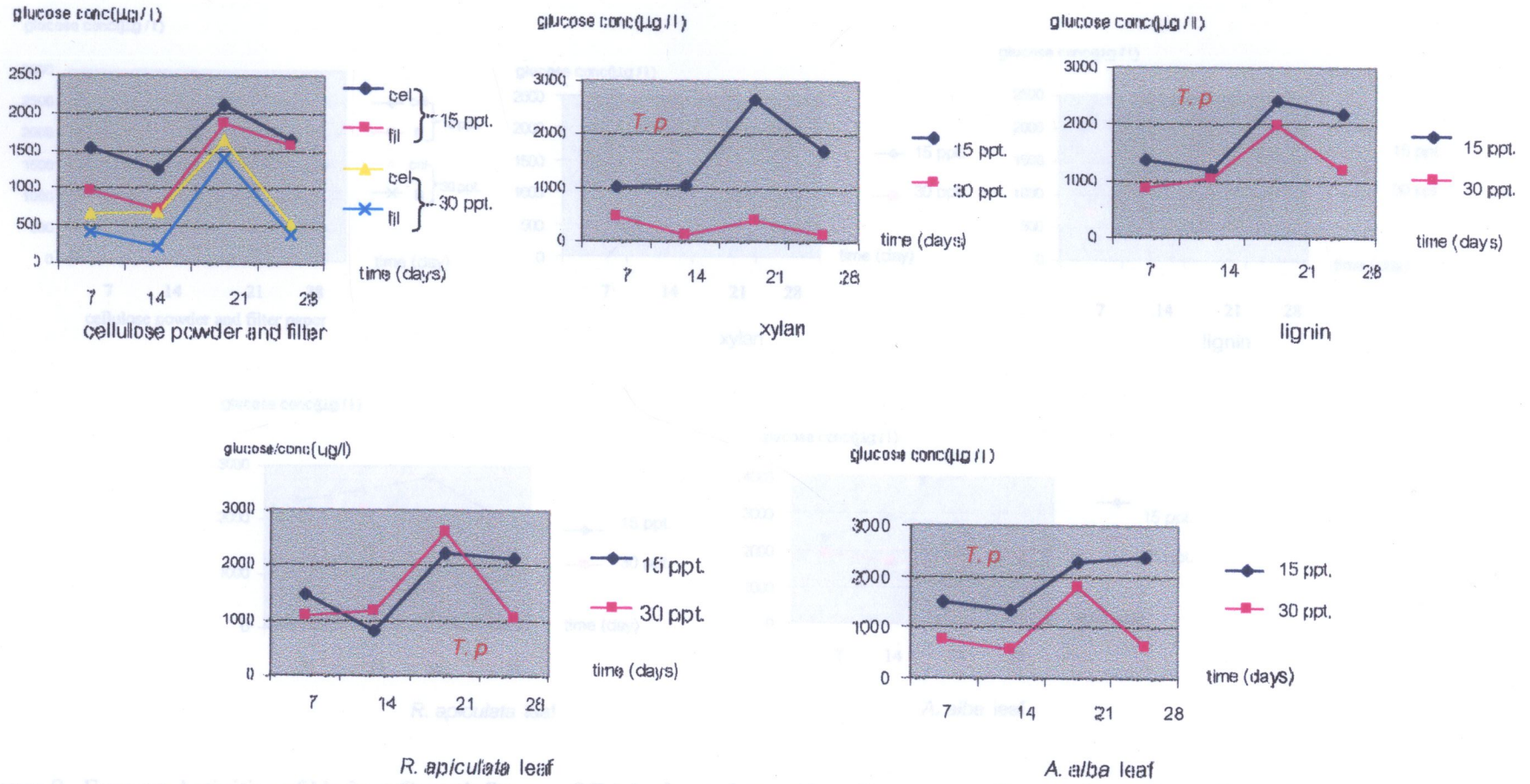


Figure 8 Enzyme Activities of Various Growth Stages of *Trichoderma polysporum* to Decompose *R apiculata* and *A. alba* leaf components

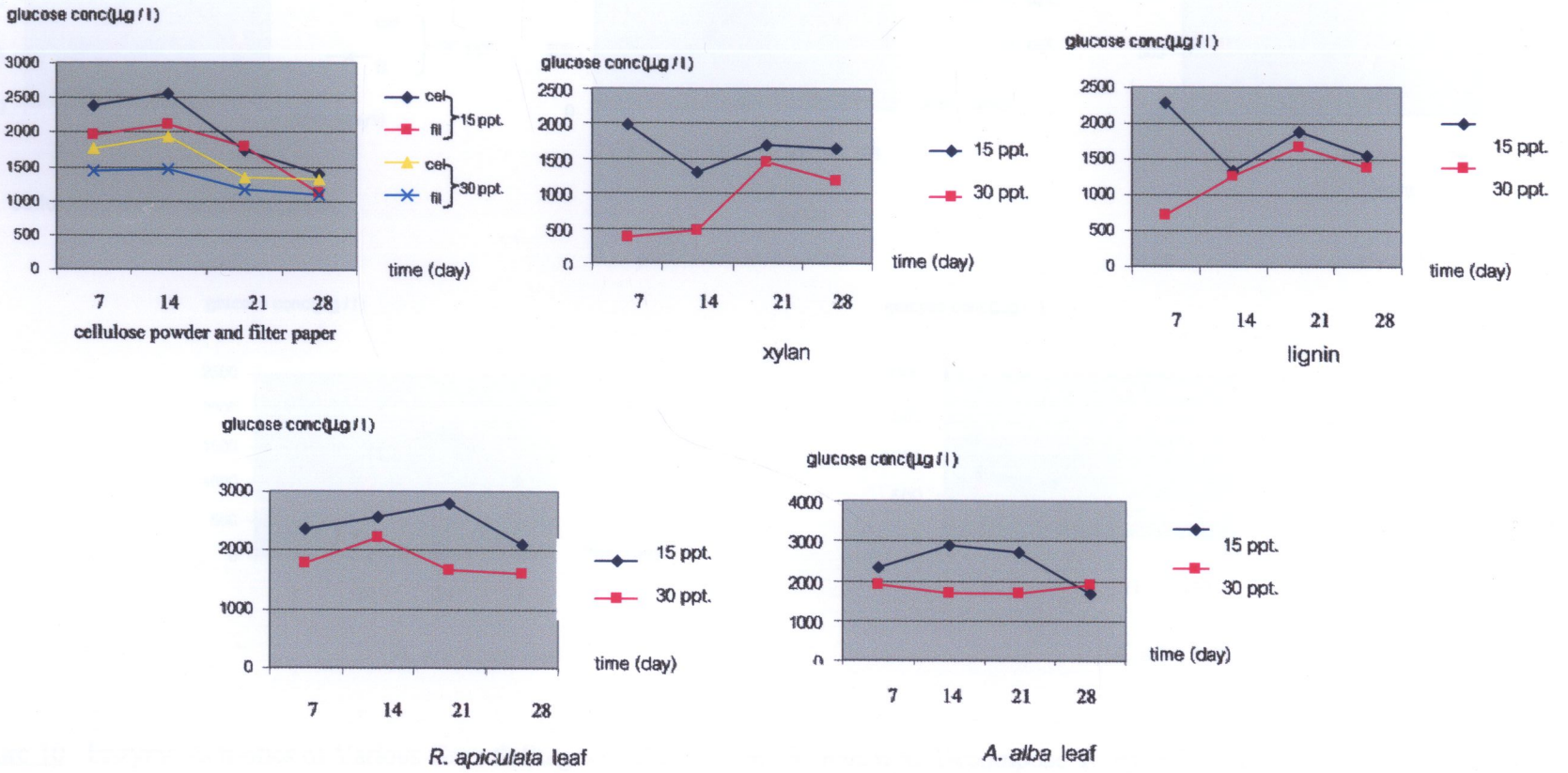


Figure 9 Enzyme Activities of Various Growth Stages of *Trichoderma koningii* to Decompose *R. apiculata* and *A. alba* leaf components

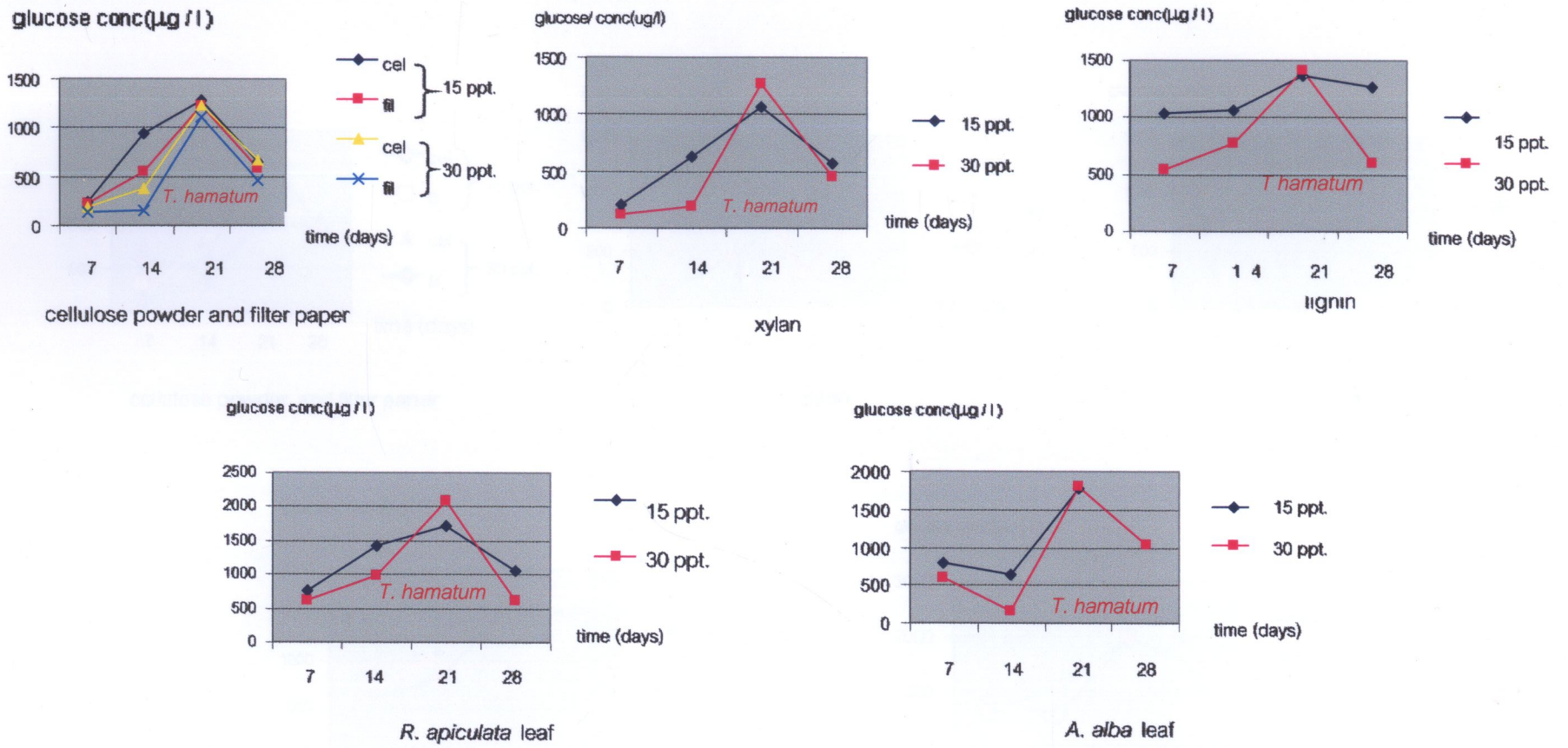


Figure 10 Enzyme Activities of Various Growth Stages of *Trichoderma hamatum* to Decompose *R. apiculata* and *A. alba* leaf components

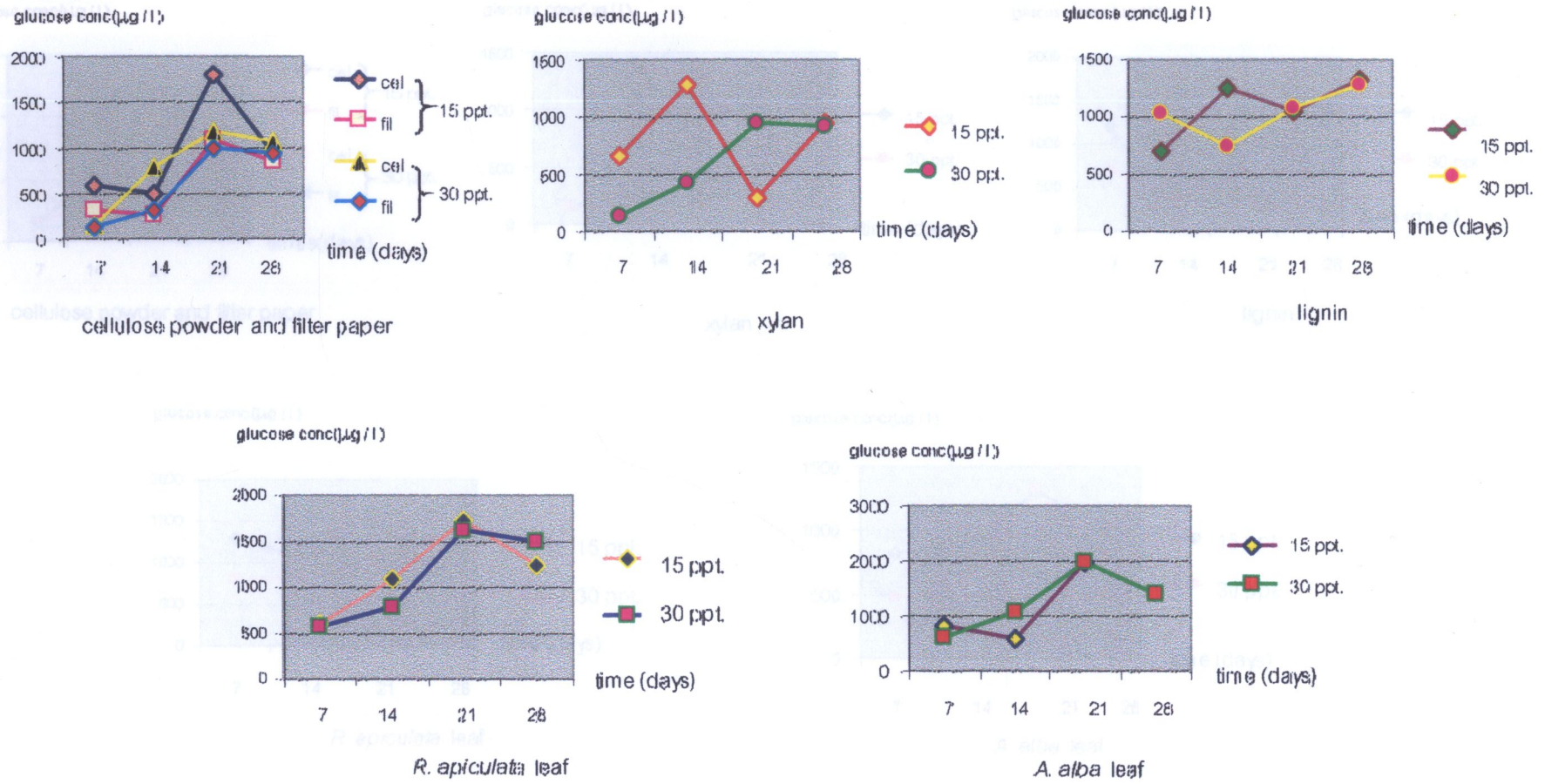


Figure 11 Enzyme Activities of Various Growth Stages of *Trichoderma pseudosporum* to Decompose *R apiculata* and *A. alba* leaf components

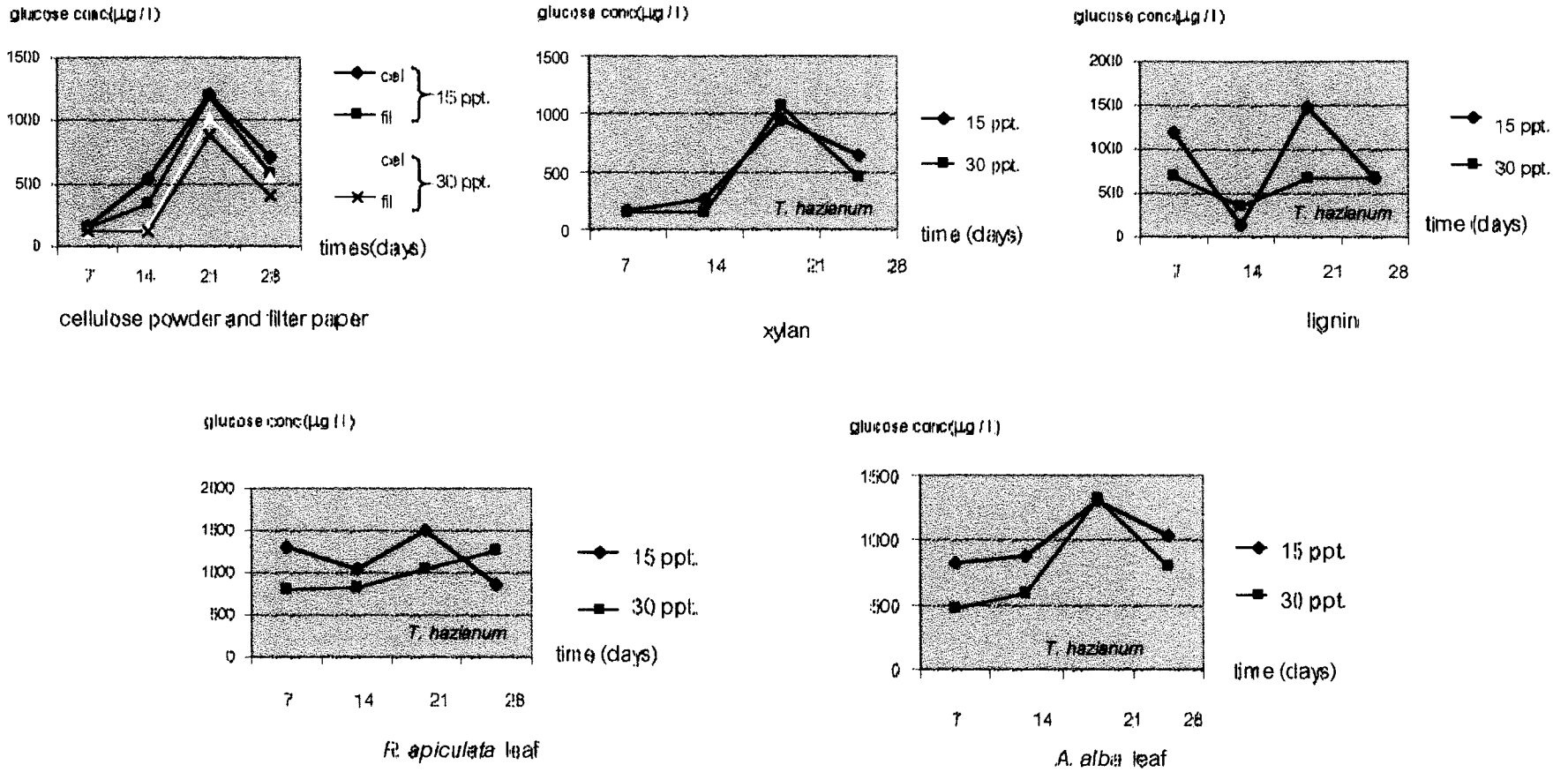


Figure12 Enzyme Activities of Various Growth Stage of *Trichoderma haziamun* to Decompose *R. apiculata* and *A. alba* leaves components

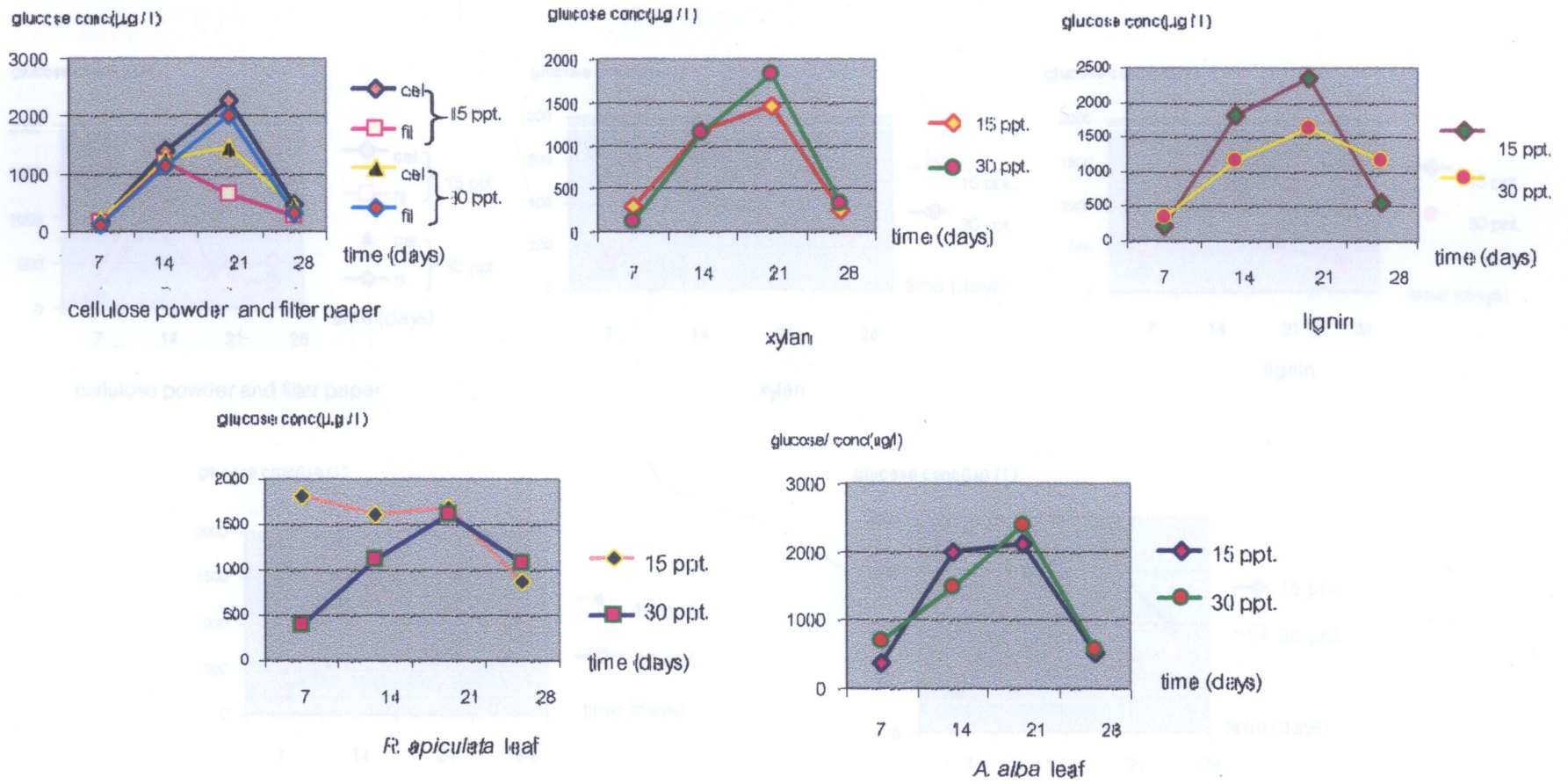


Figure 13 Enzyme Activities of Various Growth Stages of *Trichoderma viride* to Decompose *R. apiculata* and *A. alba* leaf components

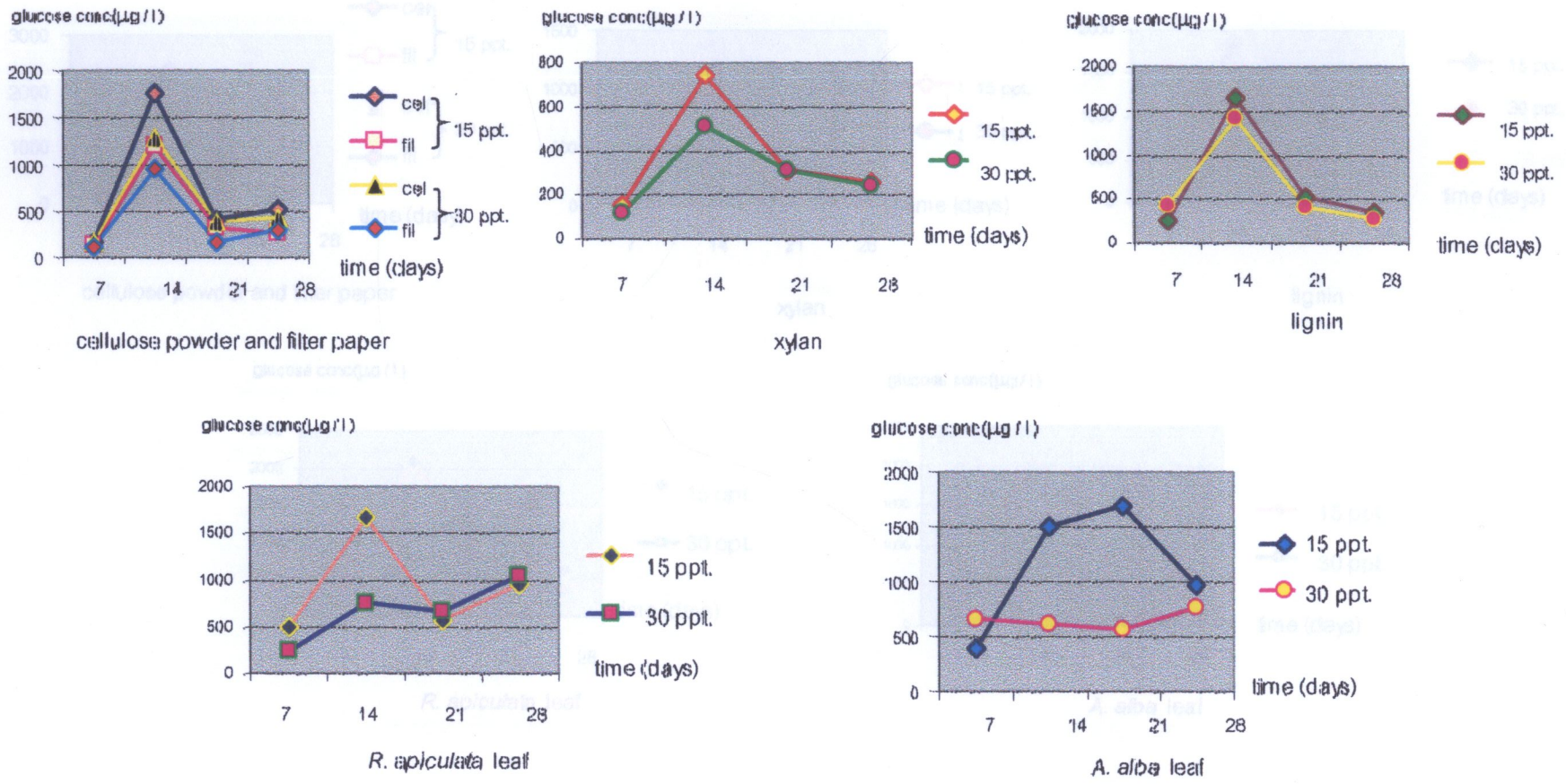


Figure 14 Enzyme Activities of Various Growth Stages of *Aspergillus ustus* to Decompose *R. apiculata* and *A. alba* leaf components

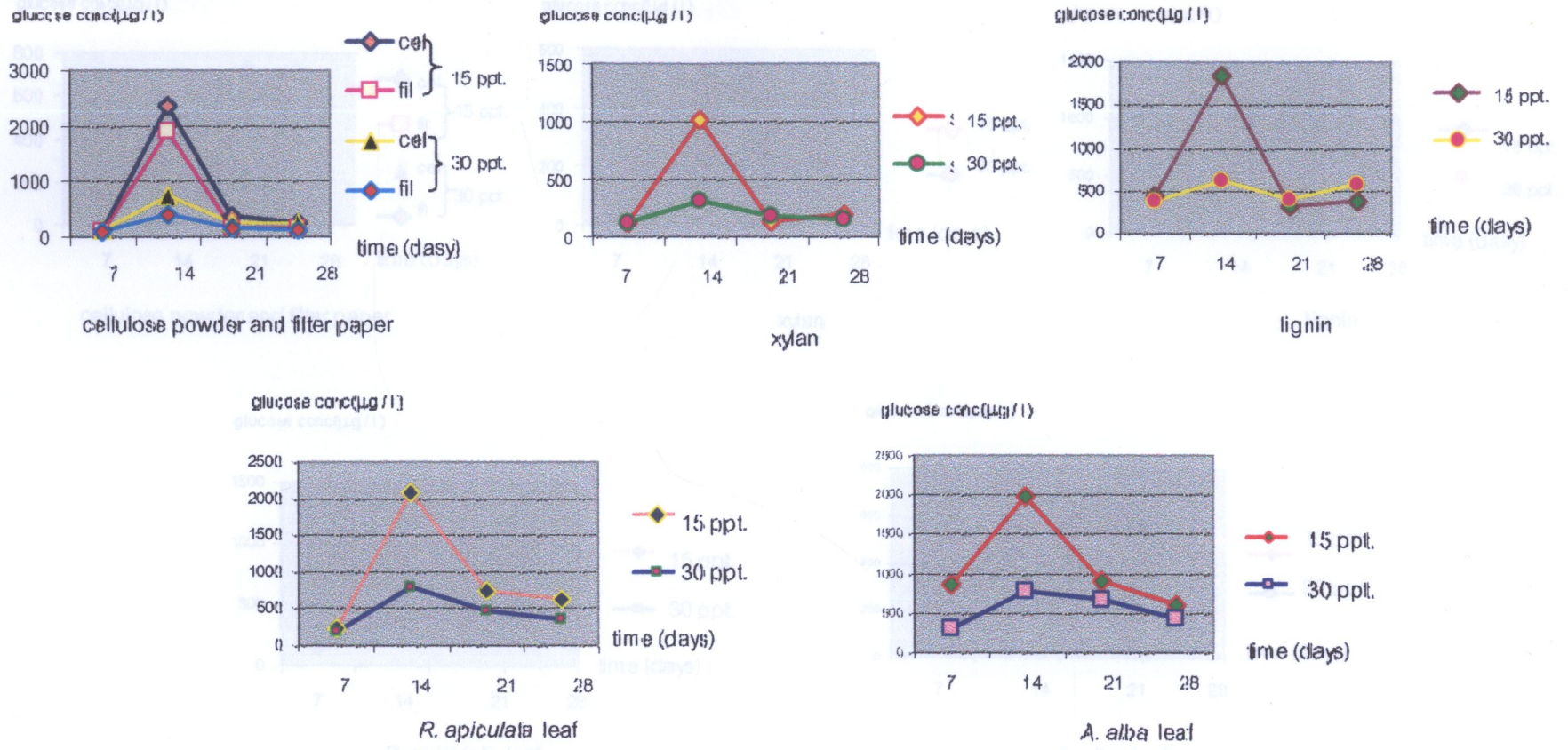


Figure 15 Enzyme Activities of Various Growth Stages of *Aspergillus niger* to Decompose *R. apiculata* and *A. alba* leaf components

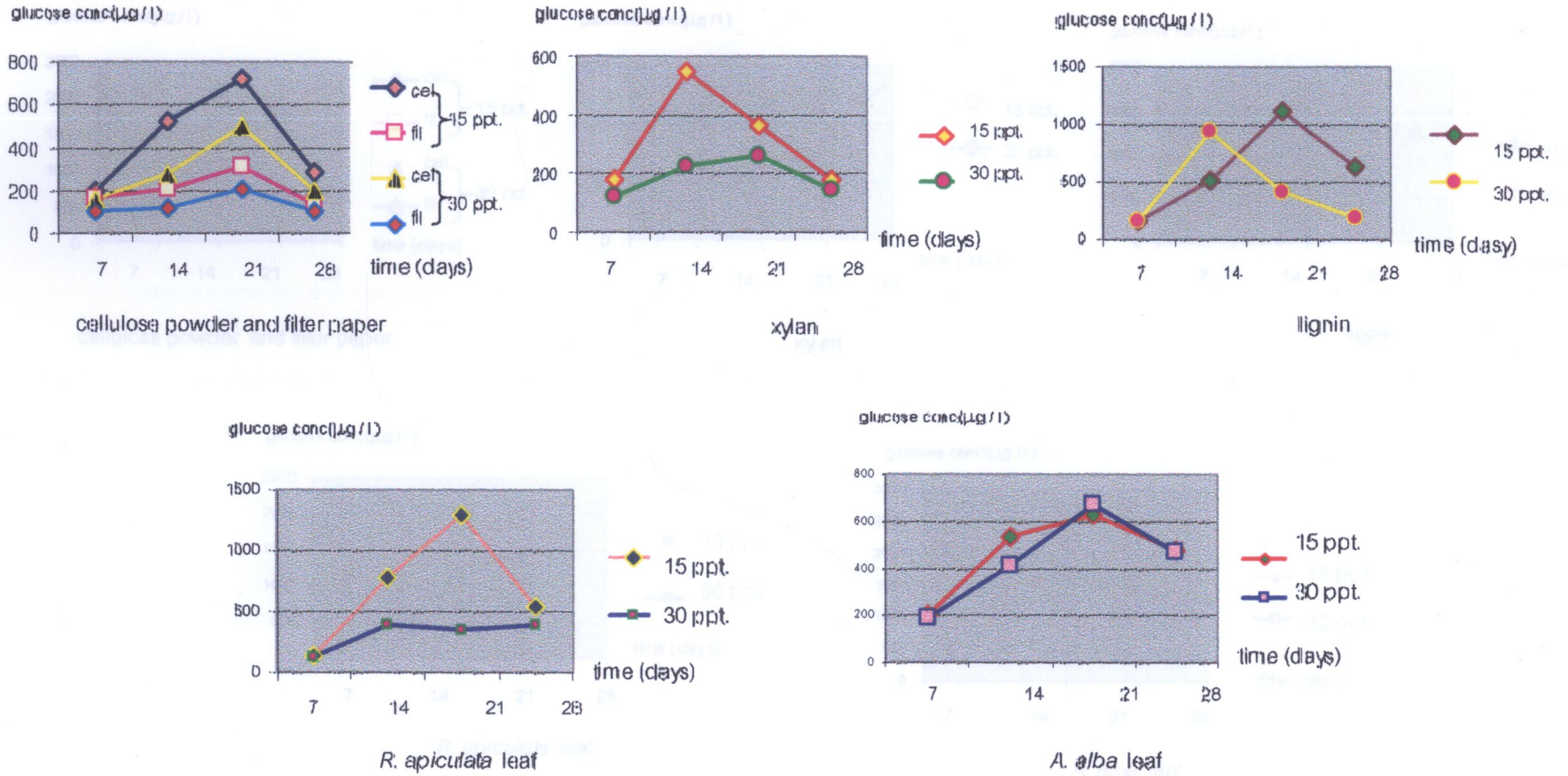


Figure 16 Enzyme Activities of Various Growth Stages of *Pestalotiopsis guiepinii* to Decompose *R. apiculata* and *A. alba* leaf components

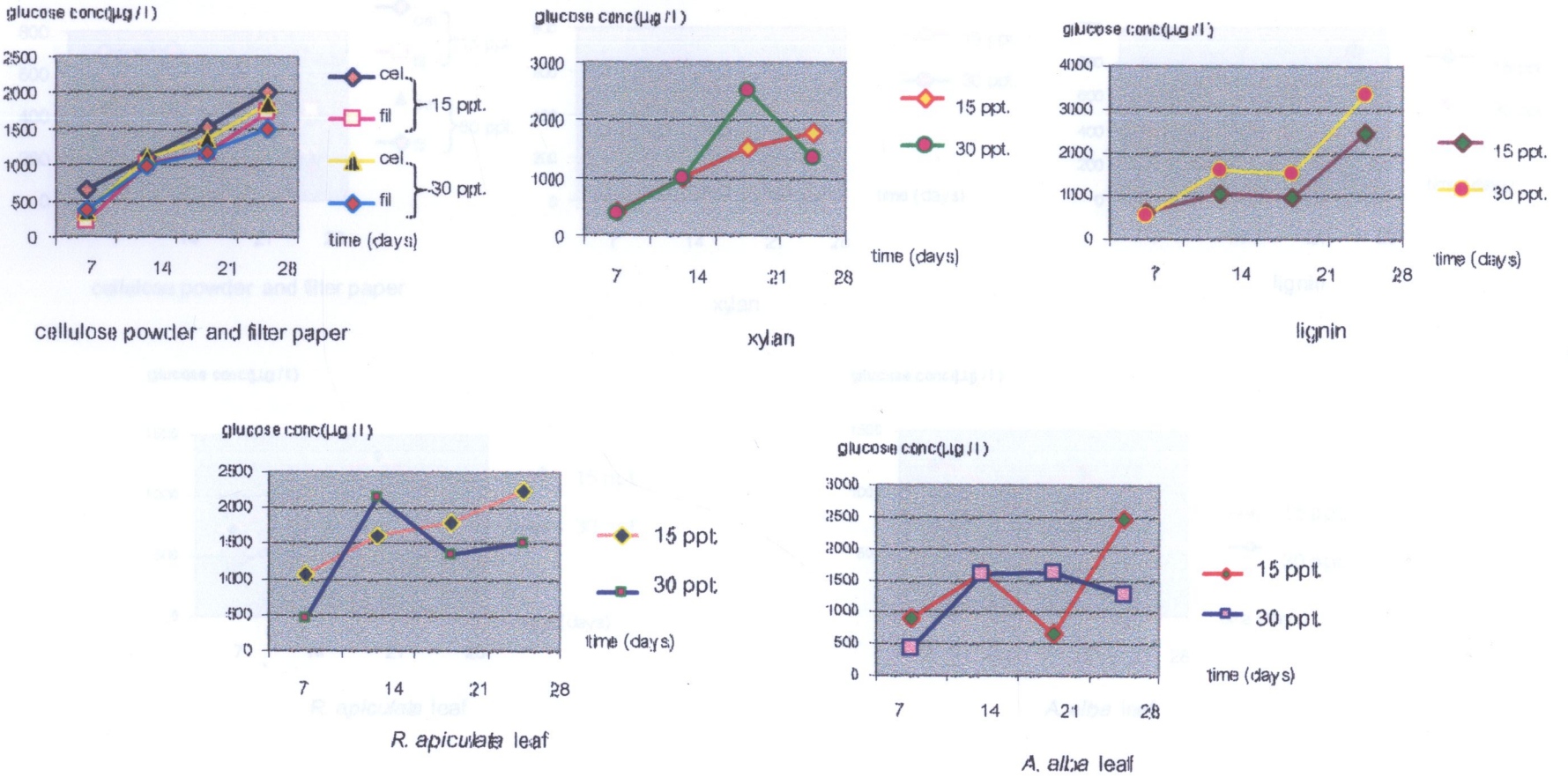


Figure 17 Enzyme Activities of Various Growth Stages of *Rhizoctonia sp.* to Decompose *R. apiculata* and *A. alba* leaf components

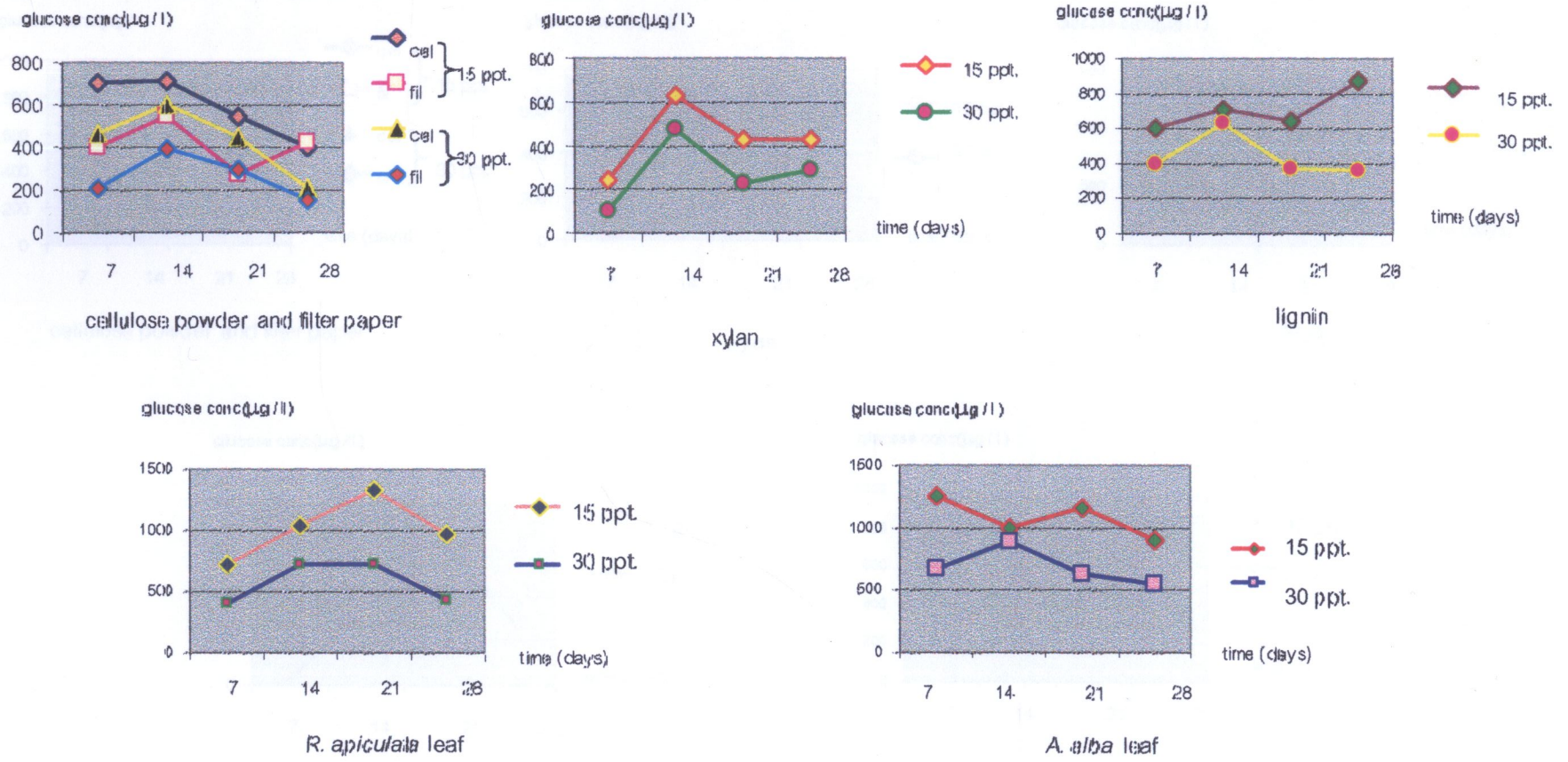


Figure 18 Enzyme Activities of Various Growth Stages of *Penicillium sp.* to Decompose *R. apiculata* and *A. alba* leaf components

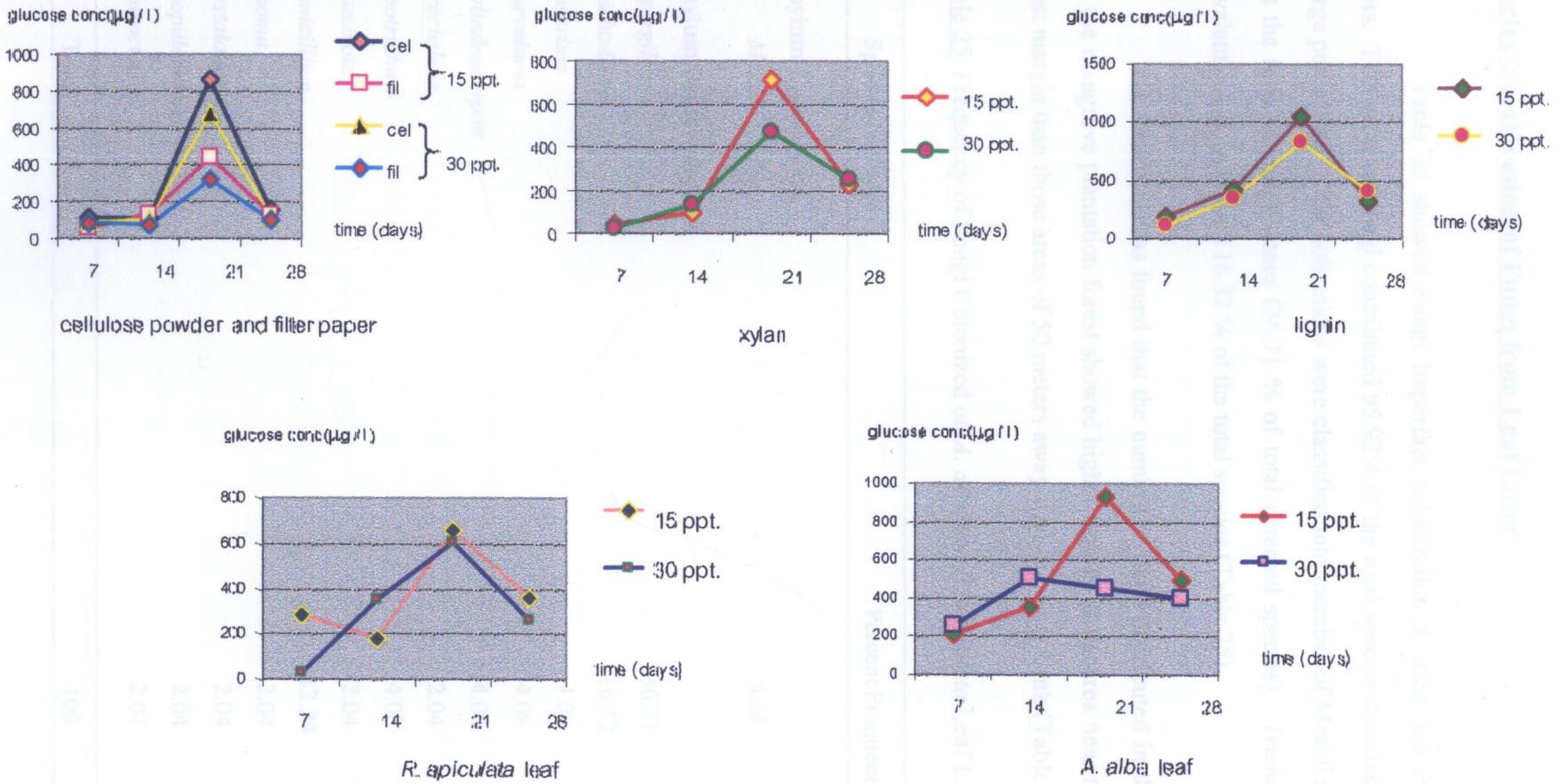


Figure 19 Enzyme Activities of Various Growth Stages of *Geotrichum sp.* to Decompose *R. apiculata* and *A. alba* leaf components

Species Identification of Fungi from Leaf Litter

Table 25 showed Fungi Imperfact colonizedon *A. alba* and *R. apiculata* leaf litters. This group of fungi contributed 95.92% of the total species detected. Among them, a large percentage of the collections were classified into member of Moniliales. *Aspergillus* was the most common genus (36.71 % of total detected species). *Trichoderma*, another prevalent genus, indicated 16.32 % of the total species (Table 25).

However, it was found that the number of fungi distributed in the natural forest and the mangrove plantation forest showed higher density at the area near the river bank or forest margin than those areas of 50 meters away from the river bank (Table 13, 14).

Table 25 Frequency of Fungi Colonized on *A. alba* and *R. apiculata* Leaf Litters

Species of Fungi	Percent Frequency
Phylum Zygomycota	
Mucor	4.08
Phylum Deuteromycota	
Aspergillus	36.71
Trichoderma	16.32
Fusarium	4.08
Curvularia	4.08
Cylindrocarpon	4.08
Drechslera	2.04
Geotrichum	4.08
Humicola	2.04
Penicillium	12.24
Phoma	2.04
Pestalotiopsis	2.04
Scopulariopsis	2.04
Rhizoctonia	2.04
Total	100

Similarity Index of number of fungi colonized on *A. alba* leaf in comparison with different study sites could be discussed as the following. The similarity index between natural mangrove forest (Site I and II) and mangrove plantation was valued 0.33. Regarding to natural mangrove forest. The similarity index between the west oast and east coast of estuary was expressed 0.31. The similarity index of natural mangrove forest between (Site I and II) at forest margin and 50 meters away from the margin was found 0.27. In mangrove plantation, the similarity index between river bank and 50 meters away from the margin was illustrated 0.40.

Similarity Index of number of fungi colonizedon *R. apiculata* leaf in comparison with different study sites could be discussed as the following. The similarity index between natural mangrove forest (Site I and II) and mangrove plantation was shown 0.19. Regarding to natural mangrove forest, the similarity index between the west coast and east coast of estuary was indicated 0.55. The similarity index of natural mangrove forest between (Site I and II) at forest margin and 50 meters away from the margin was revealed 0.28. In mangrove plantation similarity index between river bank and 50 meters away from the margin was demonstrated 0.00.

Details of similarity index of number of fungi in different leaf species and study sites were shown in Table 26.

The biodiversity index of number of fungi colonized on *A. alba* in natural forest (Site I and II) was valued 0.89 while at the area of forest margin and at 50 meters away from the margin were depicted 0.92 and 0.90 respectively. Regarding to mangrove plantation, the biodiversity index was expressed 0.89, and 0.99 at forest margin and 0.85 at 50 meters away from the forest margin. Similarity index in natural forest Site I was showed 0.88 while at the area of forest margin and at 50 meters away from the margin were valued 0.94 and 0.94 respectively. Regarding to natural forest site II, the biodiversity index was implicated 0.72, and 0.91 at forest margin and 0.75 at 50 meters away from the forest margin.

The biodiversity index of number of fungi colonizedon *R. apiculata* in natural forest (Site I and II) was valued 0.85 while at the area of forest margin and at 50 meters away from the margin were shown 0.83 and 0.89 respectively. Regarding to mangrove plantation, the biodiversity index was valued 0.93, and 0.89 at forest margin and 0.75 at 50 meters away from the forest margin. Similarity index in natural forest Site I was determined 0.90 while at the area of forest margin and at 50 meters away from the margin were 0.87 and 0.85 respectively. Regarding to natural forest site II, the biodiversity index was calculated 0.88, and about 0.87 at forest margin and 0.84 at 50 meters away from the forest margin.

The results indicated that biodiversity index of mangrove plantation forest was shown less than natural mangrove forest. The reason was that the mangrove plantation contained less plant species than natural mangrove. Therefore more substrates and also more physical factors were supported for fungal development in natural mangrove forest than mangrove plantation.

Details of biodiversity index of number of fungi in different leaf species and study sites were shown in Table 27.

The values of similarlity index and biodiversity index of fungi on mangrove leaves of two species in different sites were determined by multi-way analysis at 95% level of confidence. The results showed insignificant differences.

Table 26 Similarity Index of Number of Fungi Colonized on *A. alba* and *R. apiculata* in Different Study Sites

Forest Type	Similarity Index	
	A. alba	R. apiculata
Natural Mangrove Forest (I and II) V.S Mangrove Plantation$_{0,50\ meters}$	0.33	0.19
Natural Forest I V.S Natural Forest II $_{0,50\ meters}$	0.31	0.55
Natural I and II $_{0\ meters}$ V.S Natural I and II $_{50\ meters}$	0.27	0.28
Mangrove Plantation$_{0\ meters}$ V.S Mangrove Plantation$_{50\ meters}$	0.40	0.0

Table 27 Biodiversity Index of Number of Fungi on *A. alba* and *R. apiculata* Leaf in Different Study Sites

Forest Type	Biodiversity Index		
	Total	0 Meter	50 Meter
A. alba			
Natural Forest (I and II)	0.89	0.92	0.90
Mangrove Plantation Forest	0.89	0.99	0.85
Natural Forest Site I	0.88	0.94	0.94
Natural Forest Site II	0.72	0.91	0.75
R. apiculata			
Natural Forest (I and II)	0.85	0.83	0.89
Mangrove Plantation Forest	0.93	0.89	0.75
Natural Forest Site I	0.90	0.87	0.85
Natural Forest Site II	0.88	0.87	0.84

CONCLUSION

The investigation on the decomposition rates and associated degradation fungi on mangrove leaf litter of *Rhizophora apiculata* and *Avicennia alba* were conducted at Tachine estuary, Samut Sakhon province from December 1997 to January 1999. The studies dealed with leaf litter producttion, decomposition rates of leaves, nutrients from litter falls, associated fungal species and activities of fungi on leaf decomposition in relation to environments. The results of study could be summerized as follows:

Leaf Litter Production in Natural Mangrove Forest and Mangrove Plantation

The amount of litter falls in mangrove forest at Thachins estuary, Samut Sakhon was estimated over 12 months period. The average litter fall was 1,656 kg dry weight/year in the natural forest and 1,943 kg dry weight/year in the mangrove plantation. The majority of the leaf litter was 54 %. The monthly maximum leaf litter fall was ranged 100-370 g/ month during August to December while the monthly minimum was ranged 40-90 g/month during Febuary to July.

Decomposition Rate of Leaf Litters in Natural Mangrove Forest and Mangrove Plantation

The decomposition of the mangrove senescent leaf litters was conducted during the period of 12 months in 3 study sites, in natural mangrove forest site I, on the west coast of the estuary, natural forest site II on the east coast of the estuary and mangrove plantation. Two plots, at river bank and 50 meters away from river bank were established in each study site. Weight loss of litter occurred rapidly in the first 8 weeks which estimated about 90 % less of the initial leaf weight during this period. Thereafter, the rate of decay gradually decreased. However, the litter was completely decomposed within 6 months. The decomposition rates at the area closed to the mouth of the estuary or at the river bank showed a faster rate of decomposition than those at 50 meters away from river bank. The decomposition of leaf litter for *R. apiculata* in the natural mangrove forest and

mangrove plantation at the river bank and at 50 meters away from river bank was completely decomposed in 5-6 months. As well as *A. alba* in natural mangrove forest site I and II at the river bank and at 50 meters away from river bank was also completely decomposed within 5-6 months. In the mangrove plantation at the river bank and at 50 meters away from the river bank the litters were completely decomposed within 3-5 months. In comparison with the decomposition of both leaves at the natural mangrove forest and the mangrove plantation at the river bank were decomposed faster than at 50 meters away from the river bank approximately 2-5 %. Not only the tidal factor but also benthos fauna such as crabs, polychaetes, mollusks, amphipods and sipunculids in the litter bags and of course fungi also played an important role in the degradation of the mangrove litter.

Nutrients from Litter Fall

The total nutrient contents including Nitrogen, Phosphorus, Potassium, Cacium, Megnesium and Sodium from the total leaf litter production in natural mangrove forest and mangrove plantation were determined 118.5 and 139.02 g/rai/year respectively. *A. alba* contained the higher amount of nitrogen (1.824 %) than *R. apiculata* (1.048%). Nutrient sources in the mangrove were depended on the plant species, the percentage of the nutrient content in the leaf litters and the total production of leaf falls of each species.

Species of Fungi from Leaf Litters

Fungi isolated from *R. apiculata* and *A. alba* leaf litters were found totally 49 species and 19 genera belonging to the Phylum Zygomycota 2 genera, Deuteromycota 16 genera and Ascomycota 1 genera. The Number of the fungi on *R. apiculata* and *A. alba* leaf were examined for 30 and 36 species respectively. The common genera were *Aspergillus, Trichoderma, Penicillium,* and *Fusarium.* The distribution of the number of fungi in natural forest during rainy season was higher than that in the mangrove plantation.

The species of fungi on *A. alba* leaves in natural mangrove forests (Site I and II) at the river bank and at 50 meters away from the river bank were identified for 22 and 12 species respectively. In the mangrove plantation at the river bank and at 50 meters away from river bank revealed 13 and 7 species respectively. Moreover, the species of fungi on the *R. apiculata* leaves in natural mangrove forest (Site I and II) at the river bank and at 50 meter away from the river bank were shown12 and 11 species respectively but in the mangrove plantation at the river bank and at 50 meter away from river bank were indicated 9 and 4 species respectively. The number of fangal species in natural mangrove forest and mangrove plantation at river bank had depicted more than at 50 meters away from river bank. The species of fungi in natural mangrove forests (Site I and II) and mangrove plantation at the river bank were expressed higher than that at 50 meters away from the river bank. The species of the fungi in natural mangrove forest site I was illustrated higher in number than those in natural mangrove forest site II. This might be due to the west coast of the estuary was composed of new flat mud.

The majority of fungal species examined was mostly belonged to the Fungi Imperfecti. *Aspergillus* and *Trichoderma* were the most common genera, accounting for almost 36.71 and 16.32 percent of the total species respectively. A comparatively high proportion of the species encoutered was *Aspergillus*, with 17 species (excluding ascoscopic forms) representing 36.71% of the total population. Zygomycota was representing 4.08% in the 2 species of the genus *Mucor,* whereas Ascomycota representing 2.04% of one species of the genus *Emericella.* Basidiomycota was entirely absent in the mangrove soil. A comparison with the fungal species colonized on *R. apiculata* and *A.alba* leaves, occurring in natural forest and the mangrove plantation indicated fairly similar trend of 26.69 and 19.04% respectively. However it was found that environmental factors which controlled the distribution of fungi might be salinity, hydrogen sulfide, organic matter content, sea currents, temperature, nutrient levels, oxygen content, and the pH of seawater.

Soil Chemical Properties

Physical and chemical conditions of the mangrove soils were determined. The soils was alkaline with pH values of about 7.4-7.7. The salinity of seawater was ranged 15-25 ppt, and the temperature was recorded between 30-35° C, soil texture was clay. The soil contained rather high amount of organic matter (23.6-27.1%); phosphorus about 85 and 87 ppm and potassium about 1,636-1,644 ppm.

Species of Soil Fungi

The total soil fungi isolated in summer and in the rainy season were found 25 species. It distributed in the natural forest at the river bank or forest margin more than at 50 meters away from the river bank. The fungal species were determined similar to the leaf litter fungi such as *Aspergillus, Penicillium, Trichoderma,* and *Phoma* .

The number of soil fungi distributed in natural mangrove forest (Site I and II) and mangrove plantation in summer season at the forest margin or the river bank was found more than at 50 meters away from the river bank. There were 13 fungal species at the forest margin and 5 species at 50 meters away from the river bank. In natural mangrove forest and mangrove plantation indicated 7 and 3 species respectively. Moreover, in the rainy season in natural mangrove forest (Site I and II) and mangrove plantation at the river bank and at 50 meters away from the river bank the fungal species were examined for 11 species at river bank and 7 species at 50 meters away from river bank. In natural mangrove forest and mangrove plantation found 5 species of both sites. In the west coast of the estuary, the number of fungi was greater than that the east coast of the estuary.

Species Identification of Fungi Leaf Litter

Similarity Index of number of fungi on *A. alba* leaf in comparison with different study sites was concluded. The similarity index of fungi in natural mangrove forest (Site I and II) and mangrove plantation was measured 0.33. Regarding to natural mangrove forest, similarity index in the west coast and east coast of estuary was calculated 0.31.

The similarity index of fungi in natural mangrove forest (Site I and II) at forest margin and 50 meters away from the margin was shown0.27. In mangrove plantation similarity index in the river bank and 50 meters away from the margin was determined 0.40.

Similarity Index of number of fungi on *R. apiculata* leaf in different study sites was concluded. The similarity index of fungi in natural mangrove forest (Site I and II) and mangrove plantation was implicated 0.19. Regarding to natural mangrove forest, similarity index of the west coast and east coast of estuary was expressed 0.55. The similarity index of fungi in natural mangrove forest (Site I and II) at forest margin and 50 meters away from the margin was found 0.28. In mangrove plantation similarity index of fungi in the river bank and 50 meters away from the margin was shown 0.00.

The biodiversity index of number of fungi colonized on *A. alba leaf litter* in natural forest (Site I and II) was depicted 0.89 while in the area of forest margin and at 50 meters away from the margin were shown 0.92 and 0.90 respectively. In mangrove plantation, the biodiversity index was found 0.89, and 0.99 at forest margin and 0.85 at 50 meters away from the forest margin. Similarity index in natural forest Site I was 0.88 while at the area of forest margin and at 50 meters away from the margin were 0.94 and 0.94 respectively. In natural forest site II, the biodiversity index was 0.72, and 0.91 at forest margin and 0.75 at 50 meters away from the forest margin.

The biodiversity index of number of fungi colonized on *R. apiculata* leaf litter in natural forest (Site I and II) was examined 0.85 while at the area of forest margin and at 50 meters away from the margin were 0.83 and 0.89 respectively. In mangrove plantation, the biodiversity index was determined for 0.93, and about 0.89 at forest margin and 0.75 at 50 meters away from the forest margin. Similarity index in natural forest Site I was indicated 0.90 while at the area of forest margin and at 50 meters away from the margin were 0.87 and 0.85 respectively. In natural forest site II, the biodiversity index was found 0.88, and 0.87 at forest margin and 0.84 at 50 meters away from the forest margin.

Growth Rates of Fungi Cultured in Different Percentages of Cellulose and Xylan on CMA mixed with Salinity 15 and 30 ppt of Seawater

The growth rates of 12 fungi isolated from leaves litter were grown particularly on a range of seawater salinities of 15 and 30 ppt. The fungi grew best at 15 ppt salinity of seawater in CMA media incubated at room temperature (25-30° C). It was concluded that the salinity was a major controlling factor for growth and distribution of fungi in the mangrove forest. The analysis also showed that the fungus in genus *Trichoderma* grew fast at 15 ppt seawater and 0.1 percent cellulose powder in CMA.

Methods for Investigation on Decomposition of Cellulose Powder, Filter Paper, Xylan, Lignin, *R. apiculata* Leaves and *A. alba* Leaves in Terms of Glucose Detected by 12 Fungal Crude Enzyme from Different Ages at 15 and 30 ppt Salinities.

Enzyme activities of 12 fungal species in 6 genera: *Trichoderma, Aspergillus, Penicillium, Pestalotiopsis, Geotrichum* and *Rhizoctonia* were investigated for the decomposing cellulose powder, xylan, lignin and cellulose on *A. alba, R. apiculata* leaves into glucose. Leaf components were deecomposed faster at 15 ppt salinity of seawater in CMA media by *Trichoderma,* followed by *Aspergillus, Penicillium, Pestalotiopsis, Geotrichum* and *Rhizoctonia* respectively. In comparison with decomposition between *R. apiculata* and *A. alba* leaf litters, it was found that *A. alba* leaf litter was decomposed faster than *R. apiculata* leaf litter due to *A. alba* leaf litter containing cellulose less than *R. apiculata* leaf litter. The decomposition on leaf litter of *A. alba* produced glucose productsmore higher than *R. apiculata.*

The important factors on degradation of *A. alba* and *R. apiculata* leaf components were corelated with the growth stages of fungi, the salinity of media and also the fungal species. The growth ages of brown rot fungi during 14-21 days in CMA at 15 ppt salinity could decompose faster than other factors whereas white rot fungi decomposed *A. alba* and *R. apiculata* leaf components quickly for only 7 days at 15 ppt salinity in CMA.

RECOMMENDATIONS

The wise management of the mangrove ecosystem depends closely upon a comprehensive ecological knowledge. Thus far, mangrove management in Thailand has been based primarily on economic returns, with little regarding to any importance of environmental considerations. The objective of the Royal Forest Department is to manage this resource on a sustained yield basis, with due emphasis towards the control of effectivel environmental quality.

The recommendations reported here are based on preliminary investigations studied in the mangrove forest at Thachine estuary, Samut Sakhon province. Although they are directly applied only to the development of future research in this particular mangrove area, but it is felt that they may also be considered to apply this results of study for sound management of mangrove forest in Thailand. These recommendations are as follows:

1. The results study of this study showed that litter production and nutrients of litter falls in natural mangrove forest and mangrove plantation at Thachine Estuary, Samut Sakhorn were indicated higher than those found in other mangrove areas in Thailand. Based on the results of this study, mixed pioneer plant species, such as *A. alba, A. marina, Sonneratia sp.,* and *R. apiculata,* of which the growth rate were rapid and the nutrient production was high. These plant species should be planted in deteriorating areas as the mangrove plantation at Thachine Estuary, Samut Sakhon and also elewhere in degraded mangrove forest of the country in helping to balance the mangrove ecosystem.

2. The result of this study showed that there were totally 49 species in 19 genera of fungi found at Thachine Estuary. However, some genera (i.e., *Penicillium, Fusarium*) were not already classified into species. The composition and density of these unclassified species, therefore should be conducted in the future by studying morphology and molecular aspects by using Gas Chromatography and Electrophoresis in order to discover new fungal species producing novel secondary metabolites.

3. Eight fungal species of *Trichoderma* were found at Thachine Estuary. These species were known to producing antagonistic bioactive compounds or toxic metabolic products which damaged one or more of the associated fungi. Therefore, the antagonistic bioactive compounds from *Trichoderma* and other fungi should be further studied and extracted in order to utilize its pharmaceutically economic products to controll mangrove tree disease particularly root rot.

4. A number of fungi in the mangrove areas at Thachine Estuary can produce several kinds of antibiotic products such as *Acremonum* sp. producing cephalosporins, *Aspergillus fumigatus* producing fumigillin, fumigatin, gliotoxin and trypacidin; *Phoma* sp. producing phomin, and afla toxin from *Aspergillus flavus*. Imamura *et al.* (1994) reported siccayne from *Halocyphina villosa* and *Helminthosporium siccans* and trapoxin from *Corollospora intermedia* and *Helicoma ambiens*. Effective methods for extracting antibiotic products from these fungi should be created. These antibiotic agents can be applied in industrial and medical uses in order to increase the national income in the future.

5. Finally, a comparative studies on decomposing of various types of fungi under different temperature and other methods such as Gas Chromatography, Electrophorysis Molecular Biology and Genetic Engineering should be experimented and developed. This will help to understand fungi more about the optimal conditions for wood or litter-decomposing process. DNA Homology and DNA Sequencing of less-known and remarkable fungi should be developed for identification aids and genetically modified organisms (GMO) in future research. Knowledge-based economy or new economy in the field of microbiology should be urgently established so that Thailand could be competitive with the Era of free trade and globalization.

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APPENDIX

Preparation of Isolated media

Glucose-ammonium nitrate agar for isolating fungi in general (Gochennaur 1964) (GAN)

NH_4NO_3	1.0	gm
Glucose	5.0	gm
Yeast extract	1.0	gm
K_2HPO_4	1.0	gm
$MgSO_4.7H_2O$	0.5	gm
Rose bengal	0.03	gm
Agar	18.0	gm
Sea water 15 ppt	1000	ml
Streptomycin	30	ppm

After medium has been autoclaved, 4 ml of 30 ppm streptomycin are added.

Potato dextrose agar (PDA) for growing fungi in General

Potato	200.0	gm
Dextrose	20.0	gm
Agar	18.0	gm
Sea water 15ppt	1000	ml

Cornmeal agar (CMA) for growing fungi in general

Difco cornmeal agar	17.0	gm
Sea water 15ppt	1000	ml

Czapek-Dox agar for growing *Aspergillus* and *Penicillium*

$NaNO_3$	3.0	gm
K_2HKPO_4	1.0	gm
$MgSO_4.7H_2O$	0.5	gm

KCl	0.5	gm
$FeSO_4.7H_2O$	0.01	gm
Sucrose	30.0	gm
Agar	15.0	gm
Sea water 15ppt	1000	ml

Vegetable juice Agar (v-8)

v-8 juice	180	ml
calcium carbonate	29	m
Agar	20	gm
sea water 15ppt	1000	ml

Solution Preparation for Enzyme Activities

1) 3,5 Dinitrosalicylic Acid

1.1 Solution A

Balance phenol 7 g in solution of 10 % NaOH 1505 ml. Added with seawater 15 ppt for 70 ml

1.2 Solution B

Balance sodium bicarbonate 6.9 g, dinitrosalicylic acid 8.8 g and sodium potassium tartrate 255 g and sodium hyroxide 13.5 g dissovled in seawater 15 ppt for 1180 ml.

Mixed solution A and B and keep in dark bottle.

2) Phosphate buffer 0.02 M at pH 6.0

Use solution of 0.2 M monobasicsodium phosphate 87.7 ml and solution 0.2 of M dibasic sodium phosphate 12.3 ml. Mixed two solutions and ajusted volume to 1000 ml.

3) Acetate buffer pH 5.5

Prepared solution of 0.2 M acetate acid 6.8 ml and 0.2 M sodium acetate 43.2 ml.

Mixed well 2 solutions and ajusted to 500 ml.

Appendix Table 1 Similarity Index of Number of Fungi on *A. alba* and *R. apiculata* in Different Study Site

Forest Type	Similarity Index
A. alba	
Natural Mangrove Forest (I and II) V.S Mangrove Plantation $_{0,50\ meters}$	12x2/17+11+13+19+4+7 = 0.33
Natural Forest I V.S Natural Forest II $_{0,50\ meters}$	8x2/17+11+19+4 = 0.31
Natural I and II $_{0\ meters}$ V.S Natural I and II $_{0,50\ meters}$	7x2/17+11+19+4 = 0.27
Mangrove Plantation $_{0\ meters}$ V.S Magrove Plantation$_{50\ meters}$	4x2/13+7 = 0.40
Natural Forest I $_{0\ meters}$ V.S Natural Forest II $_{0\ meters}$	0.43
Natural Forest I$_{50\ meters}$ V.S Natural Forest II $_{50\ meters}$	0.086
R. aculata	
Natural Mangrove Forest (I and II) V.S Mangrove Plantation $_{0,50\ meters}$	4 x2/8+8+9+7+6+4 = 0.19
Natural Forest I V.S Natural Forest II $_{0,50\ meters}$	8 x2/8+8+7+6 = 0.55
Natural I and II $_{0\ meters}$ V.S Natural I and II $_{50\ meters}$	74x2/8+8+7+9 = 0.28
Mangrove Plantation $_{0\ meters}$ V.S Magrove Plantation$_{50\ meters}$	40x2/9+4 = 0
Natural Forest I $_{0\ meters}$ V.S Natural Forest II $_{0\ meters}$	0.50
Natural Forest I$_{50\ meters}$ V.S Natural Forest II $_{50\ meters}$	0.31

Appendix Table 2 Biodiversity Index of Number of Fungi on *A. alba* and *R. apiculata* Leaf in Different Study Site

A. alba	Natural Forest (I and II)		Mangrove Forest		Natural Forest I		Natural Forest II	
$\sum P_i^2$	0.105		0.107		0.123		0.27	
Biodiversity Index	0.89		0.89		0.88		0.72	
	Natural Forest (I and II)		Mangrove Forest		Natural Forest I		Natural Forest II	
	0	50	0	50	0	50	0	50
$\sum P_i^2$	0.081	0.10	0.00	0.14	0.057	0.519	0.089	0.25
Biodiversity Index	0.92	0.90	0.99	0.85	0.94	0.94	0.91	0.75
R. apiculata								
	Natural Forest (I and II)		Mangrove Forest		Natural Forest I		Natural Forest II	
$\sum P_i^2$	0.142		0.069		0.09		0.115	
Biodiversity Index	0.85		0.93		0.90		0.88	
	Natural Forest (I and II)		Mangrove Forest		Natural Forest I		Natural Forest II	
	0	50	0	50	0	50	0	50
$\sum P_i^2$	0.161	0.105	0.109	0.25	0.125	0.141	0.125	0.159
Biodiversity Index	0.83	0.89	0.89	0.75	0.87	0.85	0.87	0.84

Appendix Table 3 Maring Fungi Collected from Brillant USA. (after Hyde and Jones, 1987)

Fungus	Number Collections	Percentage Occurrences
Hapocyphina villosa Kohlm. & Kohlm.	53	27.3
Lulworthia grandispora Meyers	44	22.7
Ascomycete sp.(4)	30	15.5
Antennospora quadricornuta (Cribb & Cribb) T.W. Johnson	24	12.4
Dactylospora haliotrepha (Kohlm. & Kohlm.) Hafellner	14	7.2
Aniptodera mangrovii Hyde	13	6.7
Caryosporella rhizophorae Kohlm.	10	5.2
Lulworthia medusa – like	9	4.6
Massarina velatospora Hyde & Borse	9	4.6
Aigialus grandis Kohlm & Schatz	9	4.6
Amiptodera marina (Cribb & Cribb) Hyde	6	3.1
Leptosphaeria australiensis (cribb & Cribb) Hughes	6	3.1
Ascomycete sq.(5)	6	3.1
Halosphaeria salina (Meyers) Kohlm.	4	2.1
Mucosphaerella pneumatophorae Kohlm.	4	2.1
Dictyosporium pelagicum (Linder) G.C. Hughes ex. Johnson and Sparrow	4	2.1
Didymosphareia enalia Kohlm. & Kohlm.	3	1.5
Mycosphacrella salicomae – like	3	1.5
Chrysosporium sp.	3	1.5
Cirrenalia pygmea Kohlm.	3	1.5
Halosarpheia fibrosa Kohlm. & Kohlm.	2	1.0
Halosarpheia viscosa Schmidt	2	1.0
Hydronectria tethys Kohlm. & Kohlm.	2	1.0
Leptosphaeria sp.	2	1.0
Orcadia ascophylti – like	2	1.0
Aigialus parvus Schatz & Khlm.	2	1.0
Savoryella lignicola Jones & Eatoa	2	1.0
Cirrenalia trovicalis Kohlm.	2	1.0
Humicola alopallonella Meyers & Moore	2	1.0
Cucullospora mangrovei Hyde & Jones	1	0.5
Bathyascus grandipora Hyde & Jones	1	0.5
Halosarpheia abonnis Kohlm.	1	0.5
Aniptodera ratnagiriensis (Patil & Borse) Hyde	1	0.5
Lindra sp.	1	0.5
Savoryella paucispora (Cribb & Cribb) Koch)	1	0.5
Trematosphaeria lignatilis Kohlm.	1	0.5
Monodictys pelatica (T.W. Jonson) Jones	1	0.5
Leptosphaeria savoryelliopsis Hyde and Mouzouras	1	0.5

Appendix Table 4 Percentage occurance of intertidal fungi from various tree species at Ranong Mangrove, Thailand

Fungus	*R. apiculata* (355 samples)	*S. griffithii* (300 samples)	*A. corniculatum* (50 samples)	Total
Ascomycetes				
Acrocordiopris patilii Borse & Hyde	2.3	0.7	-	1.3
Aigialus grandis Kohlm & Schatz	9.6	8.7	6.0	8.9
A. panus	-	0.7	-	0.3
Aigialus sp.	2.8	0.3	-	1.6
Aniptodera chesapeakensis Shearer & Miller	0.3	1.0	-	1.3
A. longispore Hyde	1.7	1.0	-	1.3
A. mangrodel Hyde & Jones	0.6	-	-	0.3
Antennospora quadricornuta (Cribb & Cribb) T.W. Johnson	0.6	0.7	-	0.6
Ascocralera manglicola Kohlm.	0.3	-	-	0.1
Ascocretera cf. *Manglicola* Kohlm.	3.9	1.0	-	2.4
Bathyascus grandisporus Hyde	1.2	-	-	0.6
Bathyascus sp.	0.6	-	-	0.3
Biatriospora marina Hyde & Borse	-	2.0	-	0.9
Belizrana tuberculata Kohlm. & Volkmann	0.3	-	-	1.8
Caryosporella rhizophorea Kohlm.	3.7	-	-	1.8
Cucullosporella mangrovei Hyde & Jones	1.1	-	-	0.6
Dactylospora haliotrepta (Kohlm. & Klhlm.) Hafellner	6.8	7.7	22.0	8.2
Didymospharria malia Kohlm.	7.6	0.7	-	4.1
D. rhizophorae Kohlm. & Kohlm.	0.3	-	-	0.1
Didymella avienniae Patil & Borse	-	0.3	-	0.1
Halosarpheia abonnis Kohlm.	2.8	12.3	20.0	8.1
H. minuta Leong	-	2.0	-	0.9
H. ratnagiriesis Patil & Borse	0.9	4.7	2.0	2.6
H. viscosa (Schmide) Shearer & Miller	0.9	1.0	2.0	1.0
Halosphaeria cucullata (Kohlm.) Kohlm.	-	1.0	-	0.4
Helicascus cf. *kanaloanus* Kohlm.	-	9.0	-	3.9
Heticascus kanaloanus Kohlm.	-	-	14.0	1.0

Appendix Table 4 (contd.)

Fungus	*R. apiculata* (355 samples)	*S. griffithii* (300 samples)	*A. corniculatum* (50 samples)	Total
Hydronectria tethys Kohlm. & Kohlm.	7.6	4.7	2.0	6.0
Hypophloedo rhizophore Hydre & Jones	2.0	-	-	1.0
Hypoxylon occanicum Schatz	0.6	7.0	2.0	3.4
Lautospora gigantec Hyde & Jones	-	1.0	-	0.4
Leutospore gigantre Hydde & Jones	-	1.0	-	0.4
Leptospharria custraliensis (Cribb & Cribb) G.G. Hughes	7.1	1.3	6.0	4.5
Leptospharria sp.2	-	6.3	-	2.7
Lignincola larvis Hohnk	0.6	1.7	-	1.0
L. longirostris (Cribb & Cribb) Kohlm.	1.4	2.3	4.0	2.0
Lophistoms mengrovis Kohlm. & Vittal	1.1	1.0	-	1.0
Lophiostoma sp.	-	0.3	36.0	2.7
Luluorthia grandispora Meyers	8.5	-	2.0	4.4
Luluorthia grandispora Meyers	8.5	-	2.0	4.4
Luluorthia sp. (spore range < 300 pm)	2.8	1.0	2.0	2.0
Luluorthia sp. (spore range > 400 pm)	-	0.7	6.0	0.7
Luluorthia sp. (large perithecia)	0.6	-	-	0.3
Marinosphaera mangrovei Hyde	6.2	3.0	-	1.6
Massarina thalassar Kohlm. & Volkm. – Kohlm.	0.6	3.0	-	1.6
Massorina velatospora Hyde & Borse	1.4	2.3	36.0	4.3
Massarina cf. *veatospora* Hyde & Borse	5.6	9.7	12.0	7.8
Massarina sp.	-	0.3	-	0.1
Mycosphaerella cf. *salicorniar* (Auerswald) Petrak	1.1	-	-	0.6
Nias glitra Crane & Shearer	0.3	0.3	-	0.3
Ophiodrira monosemcia Kohlm. & Volkm. – Kohlm.	2.0	3.3	-	2.4
Passeriniella sacoryellopsis Hyde & Mouzouras	0.3	5.3	-	2.4
Rhizophila marina Hyde & Jones	2.9	-	-	1.4
Savoryella lignicola Jones & Eaton	14.0	7.3	-	10.2

Appendix Table 4 (contd.)

Fungus	*R. apiculata* (355 samples)	*S. griffithii* (300 samples)	*A. corniculatum* (50 samples)	Total
Spharrulina cf. *orormaris* Linder in Barghoon & Linder	5.1	-	2.0	2.7
Swampamyces cf. *ormeniocus* Kohlm. & Volkm.	0.9	0.3	-	0.7
Thalassogena spharrica Kohlm. & Vohkm. – Kohlm.	0.6	-	-	0.3
Tremalospharria lignatilis Kohlm.	2.9	4.7	-	3.4
Ascomycete sp.	0.9	-	-	0.4
Ascomycete sp.	-	5.7	-	2.4
Xylariaccous sp.	4.3	-	-	2.1
Basidiomycetes				
Halocyphina villosa Kohlm. & Kohlm.	7.1	1.0	10.0	4.7
Heloryphins sp.	3.1	-	-	1.6
Calathello sp.	1.1	-	-	0.6
Deuteromycetes				
Bactrodesmium sp.	0.3	-	-	0.1
Cirrenalia pseudomacroplola Kohlm.	0.3	-	-	0.1
C. pygmea Kohlm.	-	0.3	-	0.1
C. tropicalis Kohlm.	1.4	-	-	0.7
Helicoon sp.	0.3	-	-	0.1
Hamicola alopallonella Meyers & Moore	0.9	-	-	0.4
Mycelia sterilia	0.6	-	-	0.3
Periconia prolifire Anastasiou	0.6	-	-	0.3
Phialopharophame cf. *litorulis* Linder	8.2	5.7	8.0	7.0
Phoma spp.	3.9	4.3	4.0	4.1
Phomapsis sp.	5.1	-	-	2.6
Xylomyces sp.	2.9	-	-	1.4

Appendix Table 5 Fungi Isolated from Soil of Washed Mangrove Roots by Dilution Plate Method. (after ITO & Nakagiri, 1997)

Species	No. of Positive Samples	Prequency (%)
DEUTEROMYCOTINA		
Acremonium spp.	11	50.0
Albophoma yamanashiensis	2	9.1
Arthrinium phaeospermum	1	4.5
Aspergillus clavatus	2	9.1
Aspergillus niger	1	4.5
Cladosporium cladosporioides	6	27.3
Coniothyrium spp.	12	54.5
Exophiala sp.	5	22.7
Fusarium spp.	8	36.4
Gliocladium roseum	3	13.6
Gliocladium virens	2	9.1
Gliocladium sp.	1	4.5
Gliomastix murorum	1	4.5
Metarhizium anisopliae	3	13.6
Myrothecium sp.	1	4.5
Nodulisporium sp.	3	13.6
Paecilomyces lilacinus	8	36.4
*Paecilomyces s*spp.	5	22.7
Penicillium citrinum	6	27.3
P. corylophilum	2	9.1
P. crustosum	3	13.6
P. funiculosum	2	9.1
P. janthinellum	4	18.2
P. purpurogenum	8	36.4
Penicillum spp.	3	13.6
Pestaloriopsis sp.	1	4.5
Phialophora fastigiata	5	22.7
Phialophora spp.	6	27.3
Phoma spp.	13	59.1
Phomopsis spp.	2	9.1
Scopulariopsis spp.	5	22.7
Stimibum sp.	2	9.1

Appendix Table 5 (conted.)

Species	No. of Positive Samples	Prequency (%)
Trichoderma aureoviride	2	9.1
T. harzianum	10	45.5
T. koningii	3	13.6
T. pseudokoningii	2	9.1
Trichoderma spp.	3	13.6
ASCOMYCOTINA		
Achaetonium macrosporum	1	4.5
Talaromyces flavus var. *flavus*	1	4.5
ZYGOMYCOTINA		
Cunnighamella sp.	1	4.5
Mortierella sp.	1	4.5
Mucor sp.	1	4.5
Sterilemycelium	16	72.7

A : Number of positive samples /

A total number of samples.

Appendix Table 6 Fungi Isolated from Mangrove Muds by Four Isolation Methods. (after ITO & Nagakiri, 1997)

Species detected	Sample No.	Method*	Frequency** (%)
ASCOMYCOTINA			
Achaetomium macrosproum Rai et al.	11	D	2.8
Chaetomium aureum Chivers	29	D	2.8
Emericella nidulans (Eidam) Vuillelmin var. *nidulans*	1	H	2.8
Eupenicillium parvum (Raper & Fennell) Stolk & Scott	9, 12	T,E	5.6
Eurotium rubrum Konig et al.	27	E	2.8
Microascus cinereus (Emile-Weil & Gaudin) Curzi	20	D	2.8
Neosartorya fischeri (Wehmer) Malloch & Cain var. *Glabra* (Fennelll l& Raper) Malloch & Cain	24,25,27	H, T	8.3
N. quadriocincta (Yuill) Malloch & Cain	13,27,28	H, T	8.3
Penicilliopsis clavariaefomis Solms-Laubach	12	E	2.8
Talaromyces flavus (Klocker) Stolk & Samson var. *Flavus*	9,10,12,24 25,27,35	H,T,E,D	22.2
T. ohiensis Pitt	25	T	2.8
T. helicus C.R. Benjamin apud Stolk & *helicus*	24, 25	T, E	5.6
T. stipitarus C.R. Benjamin apud Stolk & Samson	24,25,26,27	T, E, D	11.1
T. wortmannii C.R. Benjamin spud Stolk & Samson	11,18,21,24	D	11.1
Thermoascus aurantiacus Miche	27, 30	H	5.6
Thielavia terricola (Gilman & Abott) Emmons	24	H	2.8
Westerdykella multispora (Saito & minoura) Cejp & Miko	25	D	2.8
DEUTEROMYCOTINA			
Acremonium albamense Morgan-Jones	18,24,25,26, 27,36	H	16.7
A. terricola (Miller et al.) W. Gams	27	D	2.8
Acremonium spp.	(18)[e]	D	50.0
Arthrinium phaeospermum (Corda) E.B. Ellis	25	E	2.8
Aspergillus clavatus Desmazieres	12, 17	T, D	5.6
A. fumigatus Fresenium	30	H	2.8
A. terreus Thom	14,17,18,22 24,25,27	H, D	22.2
Chalara sp.	12	D	2.8
Cladosporium cladosporioides (Fresenius) de Vries	11, 18	D	5.6
Coniothyrium spp.	4,7,8,11,18, 24,26,29,35	D	25.0
Exophiala sp.	32	D	2.8

Appendix Table 6 (conted.)

Species detected	Sample No.	Method*	Frequency** (%)
Fusarium sp.	35	D	2.8
Gliocladium virus Miller et al.	25	D	2.8
Gliocladium sp.	9	D	2.8
Metarhizium anisopliae (Metschnikoff) Sorokin	12, 26	D	5.6
Nodulisporium sp.	3	E	2.8
Paecilomyces lilacinus (Thom) Samson	12, 22, 25	D	8.3
Paecilomyces spp.	12, 22, 35	D	8.3
Penicillium citrinum Thom	26	D	2.8
P. corylophilum Dierckx	18	D	2.8
P. crustosum Thom	9,12,25,2,28,32	D	16.7
P. janthinellum Biourge	21, 25	D	5.6
P. purpurogenum Stoil	9,11,12,15,17,18 19,20,22,26,28	D	30.6
P. rugulosum Thom	16	D	2.8
Penicillium spp.	9, 18	D	5.6
Pestalotiopsis sp.	25	D	2.8
Phialophora fastigiata (Lagerberg & Melin) Conant	1,9,21,27	D	11.1
Phialophora spp.	3, 4, 11	D	8.3
Phoma herbarum Westend	13, 24	D	5.6
Phoma spp.	(19)	D	52.8
Phomopsis spp.	13, 21, 30, 32	D	11.1
Scopulariopsis brumptill Salvanet-Durval	26, 29	D	5.6
Scopulariopsis spp.	16, 22	D	5.6
Thermophymatospora fibrigera Udagawa	[27]	H	2.8
Trichoderma aureoviride Rifai	12, 22, 25	D	8.3
T. harzianum Rifai	17,18,20,25,26, 27,30	D	19.4
T. koningii Oudemans	36	D	2.8
T. pseudokoningii Rifai	10	D	2.8
Trichoderma spp. *Virgaria nigra* (Link) Nees ex S.F. Gray	24, 25	D	5.6
ZYGOMYCOTINA			
Mucor hiemalis Wehmer f. hiemalis	25	D	2.8
Rhizomucor pusillus (Lindt) Schipper	26	H	2.8
BASIDIOMYCOTINA			
Unidentified species	1.22	E, D	5.6
Sterile mycelium	(26)	E, D	69.4

* H, heat incubation; E, ethanol treatment; T, heat treatment; D, dilution plate.
** Number of positive samples/total number of samples. C : Total number of samples in which the fungi were detected.

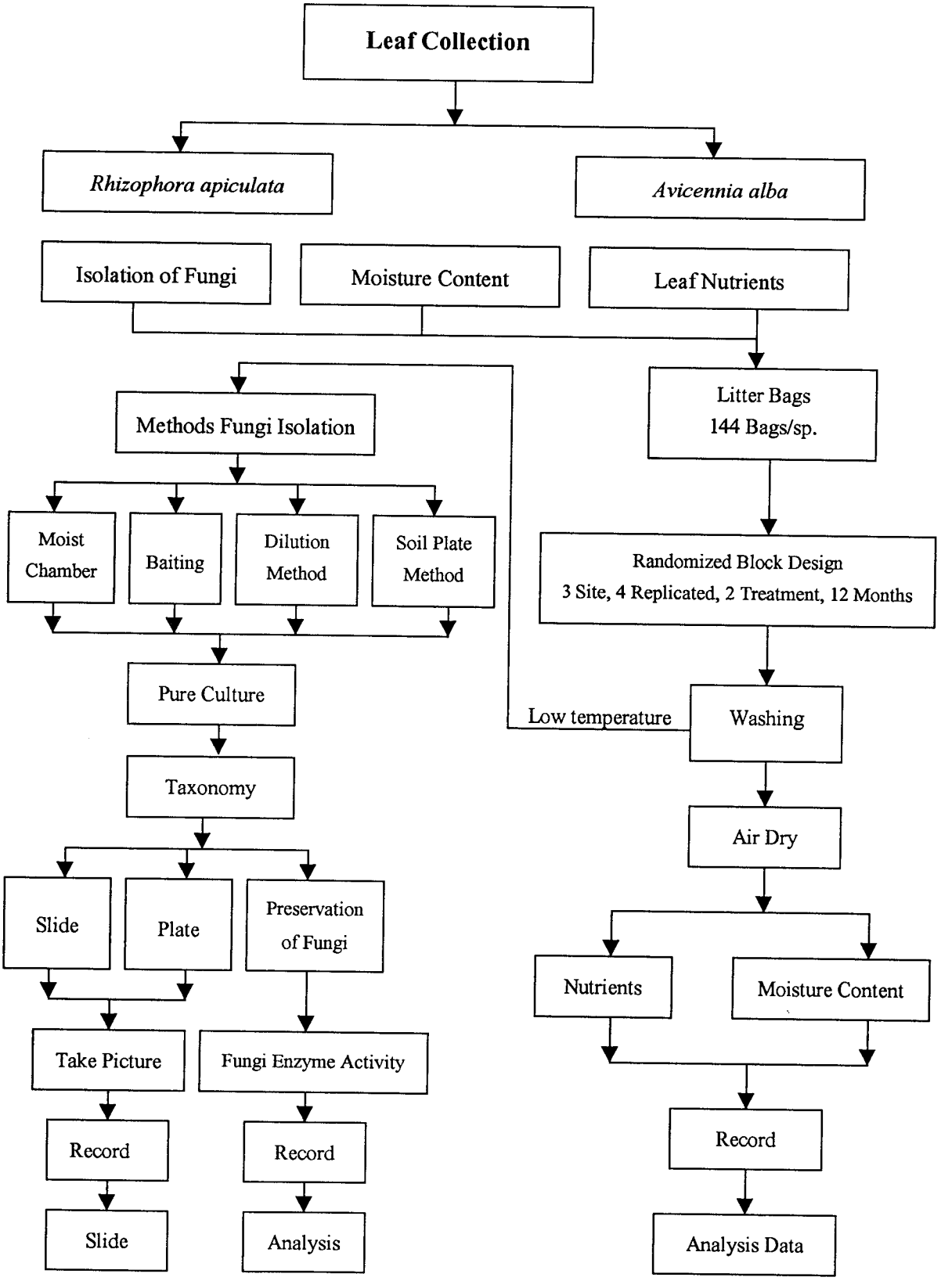
Appendix Table 7 Fungi Isolated by Two Isolation Methods from Rhizophere Soil, by Mangrove Species (after ITO *et al.*, 2001)

Fungus	Managrove Species								Frequency (%)[a]
	Avicennia alba	*Ceriops tabal*	*Rhizophora mucronata*	*Xylocarpus obovatus*	*Bruguiera sexangula*	*Rhizophora acipulata*	*Sonneratia alba*	*Bruguiera gymnorrhiza*	
Acremonium curvulum W. Gams							1		5
Acremonium spp.		1	1		3		1		30
Aspergillus aculeatus Iizuka	1	1	1		1			2	30
Aspergillus clavatus Desmaz.	2								10
Aspergillus funigatus Fres.		1	1		1				15
Aspergillus niger van Tiegh.				1	1				10
Aspergillus niger Aggr.	2	1					2		15
Aspergillus spp.		2			1	1			20
Aspergillus terreus Thom		2	1				1		20
Cladosporium cladosporioides (Fres.) de Vries		1	1	1		1			20
Coniothyrium sp.			1						5
Cylindrocladium parvum Anders.			1						5
Eupenicillum javanicum (van Veyma) Stolk & Scott	1	1	1	1	1			1	25
Eupenicillium sp.	1							1	10
Fusarium oxysporum Schlecht. Emend. Sny. & Hans.	1								10
Fusarium solani (Mart.) Appel & Woll. Emend. Syn. & Hans.	1	1							10
Fusarium sp.		1							5
Geotrichum candidum Link :Pers. Emend.Carmich.					1				5
Gongronella butleri (Lend.) Peyr. & Dal Vesco		1			1				10
Metarhizium anisopliae (Metschnik.) Sorok.	1		1					1	15
Microascus cinereus (Emil.-Weil & Gand.) Curzi			1						5

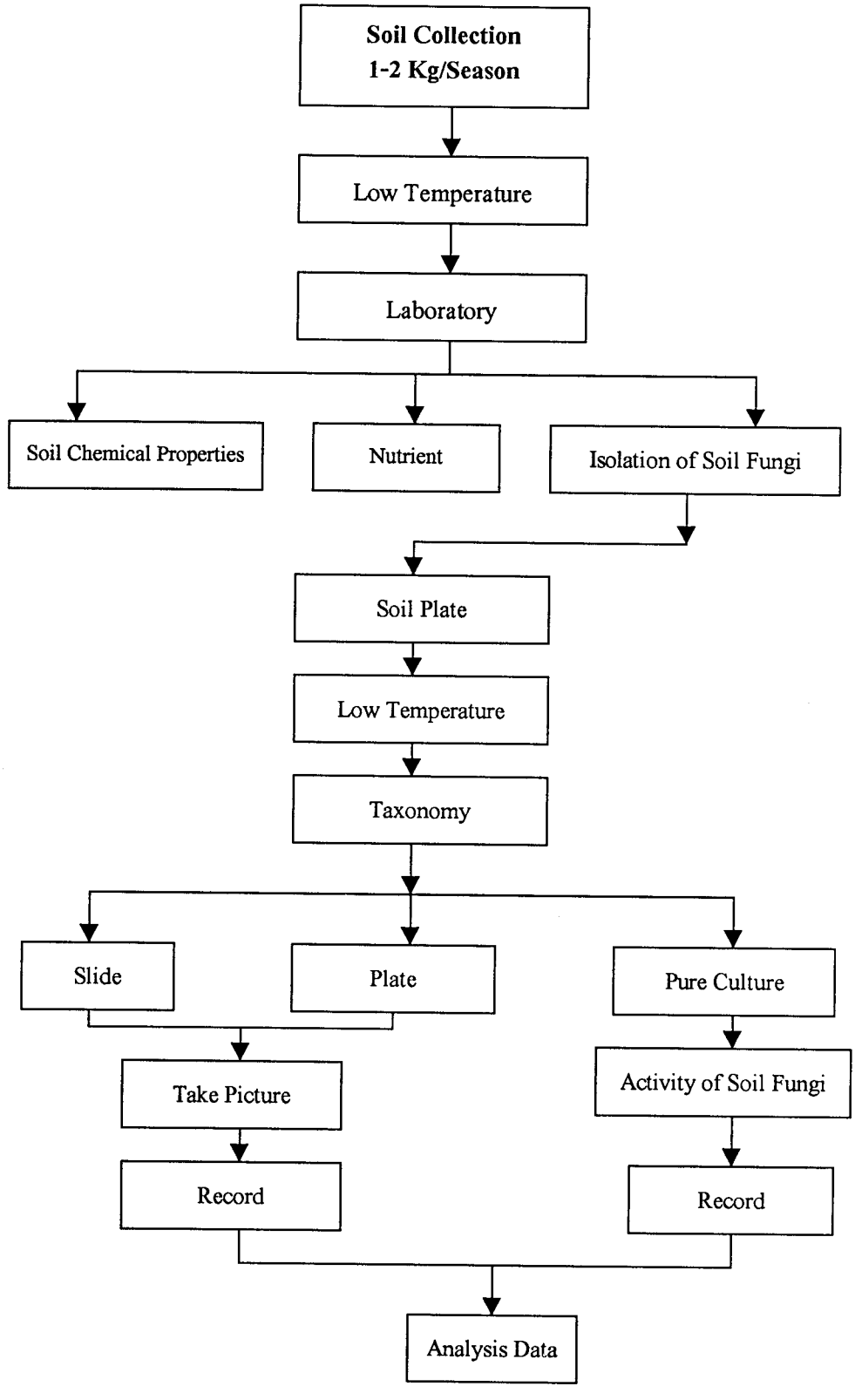
Appendix Table 7 (contd.)

Fungus	Managrove Species								Frequency (%)[a]
	Avicennia alba	*Ceriops tabal*	*Rhizophora mucronata*	*Xylocarpus obovatus*	*Bruguiera sexangula*	*Rhizophora acipulata*	*Sonneratia alba*	*Bruguiera gymnorrhiza*	
Mucor sp.			1			1			10
Neosartorya fischeri (Fenn. & Raper) Mall. & Cain var. *glabra* (Wehm.) Mall. & Cain							1		5
Paecilomyces variotii Bain.		1	2				1		20
Paecilomyces sp.		1							5
Penicillium citrinum Thom	1						1		10
Penicillium funiculosum Thom				1					5
Penicillium purpurogenum Stoll							1		5
Penicillium verruculosum Peyr.		1	1	1					15
Penicillium sp. - 1	1	1			1				10
Penicillium sp. - 2	1				1	1			15
Penicillium spp.		1	2	2	3		1	1	50
Pestalotiopsis sp.			1						5
Phoma sp.		1							5
Talaromyces byssochloamydoides Stolk & Samson	1		2			1	1		25
Talaromyces flavus (Klock.) Stolk & Samson var. *flavus*		1			1				10
Talaromyces wortmannii C.R. Benj. in Stolk & Samson	1								5
Trichoderma harzianum Rifai	2	2		2		1	1		40
Trichoderma koningii Oudem.		1							5
Trichoderma pseudokoningii Rifai	1	1	1			1			15
Trichoderma spp.		2			1	1		1	25
Unidentified strains			2	2			2		30
Total number of strains	18	16	22	12	16	8	14	6	
Number of samples	4	2	2	2	4	2	3	1	20

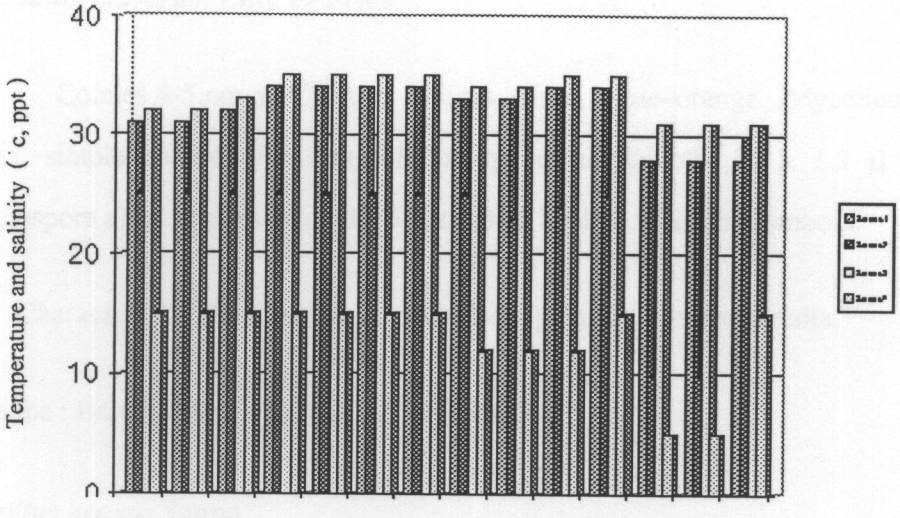
a : Number of positive sample/total number of samples x 100.



Appendix Figure 1 Flowchart of This Study



Appendix Figure 2 Flowchart of Study on Soil Chemical Properties and Analysis of Soil Fungi.



Appendix Figure 3 Physical Factors, Temperature and Salinity in Natural Mangrove

Note

series 1 = Temperature of natural forest

series 2 = Salinity of natural forest

series 3 = Temperature of mangrove plantation forest

series 4 = Salinity of mangrove plantation forest

Morphology of Fungi Associate with *A. alba* and *R. apiculata* Leaf Litter

Acremonium murorum Link ex Fries

Colnies 4-5 cm on CMA in 14 days, slime, white–orange. Mycelium white, 1.5 μ diam, simple phialide from mycelium, cylindical, smooth, 25 x 1.5 μ long, have chamydospore after 14 days. Conidia 5-6 x 2.5 μ, hyaline, elliptical, smooth.

Characters for classification: conidia from phialide, slime on media.

Refference : Barron (1968), Domsch *et al* (1980).

Aspergillus aeneus Sappa

Colonies in CZA restrictedly, 1.5-2 cm in 7 days, white, with bright red, fimbriate margin. Conidial head white, passing through yellowish–green, radiate when young but columnar in age. Conidiophore 200-250 μ long, pale brown, wall smooth, vesicle hemispherical, sterigma biverticillate. Conidia subglobose or elliptical 2–3 μ in diam, verruculose green.

Refference : Raper (1965).

Aspergillus alutaceus Berk & Curt

Colonies on CZA fairly broadly, plane yellow, reverse colour. Conidiophore long, conidial head globose, ochraceous, vesicle globose. Conidia globose or elliptical 3.5-4 μ.

Reference : Subramanian (1971).

Aspergillus candidus **Link**

Colonies on CZA slow growing, 2-2.5 cm in 14 days, conidial head white or becoming yellowish cream in age, globose when young, later adherent in loose divergent columns and reaching diam. Conidiophore smooth, colourless, 170-250 x 2.5 μ, having septate, vesicle globose to subglobose, having sterile mycelium, small sterigma 5 μ, reverse colourless, sterigma typically in two series. Conidia globose, thick walled 2.5 –3 μ.

Reference : Raper(1965)

Aspergillus flavus **Link**

Colonies on CZA 4.5 - 5 cm in 14 days, mycelium white when young. Conidial head radiate, green, sterigma biseriate, phialide 4-5 μ mutulae 7-8 μ, Conidiophore rough, slender 150-200 x 2.5μ , thick walled, hyaline. Vasicle globose 20 μ.diam. Conidiospore globose, echinuate, 3.5-4 μ green.

Characters for classification: conidial head green, sterigma mono-biveriate.

Refference : Raper and Fennell (1965), Thom and Raper (1945), Subramanian (1971), Domsch *et al* (1980).

Aspergillus flavipes **(Bain. and Sart.) Thom and Church**

Colonies on CZA growing rather slowly, 3-5 cm in diam in 14 days, buff. Conidiophore yellow, thick walled have exudate, reverse brown. Conidial head loosely columnar, brown. Condiophore 160- 200 μ in long, vesicle subglobose to elonate. Conidia globose to subglobose 2.5 μ, smooth.

Reference : Raper(1965)

***Aspergillus fumigatus* Fries.**

Colonies on CZA 5-8.5 cm in 14 days, bluish green. Conidial head columnar, compact, green. Conidiophore thick walled, short, smooth 400-450 µ, green metulae narrow. Conidia 2.5 µ, globose, echinuate.

Reference : Raper (1965).

***Aspergillus lutescens* Bainier ex Thom & Church**

Colonies on CZA broadly spreading and rapidly, 5-6 cm in 7 days floccose, white when young, mature changes to yellow, reverse colourless. Conidial head globose to subglobose, brown. Conidiophore short, septate, thick walled, vesicle globose 30 µ in diam. Conidia subglobose , rough verucose, 5 x 8 µ

Reference : Subramanian (1971).

***Aspergillus nidulans* (Eidam) Wint.**

Colonies on CZA green, 5.8 cm in 14 days. Conidial head short, columnar, 55-75 µ. Conidiophore smooth walled, 80-100 µ in long, vesicle subglobose 9-10 µ. Conidia globose, 3.2 µ, cleistothecia usually abundant,150 µ in diam, have globose hulle cell.

Reference : Raper (1965).

***Aspergillus niger* Van Tieghem**

Colonies on CZA 3.2 cm in 14 days. Conidial head radiate, black. Conidiophore wide, thick walled , brown 2 mm. Connidia 4.5 µ, globose, echinuate.

Refference : Raper (1965).

***Aspergillus ornatus* Raper, Fennell, and Tresner**

Colonies on CZA growing very sparingly, 2.0 cm in 14 days. Conidial head radiate 200 µ in diam. Conidiophore septate 1.2 mm in long, smooth, vesicle clavate 30 µ in diam. Conidia brown ,7.5 µ ,exudate yellow.

Refference : Raper (1965).

Aspergillus sparsus Raper and Thom

Colonies on CZA spreading broadly, grayish brown, reverse brown. Conidial head globose becoming more or less radiate in age and splitting into loose columnar, buff. Conidiophore straight 1 mm in long, vesicle globose. Conidia pale yellow, subglobose to elliptical roughened, 3.2 µ.

Reference : Raper (1965).

***Aspergillus sydowi* (Bain. and Sart.) Thom and Church**

Colonies on CZA growing well 3-4 cm in 14 days, less floccose. Conidial head blue-green, radiate to nearly globose, have exudate, brown, margin white, reverse deep brown. Conidiophore 450- 500 µ, smooth thick walled, vesicle globose, sterigma biseriate 1/2 of vesicle, 4.5 x 2.3 µ. Conidia globose , echinuate, bluish green, 2.5 µ.

Refference: Raper and Fennell (1965), Thom and Raper (1945), Subramanian (1971)

Aspergillus terreus var. africanus **Fennell and Raper**

Conidial head yellowish brown, long columnar. Colonies on CZA growing rather rapidlly, 3.5-5 cm in 10 days, plane, tufted, margins irregular, cinnamon-buff. Conidiophore smooth, colourless, 100-250 μ. Vesicle globose or subglobose. Sterigma biseriate ¾ of veasicle, having foot cell. Phialophore long, rough walled. Conidiospore globose, echinuate, 2-2.5 μ.

Refference : Raper and Fennell (1965).

Aspergillus ustus **(Bain) Thom & Church**

Colonies gray 5.2 cm in 14 days on CZA, mycelium white to cream, reverse yellow. Conidiophore smooth walled, 350 μ brown, conidial head columnar, vesicle globose, 10-12 μ, ½ of vesicle, sterima biseriate. Conidia glosoe, echinuate 3.5-3.8 μ, having elongate hulle cell.

Refference : Raper and Fennel (1965), Thom and Raper (1945).

Aspergillus versicolour **Vuillemin**

Conidial head radiate, 100-125 μ diam, bluish-gray. Conidiophore colourless, yellowish, smooth 140-200 μ, sterigma loosely, uniseriate or biseriate, vesicle globose or subglobose, small 5-7.5 μ. Conidial globose, echinuate 2.5-3 μ.

Refference : Kenneth B. Raper (1965).

Aspergillus wentii Wehmer

Colonies on CZA growing restrictedly 3.5 cm in 14 days yellowish to old gold, conidial head large, globose, radiate. Conidiophore over 5 mm, rough, vesicle globose. Conidia elliptical, colourless, then globose, brown at mature, 4.7 µ, smooth.

Refference : Raper (1965).

Curvularia geniculata Nelson

Colonies brown on PDA, 3-5 cm in 14 days. Conidiophore brown. Mycelium septate. Conidial in whorls, curved 25-30 x 12 µ.

Curvularia lunata (Wakker) Boedijn

Colonies brown on PDA, 4-6 cm in 14 days. Mycelium having septate, large, thick walled. Conidia at end of conidiophore, whorls, smooth. Conidia obovoid, clavate, pyriform, 4 cells, having protuberant hilum, 12 x 25-30 µ, brown, thick walled.

Characters of lassification : porospore, obovoid, having protuberant hilum.

Refference : Barron (1968), Domsch *et al.* (1980), Ellis (1971).

Cylindrocarpon destruetans Wollen

Colonies white 5-6 cm in 14 days on PDA. Conidia slimy phialospores, microspore hyaline, oval, non septate. Macroconidia hyaline, straight, 12-15 µ, whthout foot cell.

Refference : Barron (1968).

***Drechslera* sp.**

Colonies blackish brown, hairy. Conidiophores straight, 150 µ long, 8 µ thick brown, smooth. Conidia straight or curved, cylindrical with 6-8 pseudosepta, end cells hyaline, brown, 60-90 µ long, 15µ thick, hilum distincly protuberant.

Refference : Ellis (1971).

***Fusarium muliniforme* Sheld.**

Fruit body arise directly from vegetative hyphae. Colonies white, change in CMA to purple, floccose. Macroconidia 1–3 septate on phialide size 15 x 28 0 µ, oblong or elliptical, boat shaped, having foot cell at the attachment end of the spore, phialide 12.5 µ. Microconidia oval or globose 2.5 x 10 µ, non septate.

Refference : Barron (1968).

***Fusarium poae* (Peck) Wollenw.**

Colonies on CMA white, change CMA to red. Microconidia globose 9-10 µ. less macroconidia 3 septate 3.5 x 18-20 µ, phialide 5 x 12 µ.

Refference : Barron (1968).

***Fusarium illudens* (Peck) Wollenw.**

Colonies white, fluccose, many microconidia on conidiophore, 6 x 2.5 µ. Macroconidia 4-5 septate, 4 x 2.5 µ, having foot cell, no chlamydospore.

Refference : Barron (1968).

***Fusarium* sp.**

Colonies on CMA bluish green, macroconidia fusiform, thickwalled having the widest diameter in the penultimate cell. Microconidia oval, 1-2 septate, aggregate in 4-7 days, having chlamydospore, globose to oval, smooth wall, 9-12 μ.

Refference : Barron (1968) , Domsch *et al* (1980), Ellis (1971)

***Geotrichum* sp.**

Colony on CMA white, like starch, 5-7 cm in 14 days, ferment-fruit odor powder Conidiophores lacking. Vegetative hyphae hyaline. Conidia arthrospore, cylindric with truncate end, end wall some stightly convex.

Refference : Barron (1968), Domsch *et al* (1980), Ellis (1971).

***Penicillium adametziix* Zaleski**

Colonies on CZA 2.5 cm in 14 days, blunish green, zonate, smooth margin, reverse orange, short penicilli, smooth phailide walled, 2-2.2 μ, short, narrow. Conidia globose, 2.5-2.8 μ.

Refference : Ramirez (1982).

***Penicillium erythrocephalus* Abe ex Smith**

Colonies 8-9 cm in 14 days, white-green , reverse light green. Conidiophore 180- 200 μ, smooth, metula 10 μ. Conidia globose or subglobose, echinuate, 2.5 μ

Refference : Ramirez (1982).

***Penicillium paraherqueii* Abe ex Smith**

Colonies 5-7 cm in 14 days, yellowish–green, reverse light green at central. Conidiophore 150-200 x 3.5 μ, granular wall, penicilli biverticillate, metula 10-12 μ, loosely, philide 9-9.5 μ. Conidia elipptical, 3-3.1 μ, rough wall.

Refference : Ramirez (1982).

***Mucor* sp. (1)**

Colonies pale gray. Sporangiophores 8 μ wide, long sympodial branches originating short distance below sporangia. Sporangia brown, columellae globose, 40 μ diam, Sporangiospores cylindrical, 4.2 x 3.0 μ.

Refference : Domsch (1993).

***Mucor* sp. (2)**

Colonies on CMA rapid grown 9 cm in 5 days, gray, sporangiophores short and denser, sporandia on sporangium, 270 μ, columellae obovoid, 120 μ, sporangiospores thick walled, gray, cylindrical 12 x 6.5 μ diam.

Refference : Domsch (1993).

***Penicillium* sp.**

Colonies blunish gray, 5-5.2 cm in 14 days, reverse yellow brown, radiate, monoverticellate, conidia 3.2 μ globose, echinuate.

Refference : Ramirez (1982).

Penicillium sublateritium **Biourge**

Colonies on CZA 3-4 cm in 7 days, conidiophore long 100 x 2 μ, thick walled, phialide in parallel clusters 5-10 plialide, 12-15 μ, no exudate. Conidia gray, hyaline, globose or elipptical, 3-5 μ.

Colonies on CME 4-5 cm in 14 days, reverse yellow.

Refference : Ramirez (1982).

Penicillium velutinum **Van Beyma**

Colonies on CZA 3-3.5 cm in 14 days, surface colony radiate and wrinkled, smooth margin, green, central white, reverse brown, penicilli monoverticellate, 6-7 μ. Conidiophore 80 x 1.6 μ. conidia globose, 3-3.2 μ, roughened walled.

Refference : Ramirez (1982).

Pestalotiopsis guipinii **(Desm.) Steyaert**

Colonies on CMA 5-6.2 μ in 14 days, mycelium white, having black rot on media. Conidiophore smooth walled, hyaline, Fruiting body black, from simple acervuli. Hyphae white without stroma. Conidia straight, four five cells, 3-4 septate, 7.5-10 x 20 μ, having appendage long 20 μ.

Refference : Barron(1968), Sutton (1980).

Phoma nebulosa **(Pers. Ex S.F. Gray) Berk.**

Colonies white, cream in media, 1.2-1.3 cm on CMA in 7 days and 3.4 cm on V-8 in 7 days. Pycnidia brown, globose, ostiole single, central, not papillate, having light orange exudate. Mycelium immersed, pale brown, 65-70 x 4-6 μ. Conidiophore absent. Conidia hyaline, thin walled, globose or elliptical, 2 x 3-6 μ.

Refference : Sutton (1980).

***Rhizoctonia* sp.**

Colonies grown rapidly in 7 days on CMA. No conidia produceed. Hyphae broad and pigmented, brown, branching more or less at right angles, less loosely packed. Conidiospores no producing.

Refference : Barron (1968).

***Trichoderma aureoviride* Rifai aggr.**

Colonies yellowish green, olivaceous green, reverse greenish yellow. Phialide long and slender 7-14 x 2.5 μ, horn shaped. Mycelium are hyaline, wide 15 μ, septate. Clamydospore intercalary, globose and smooth wlled 7.5 μ. Phialospore obovoid smooth walled green, truncate base 3.5-5 μ.

Refference : Rifai (1969).

***Trichoderma hamatum* (Bon.) Bain. aggr.**

Colonies rapid growth, yellowish green, zonate, flocosae, reverse colourless. Mycelium septate, hyaline 2.5 μ diam, thick walled. Phialospores globose elliptical or obovoid, hyaline, smooth walled, 3-3.5 μ. Chlamydospores globose, 10 μ.

Refference : Rifai (1969).

***Trichoderma harzianum* Rifai aggr.**

Colonies are grown repidly, floccose, zonation, yellowish green, reverse colorless. Mycelium septate hyaline 1.5–12 μ diam. Chlamydospore globose hyaline intercalary 6-12 μ diam. Conidiophore dendroid, phialide 5-7 x 3-3.5 μ, ampulli formes almost verticillium- like. Phialospore aggregate, subglobose 2-2.5 x 2.5-2.8 μ smooth walled, trunctate.

Refference : Rifai (1969).

***Trichoderma koningii* Oud. aggr.**

Colonies grown repidly, dark green, reverse colorless, Phialospore eliiptical, hyaline 3-5 µ, No clamydospore. Mycelium septate, hyaline, smooth. Phailide whorl 15 µ.

Refference : Rifai (1969).

***Trichoderma pululiforum* Webster & Rifai**

Colonies grow rather slowly at room temperature and form watery white sparse mycelial mat over the surface of the media. The reverse remains uncoloured. Mycelium composed of smooth walled, septate and colourles hyphae upto 10 µ diam. Chamydospores subglobose or ellipsoidal, smooth-walled, intercalary or terminal and measure up to 12 µ diam. Conidiophore 5-7 µ diam produced many side branches. Phialides short, measure 4-6 µ long. Mostly arise in irregular whorls of two to five immediately beneath the terminal phialide. Phialide short flask-shaped. The phialospore are produced singly at the tip of each phialide, globose or subglobose, smooth walled, colourless, 2.5-3.5 µ, base of the spore truncate.

Refference : Rifai (1969).

***Trichoderma polysporum* (Link ex Pers.) Rifai aggr.**

Colonies grown slowly at room temperature, white spares mycelial mat over the surface of the media. Reverse yellowish brown. Mycelium is composed of smooth walled, septate and colourles 2.5 µ diam. Chlamydospores subglobose or ellipsoidal, smooth-walled, colourless, intercalary or terminal. Phialides 7.5-10 µ, short flask-shaped to pyriform narrower at the base than the middle. Compact tufts of conidiophores, sterile hyphal elongation. Phialospore produced singly at the tip of each phialide and aggregate in slime to form globose conidial head, globose or subglobose, smooth walled, colourles 2.5 –3.5 µ diam, truncate apiculus.

Refference : Rifai (1969).

***Trichoderma pseudokoningii* Rifai**

Colonies grow fairly rapidly, cover surface of media. Conidia greenish white, reversre yellowish. Conidiophore widely effused. Phialides in false whorls, 5.5 x 2.5 μ. Phialospose globose, 3.5 μ, smooth walled.

Refference : Rifai (1969).

***Trichoderma viride* Pers. Ex S. F. Gray aggr.**

Colonies grow rapidly cover 9 cm in 4 days. At maturity of conidial areas are dark green or bluish-green while the reverse remains uncoloured. The mycelium is composed of hyaline, smooth walled, septate, much branched, 1.5- 12 μ diam hyphae. Chamydospores arise in intercalary position, globose or ellipsoidal, hyaline, smooth walled, up to 20 μ diam. Conidiophores arise in some what compact. The main branched are 4.5 μ diam, produce several side branches which arise single or in groups of two or three, usually somewhat irregularly. Phialide mostly 8-14 x 2.4-3 μ. Phialospore are globose or short obovoid, green, 3-4 μ diam, rough walled, truncate.

Refference : Rifai (1969).

***Scopulariopsis* sp.**

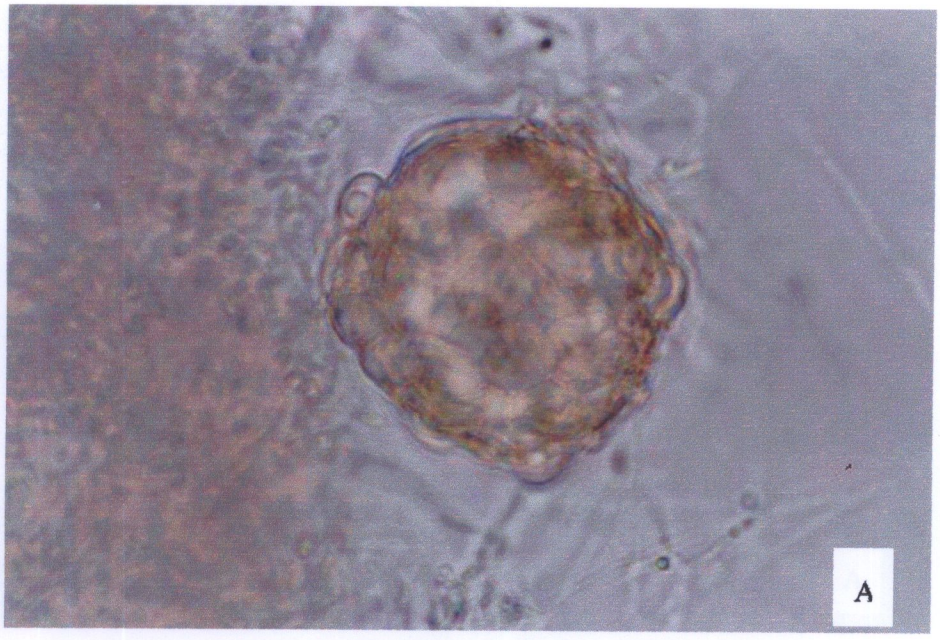
Colonies white, 5-6 cm in 14 days. Mycelium partly superficial, partly immersed. Conidiophore short 140-170 μ. macronematous, sporoginous cells anellospores, swollen. Spores dry, globose, truncate at attachment point, produced in long chains 2.5 μ. smooth, brown.

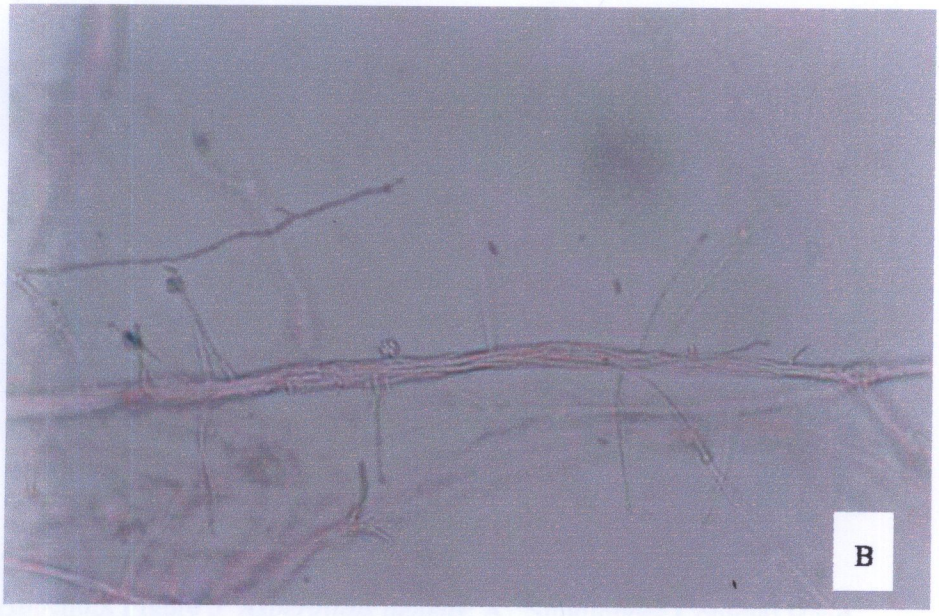
Refference : Arx (1970), Barron (1968), Ellis (1971).

***Verticillium* sp.**

Colonies on CMA 6 cm in 14 days. Conidiophore erect, septate, hyaline, 2 x 2-3 µ. Phialide 2.5 x 3-5 µ. Conidia 2-2.5 µ, hyaline.

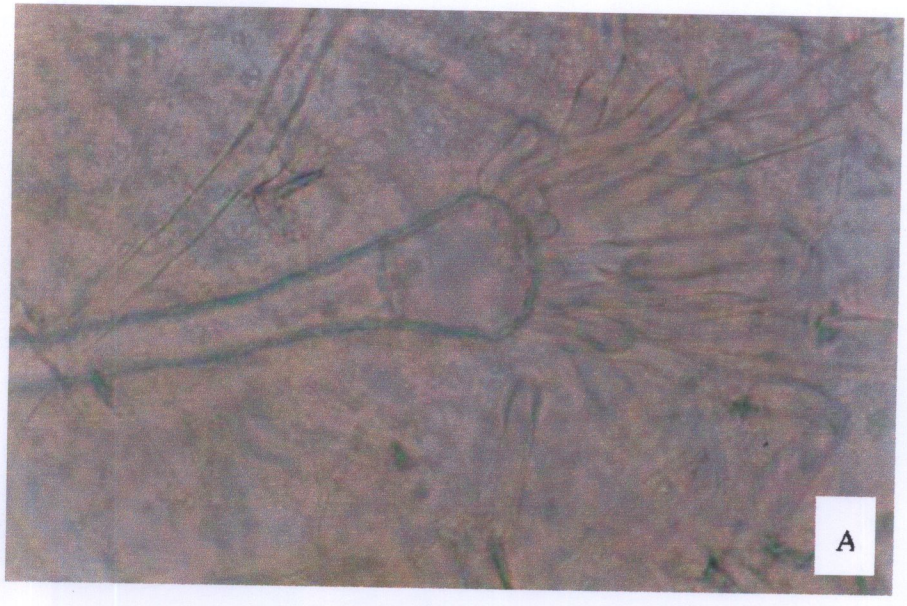
Refference : Ramirez (1982).

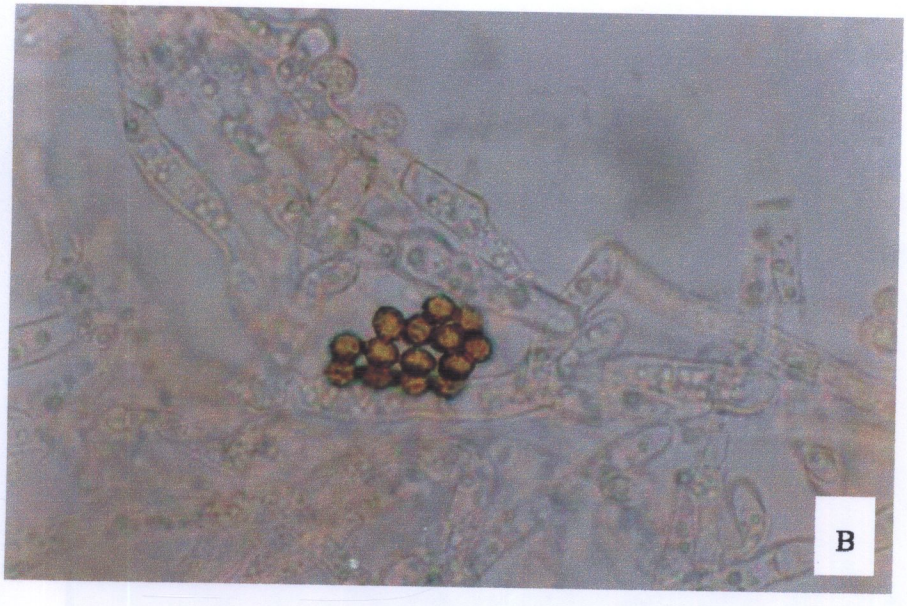




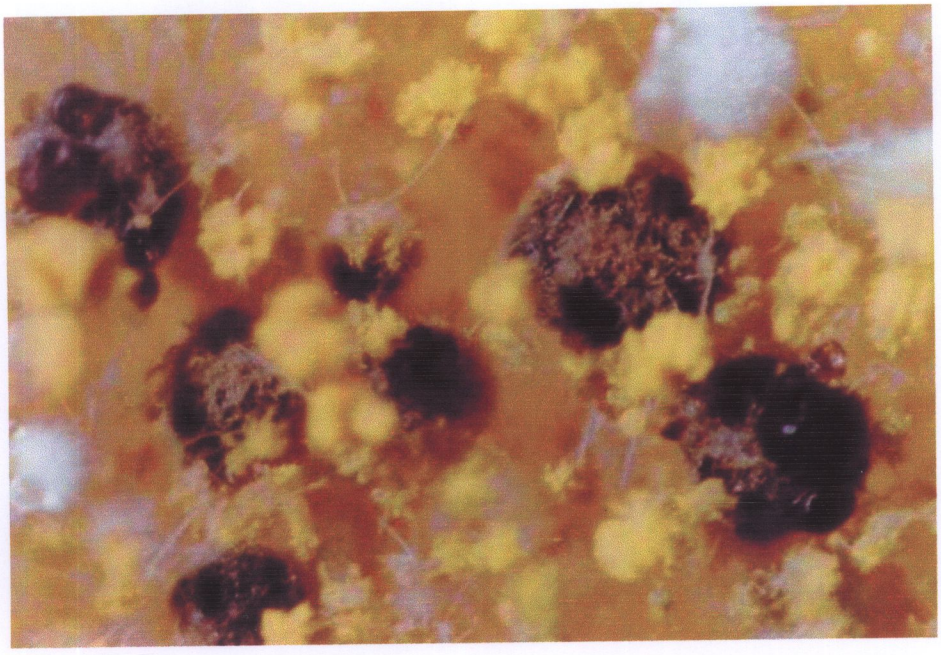
Appendix Figure 4 *Acremonium murorum*; A : Chamydospore 1000 x,

B : Conidia 400 x

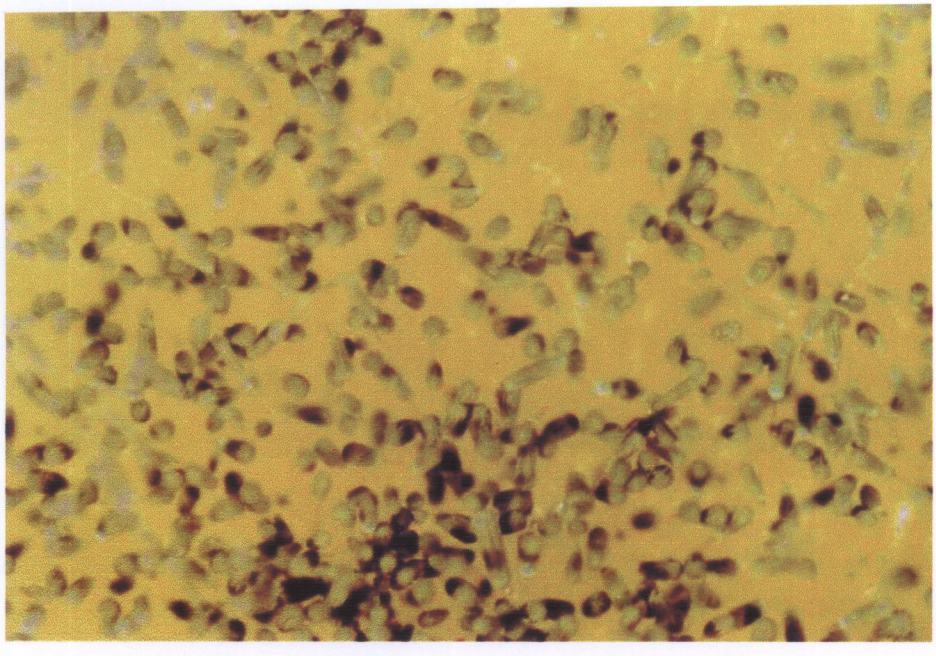




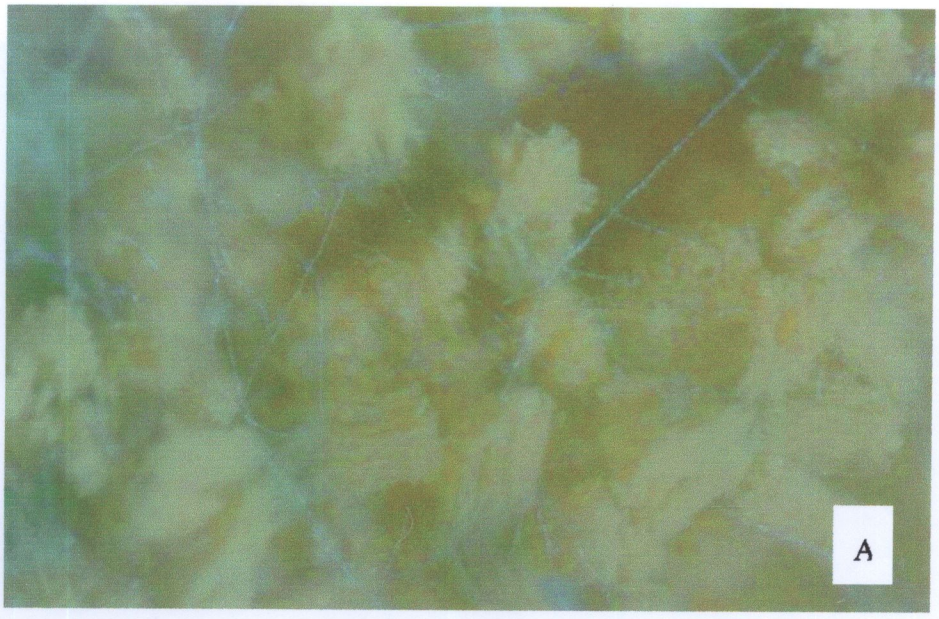
Appendix Figure 5 *Aspergillus aeneus*; A : Subglobose Conidial Head 1000 x, B : Verucose Conidiospore 1000 x



Appendix Figure 6 *Aspergillus alutaceus*; Radiate Conidial Head 60 x

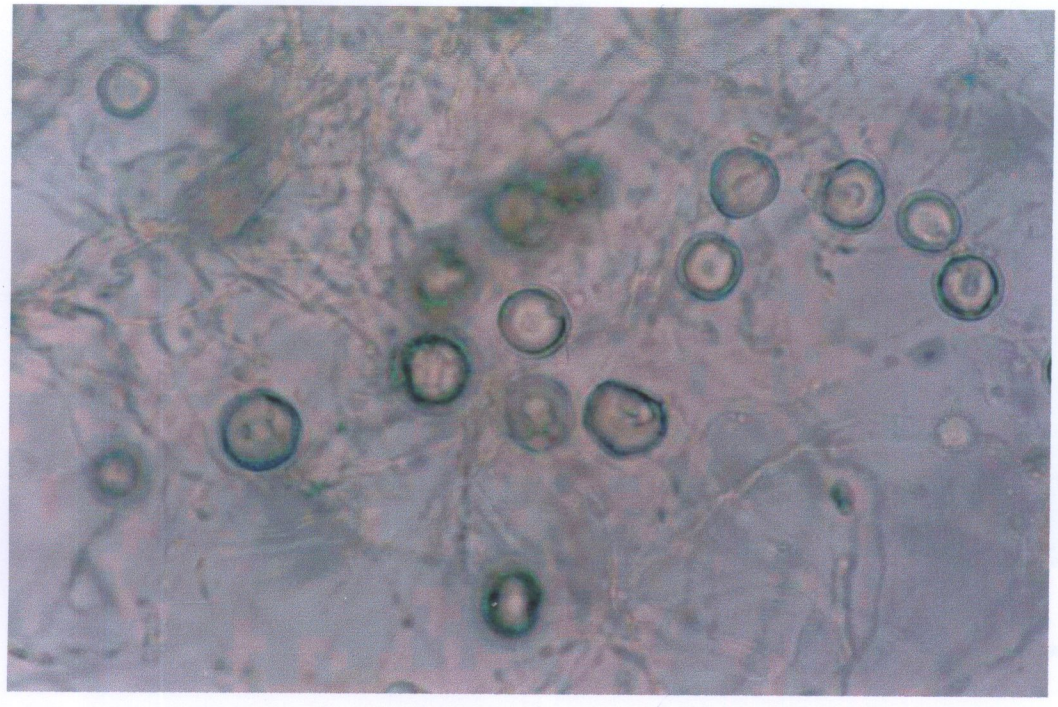


Appendix Figure 7 *Aspergillus flavipes*; Globose Conidial Head 50 x

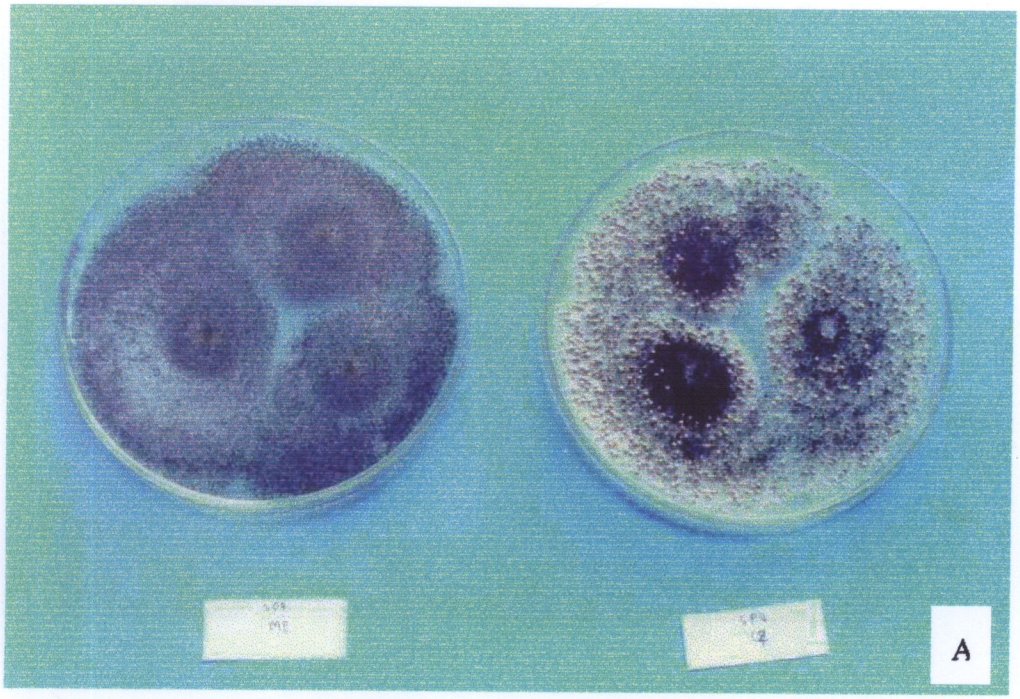


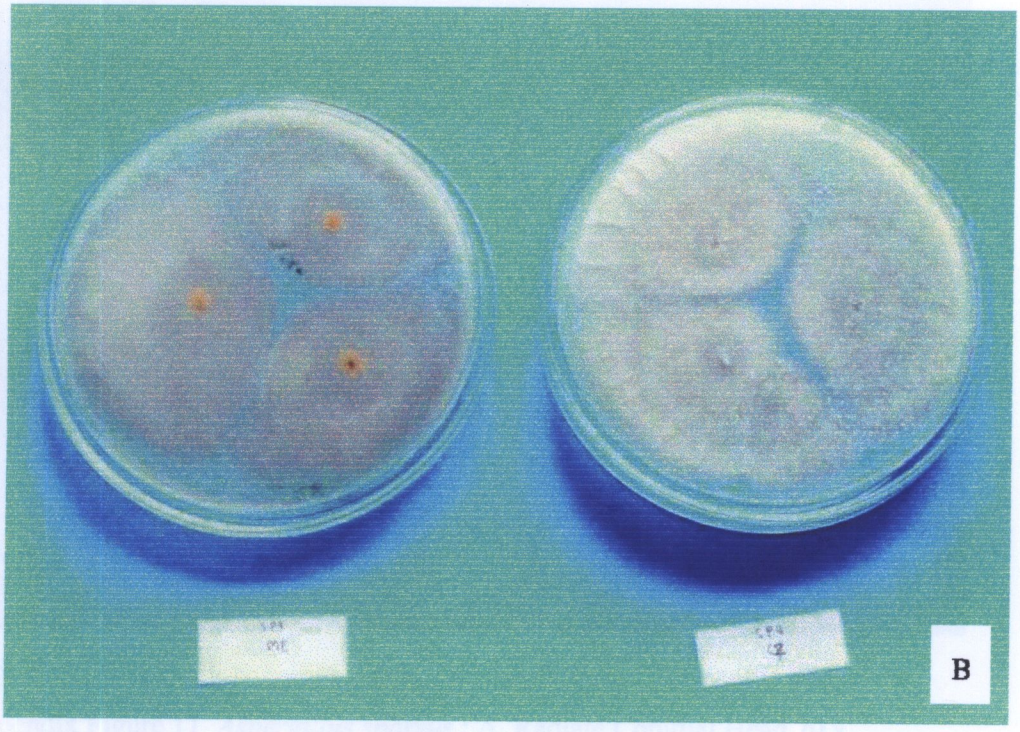
Appendix Figure 8 *Aspergillus flavus* ; A : Radiate conidial Head 70 x,

B : Conidial Head, 400 x



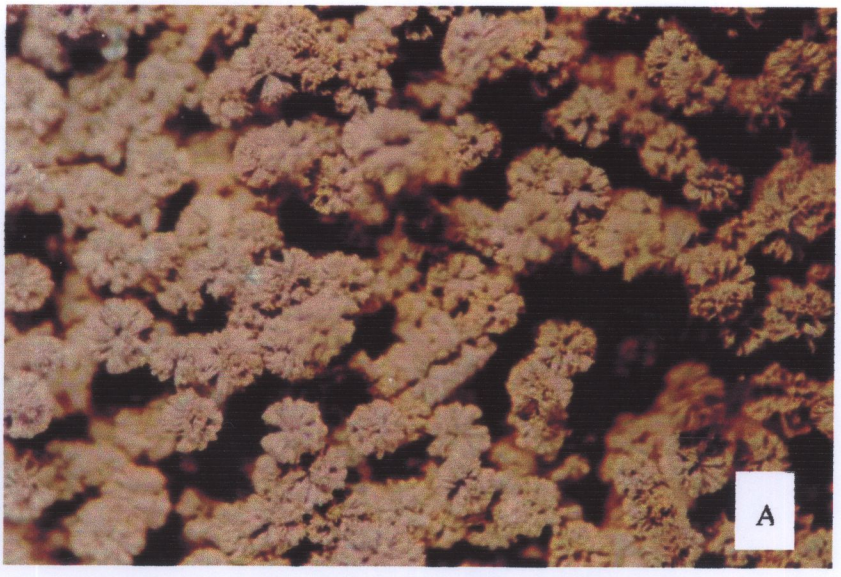
Appendix Figure 9 *Emericella nidulan* ; Hulle Cell 1000 x

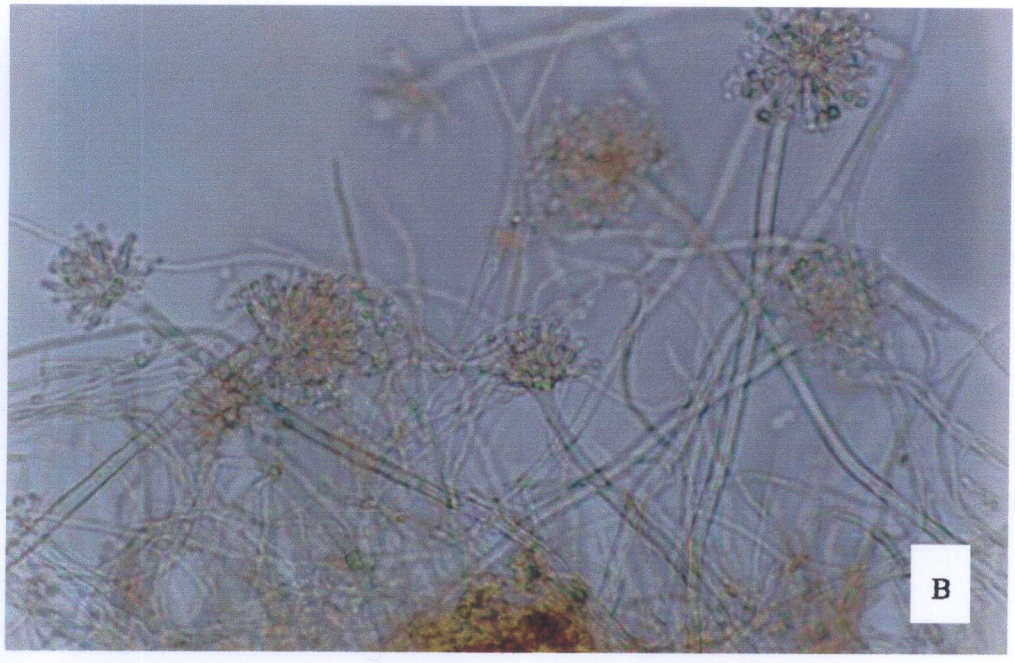




Appendix Figure 10 *Aspergillus niger* ; A : Obverse on CZA and MEA,

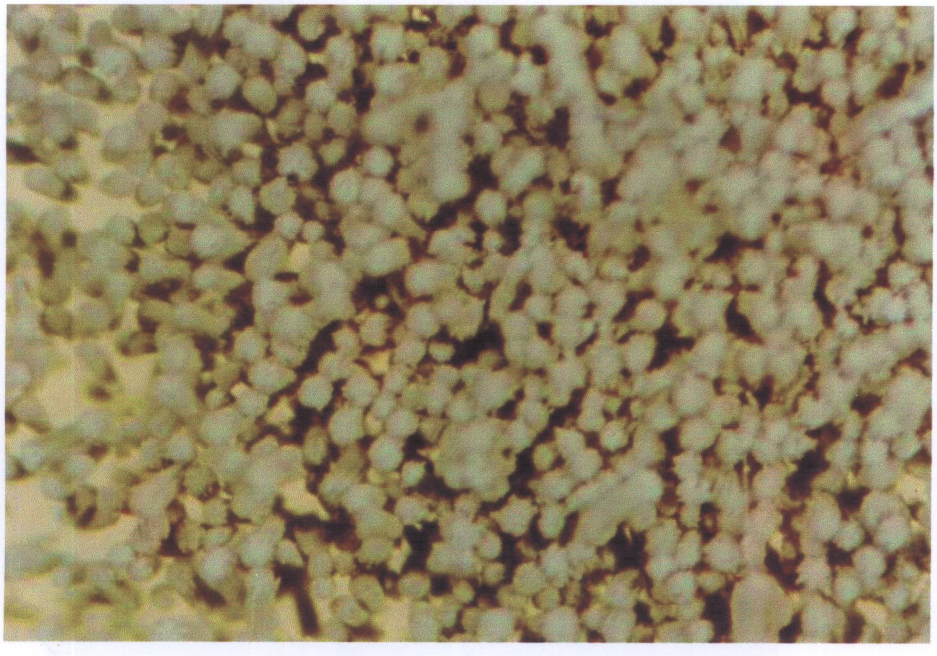
B : Reverse on CZA and MEA, 14 days,



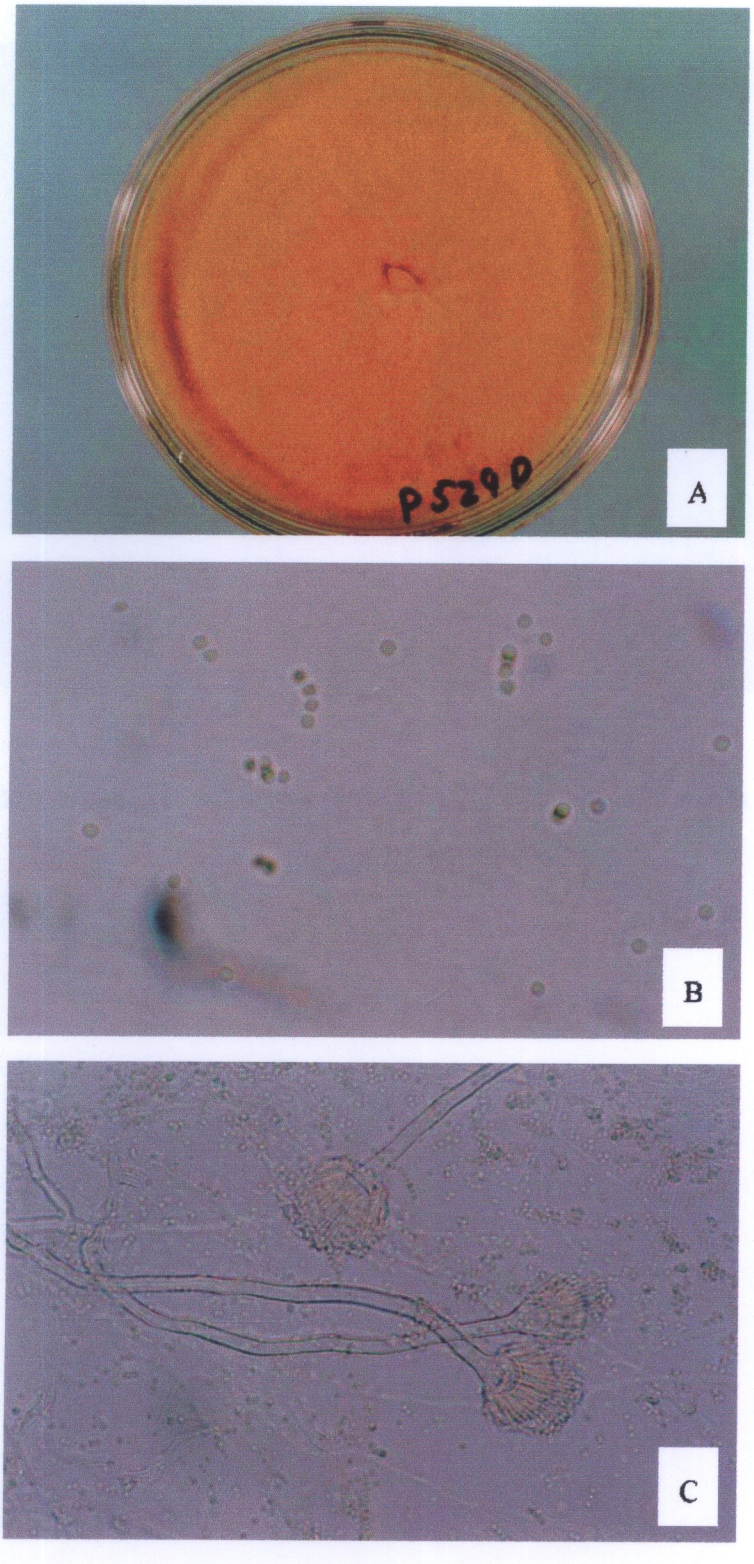


Appendix Figure 11 *Aspergillus sparsus* ; A. Radiate Conidial Head 70 x,

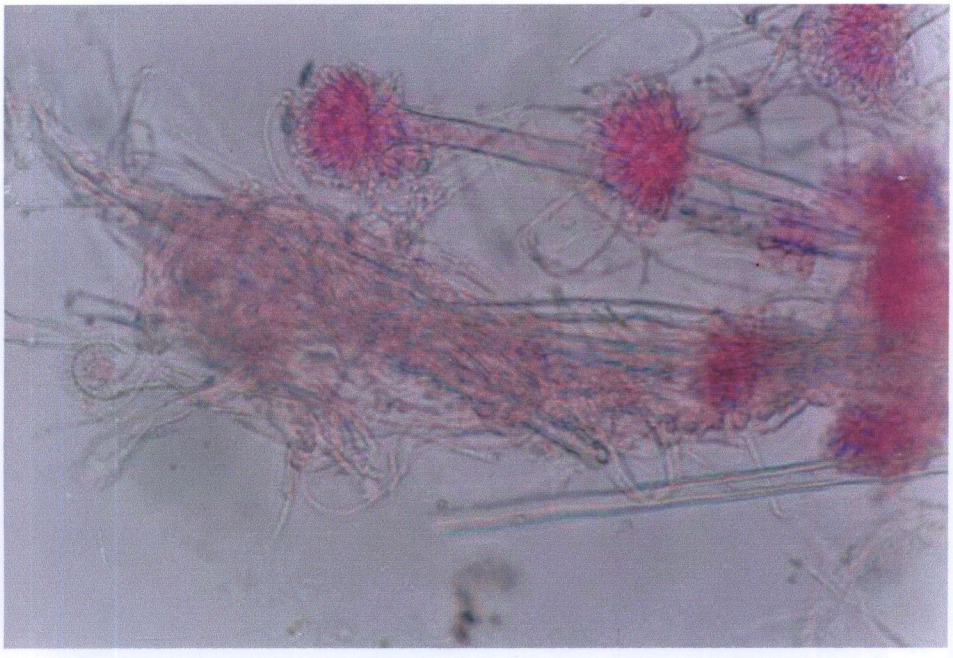
B. Conidial Head 1000 x



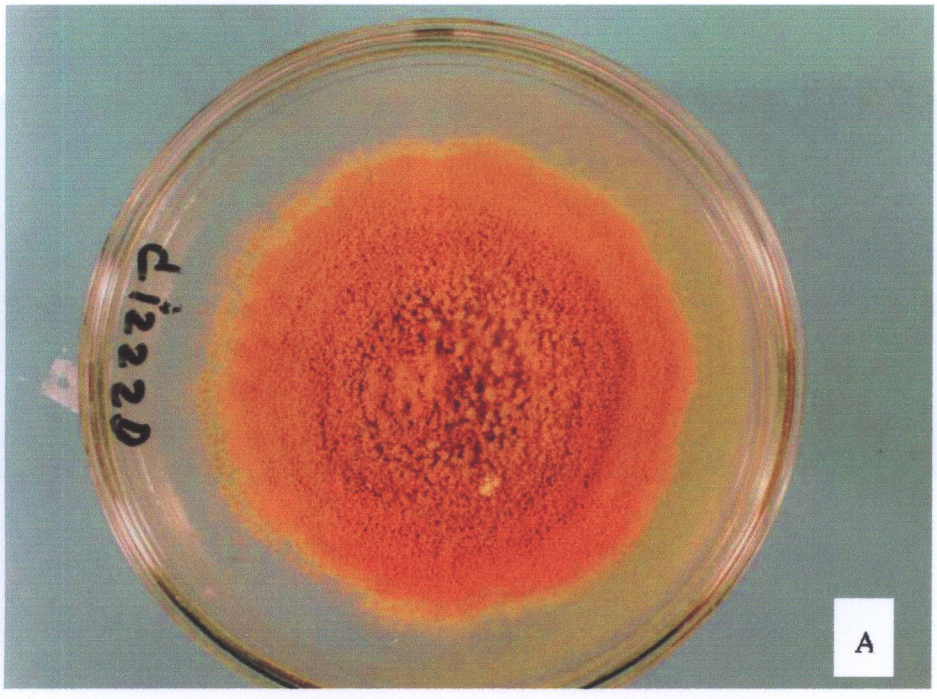
Appendix Figure 12 *Aspergillus sydowi* ; A. Conidial Head, 60 x

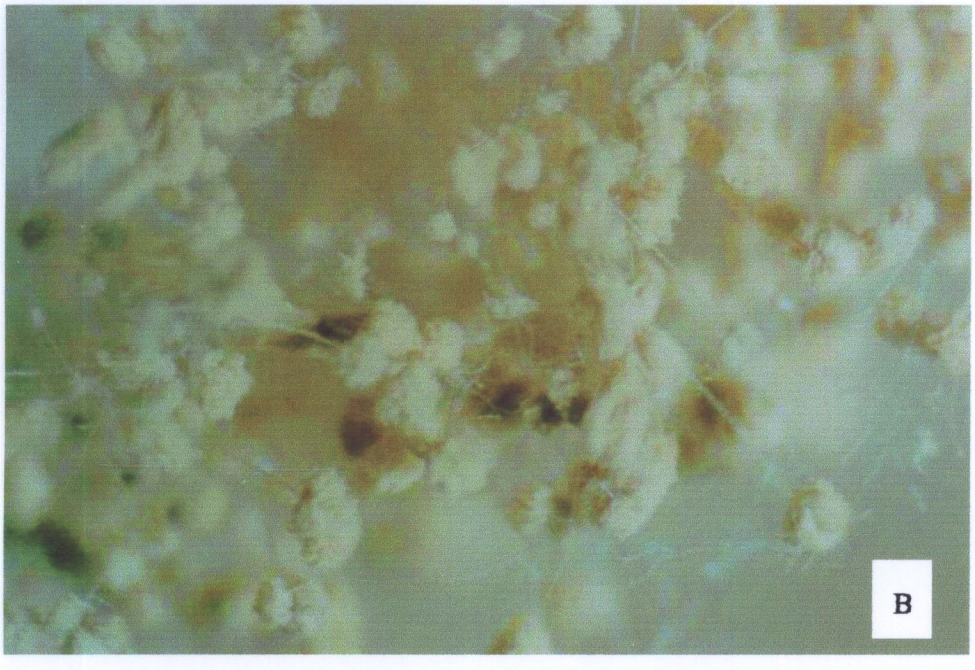


Appendix Figure 13 *Aspergillus terreus* ; A. Colony on CZA, 14 days, B : Conidia 1000 x, C : Conidial Head 1000 x



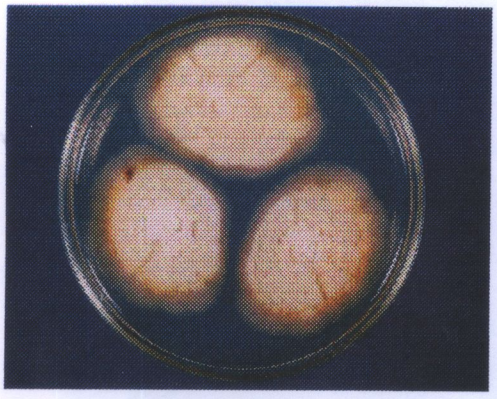
Appendix Figure 14 *Aspergillus versilolour* ; Conidial Head 1000 x



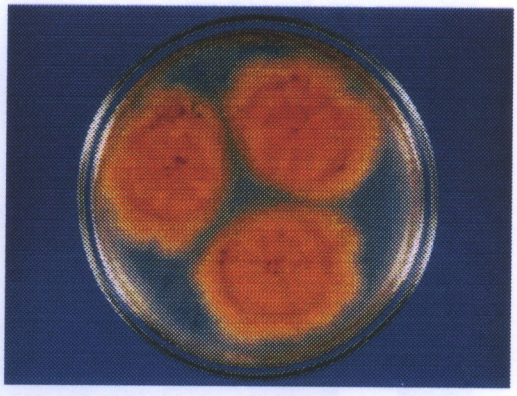


Appendix Figure 15 *Aspergillus wentii* ; A : Colony on CZA, 10 days, at 28°C

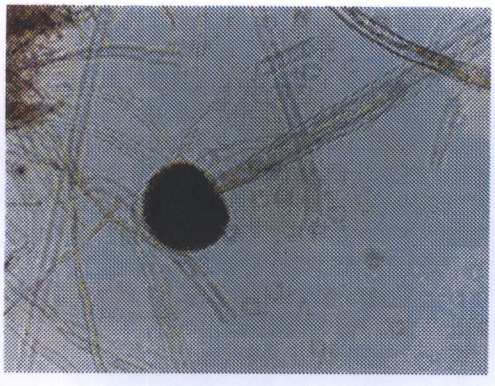
B : Radiate Conidial Head 70 x



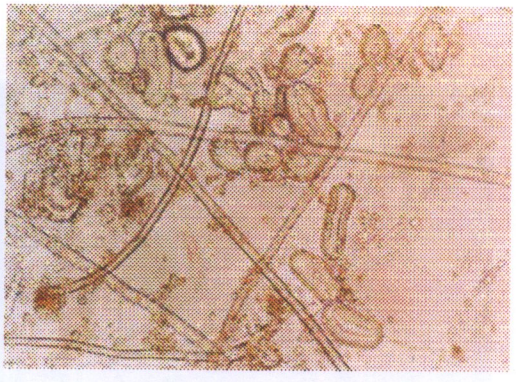
(A)



(B)

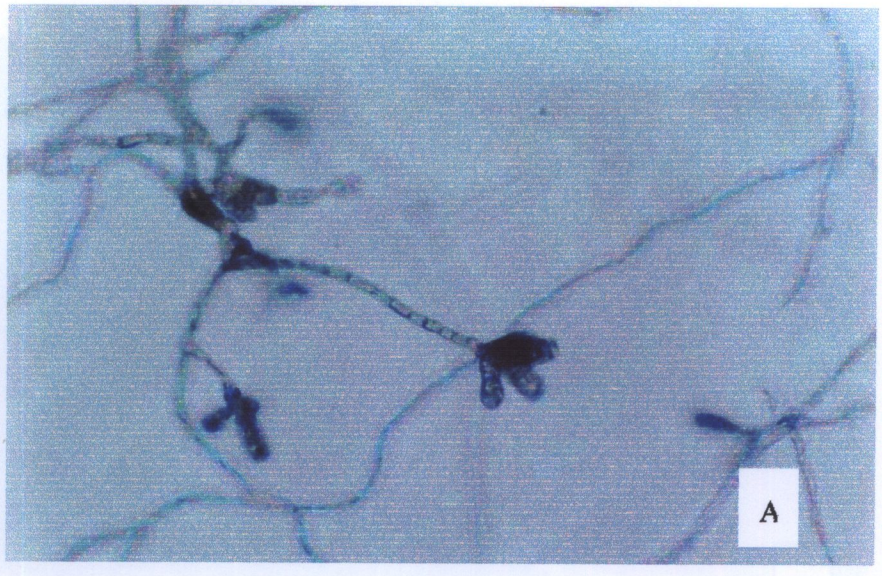


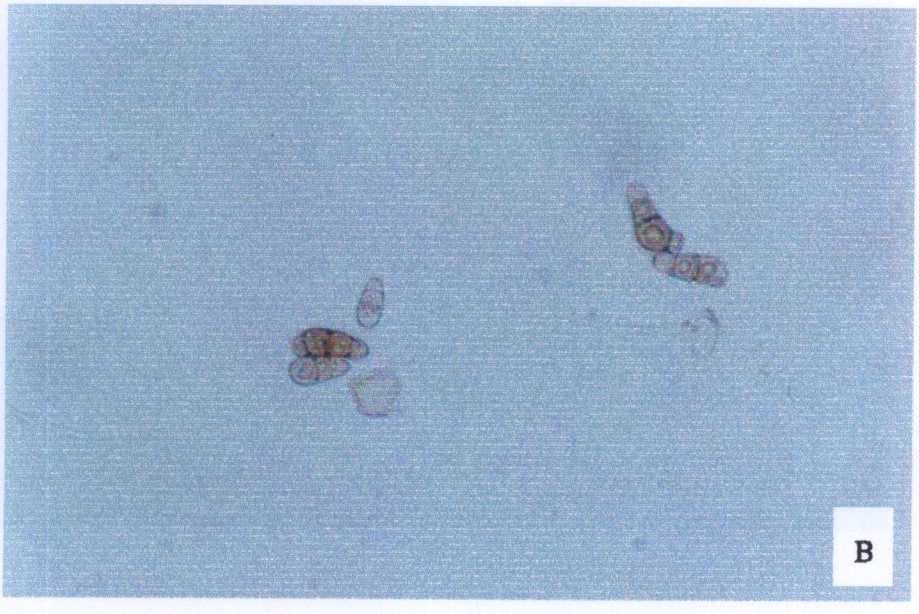
(C)



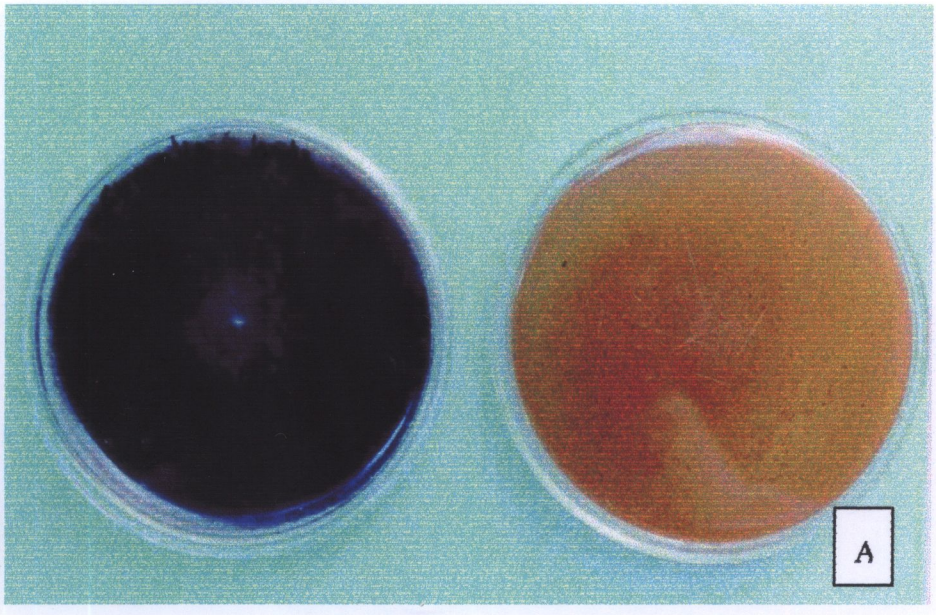
(D)

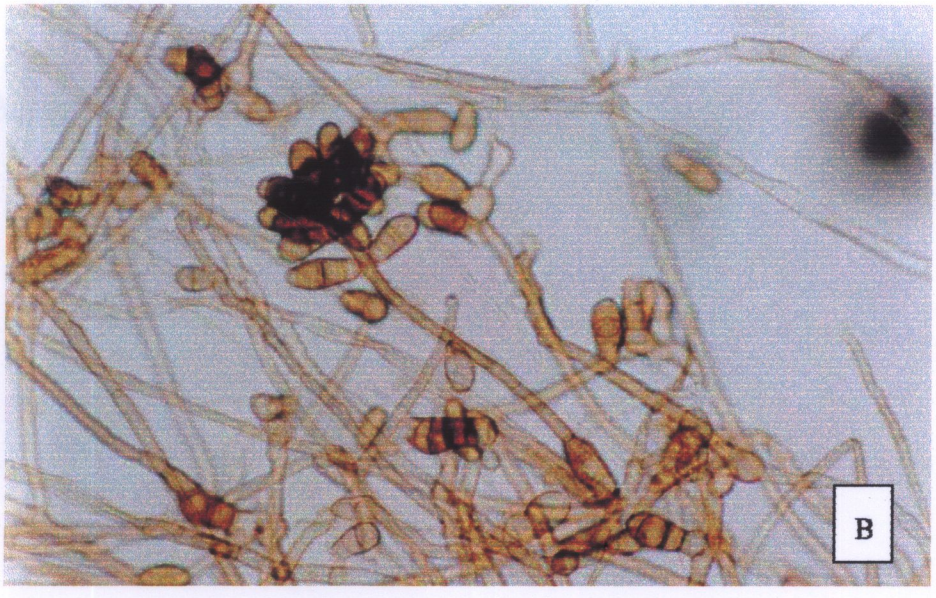
Appendix Figure 16 *Aspergillus ustus* ; A : Colonies on CZA, 14 days
B : Reverse Colonies on CZA, 14 days ; C : Conidial Head 1000x
D : Elongate Hulle Cell 1000x



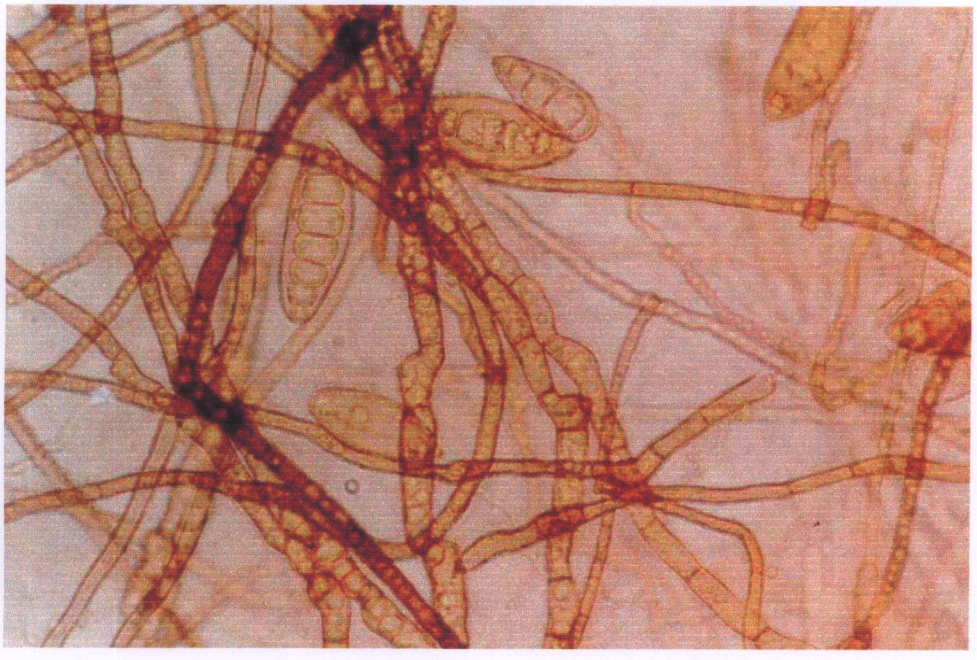


Appendix Figure 17 *Cuvularia geniculata*; A : Conidia and Conidiophore 400 x, B : Conidia 400 x

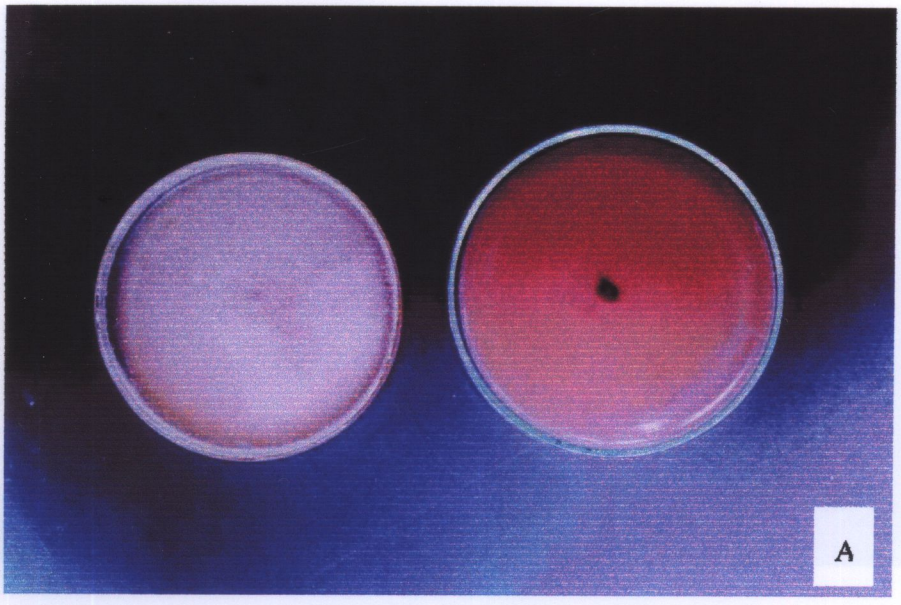


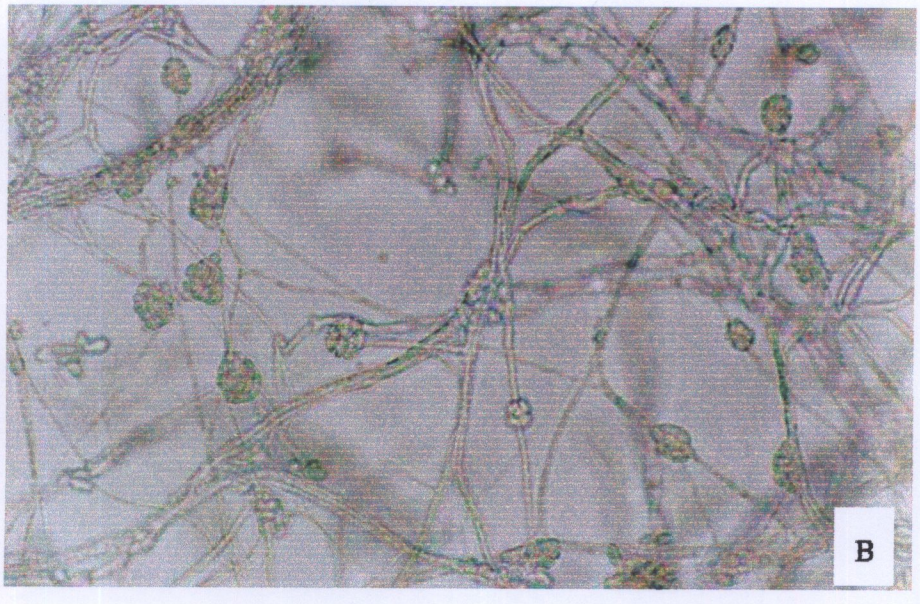


Appendix Figure 18 *Cuvularia lunata* ; A. Obverse and Reverse on CMA, 14 days, B : Conidia 400 x

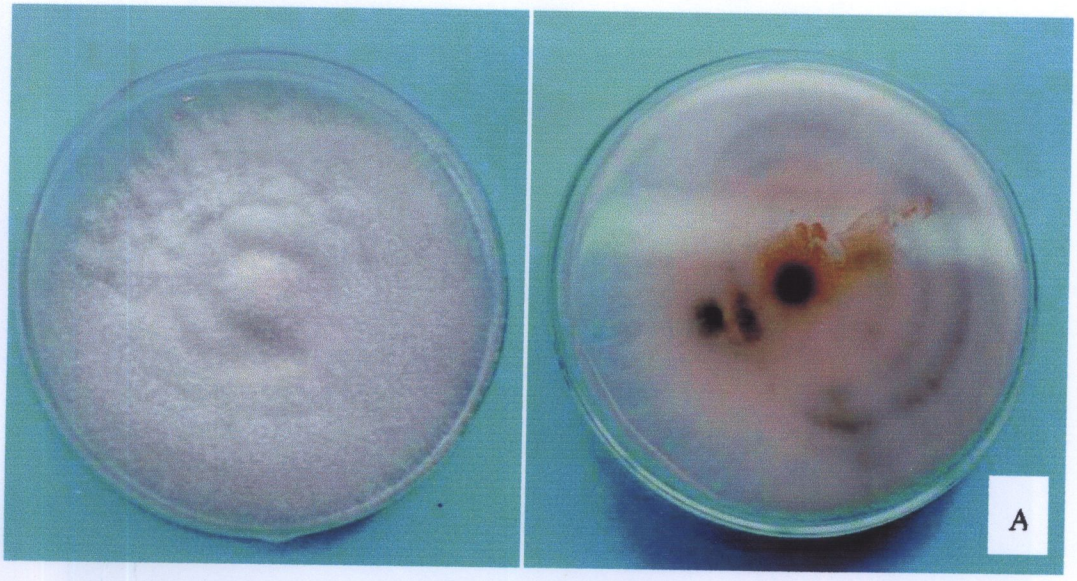


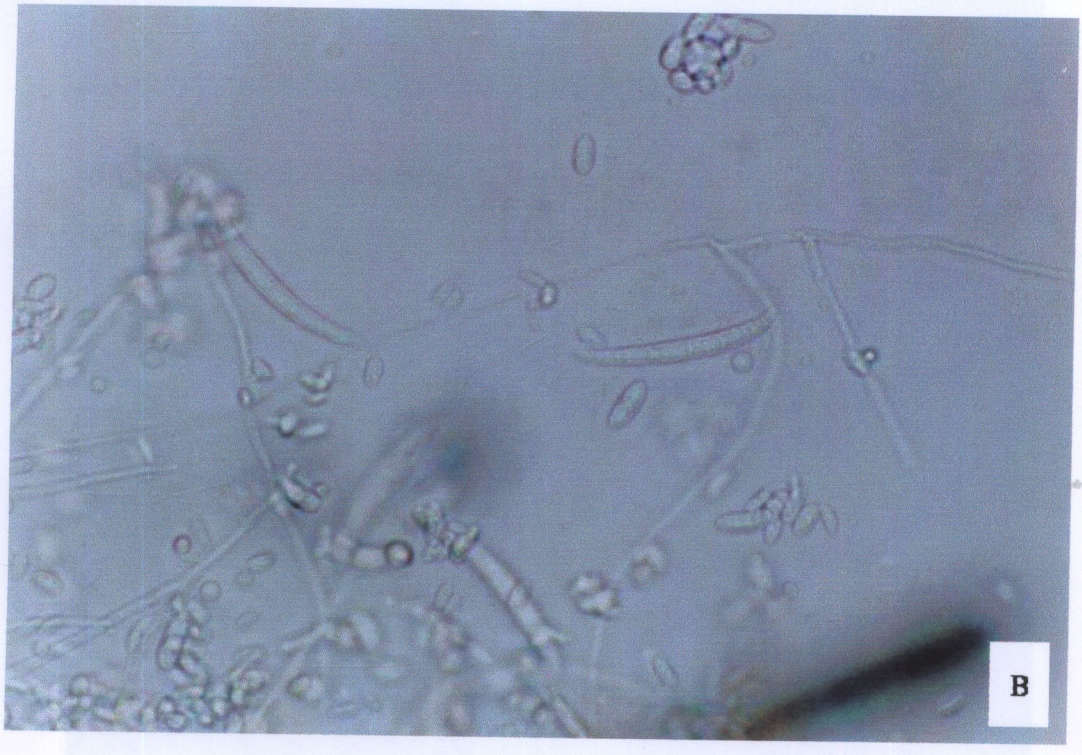
Appendix Figure 19 *Drechlera* sp., Conidia 1000 x



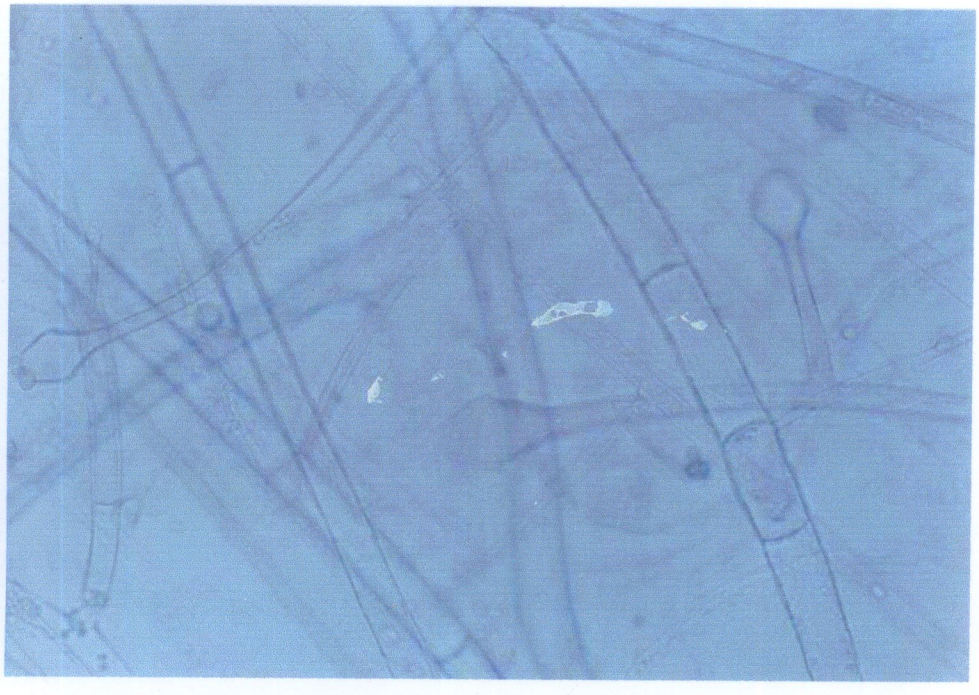


Appendix Figure 20 *Fusarium muliniforme* ; A : Obverse and Reverse on CZA, 14 days, B : Microconidia 1000 x

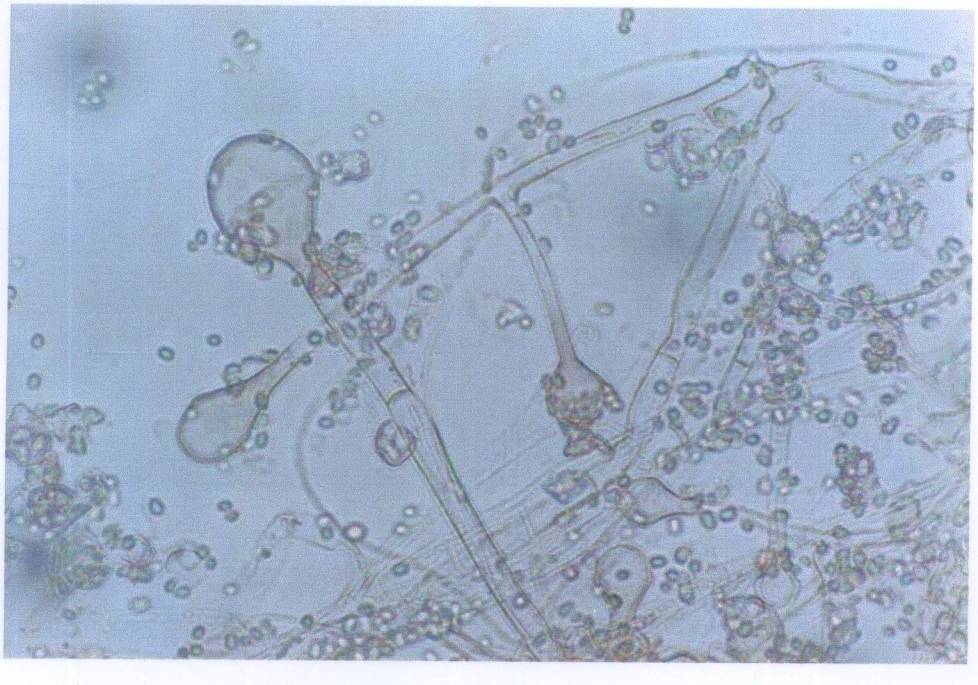




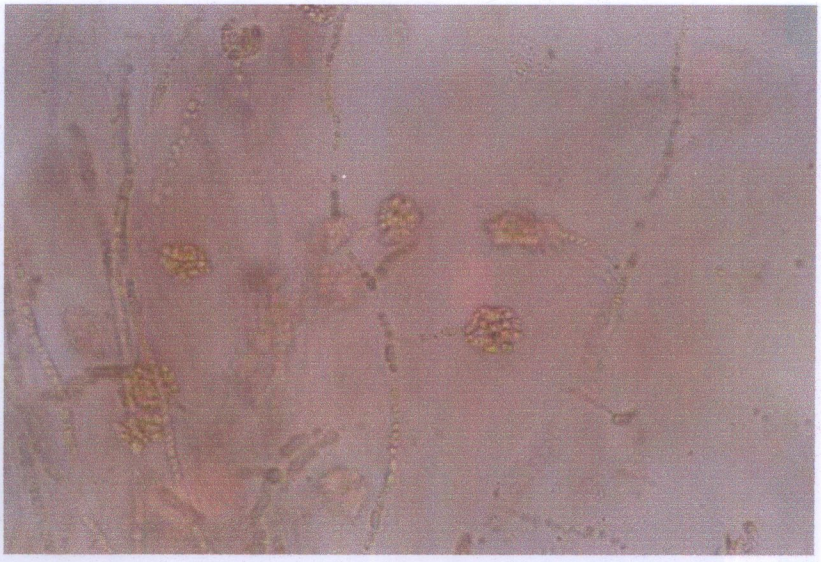
Appendix Figure 21 *Fusarium illudens* ; A : Obverse and Reverse on CMA, 14 days, B : Macroconidia and Microconidia 1000 x



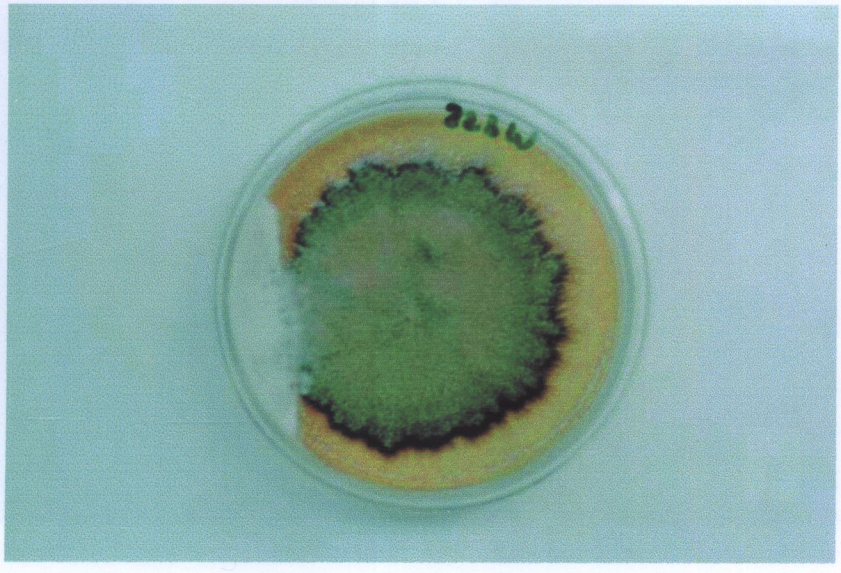
Appendix Figure 22 *Mucor* sp. 1; Vesicle 400 x



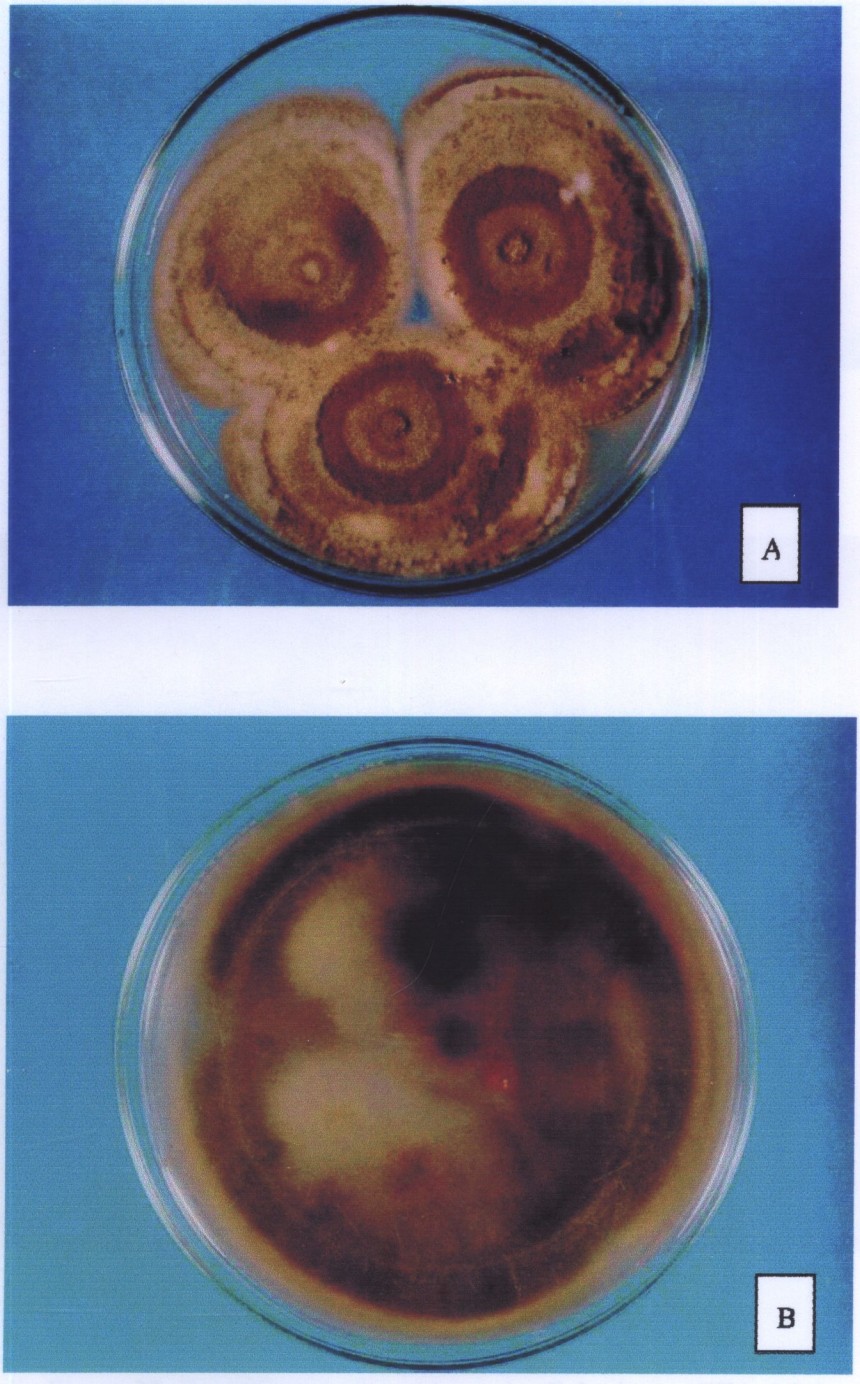
Appendix Figure 23 *Mucor* sp. 2; Vesicle and Conidia 400 x



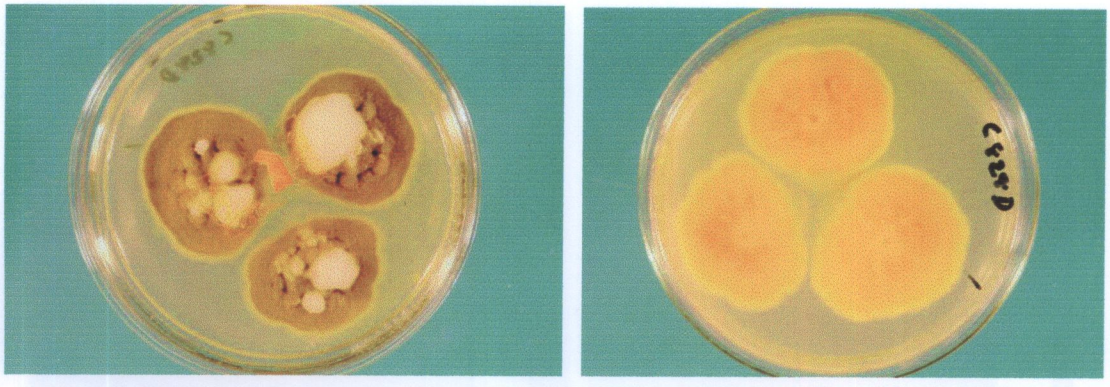
Appendix Figure 24 *Fusarium* sp.; Microconidia 1000 x

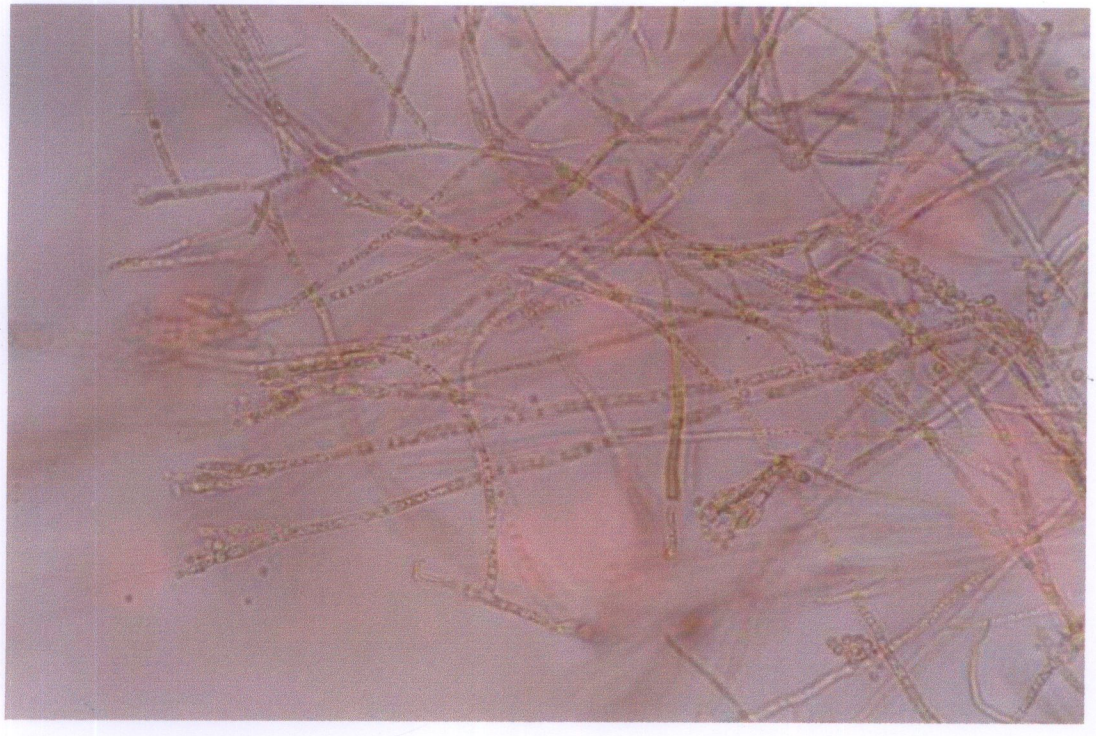


Appendix Figure 25 *Penicillium erythrocephalus*; Conoly on CZA, 14 days, at 30°C



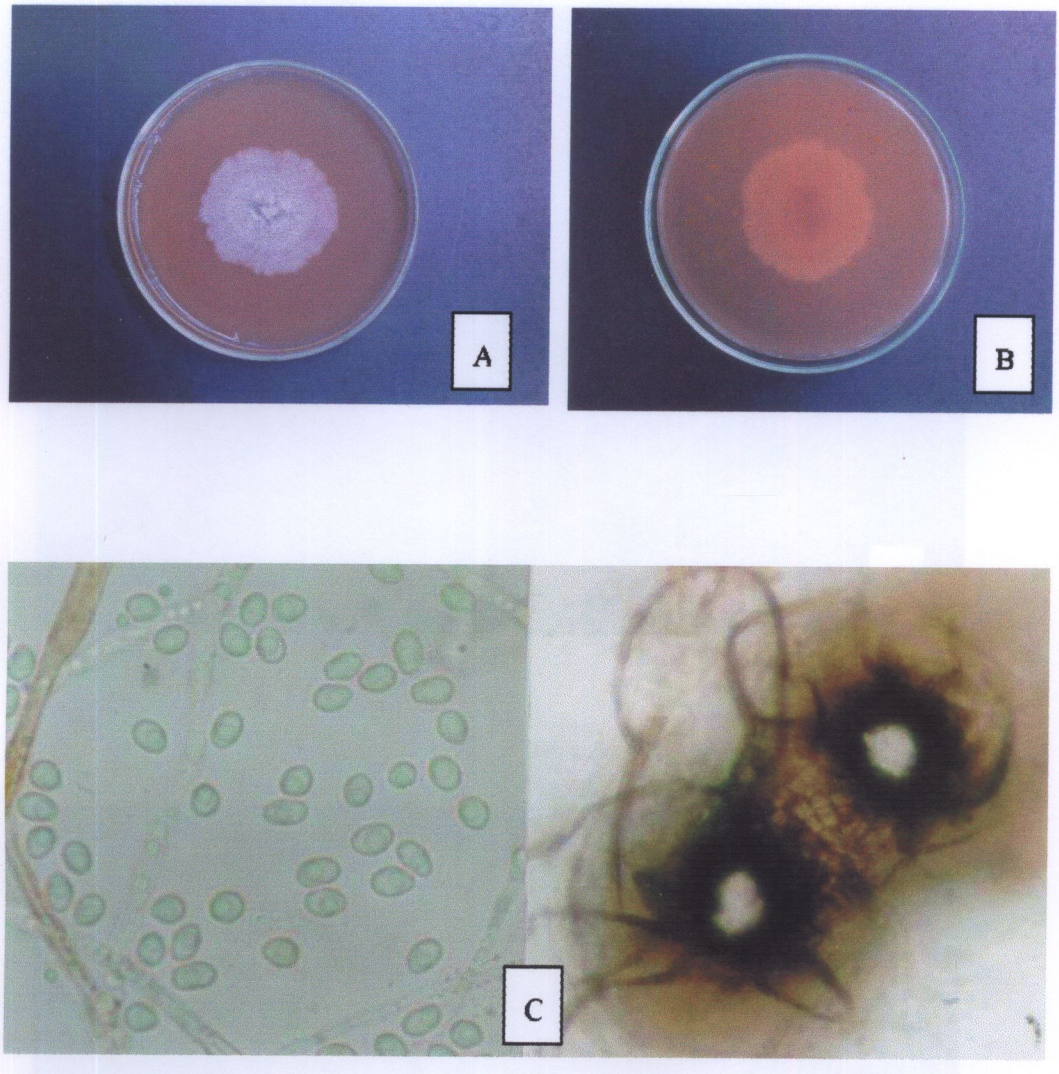
Appendix Figure 26 *Penicillium ramigenum* ; A : Colonies on CZA, 14 days, B : Reverse on CZA, 14 days



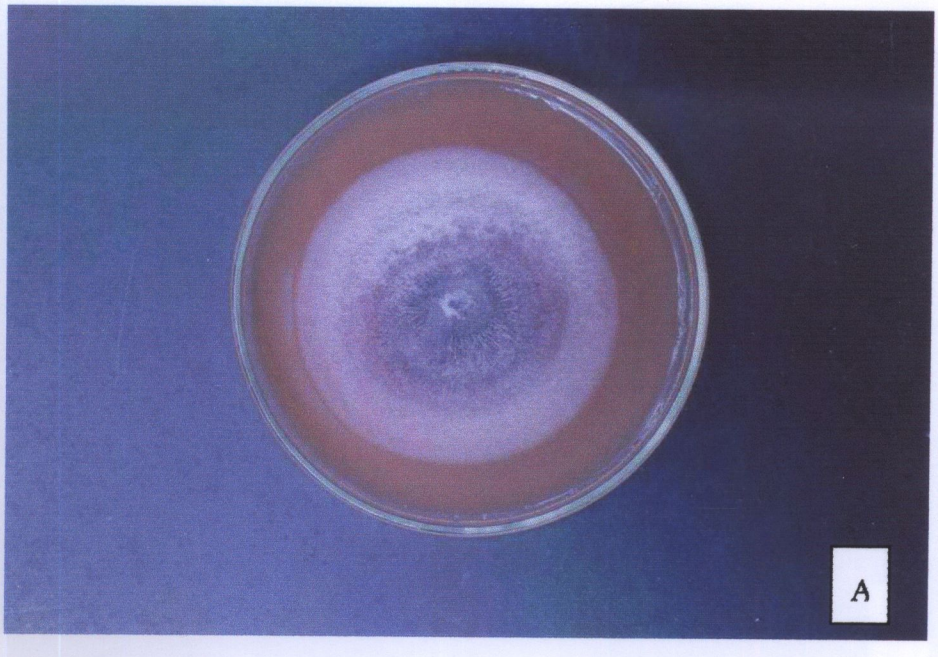


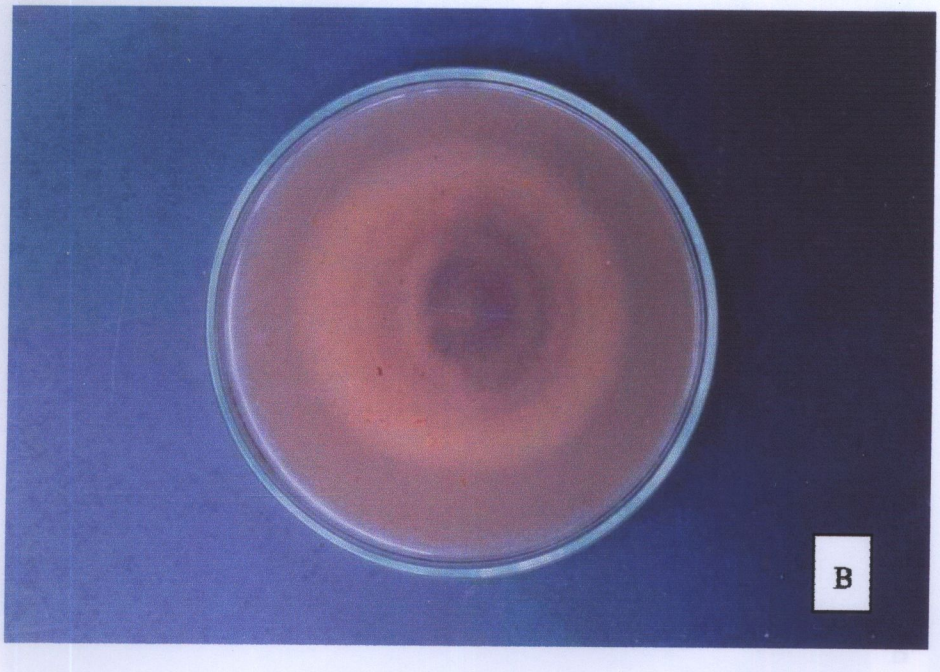
Appendix Figure 27 *Penicilium sublateritium* ; A : Colonies on CZA, 14 days,

B : Reverse on CZA, 14 days, C : Phialide and Conidia, 1000 x



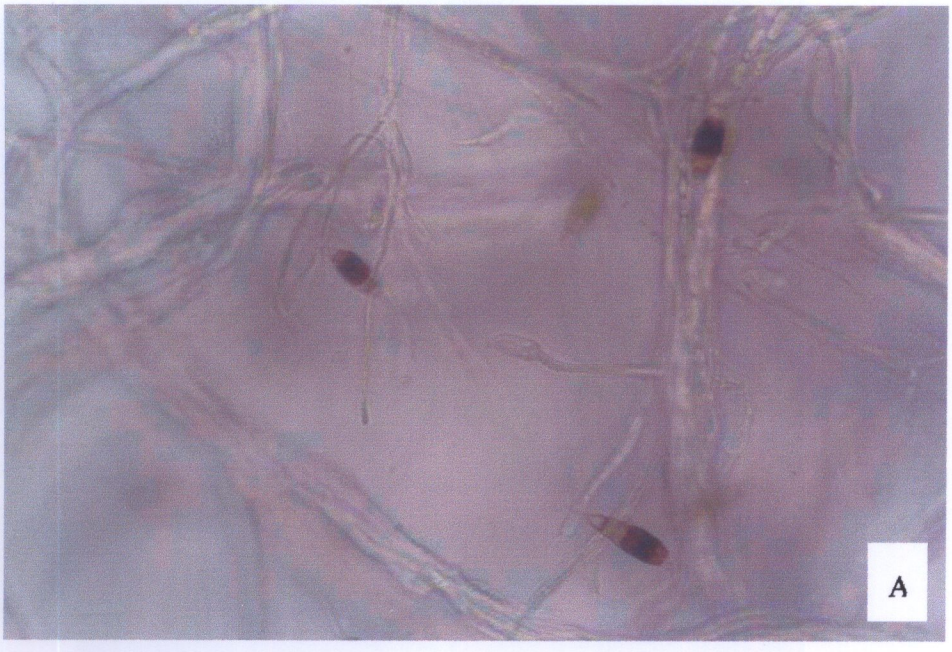
Appendix Figure 28 *Phoma lingams*; A, B : Obverse and Reverse on V-8, 14 days, C : Conidia and Pycnidia 1000 x

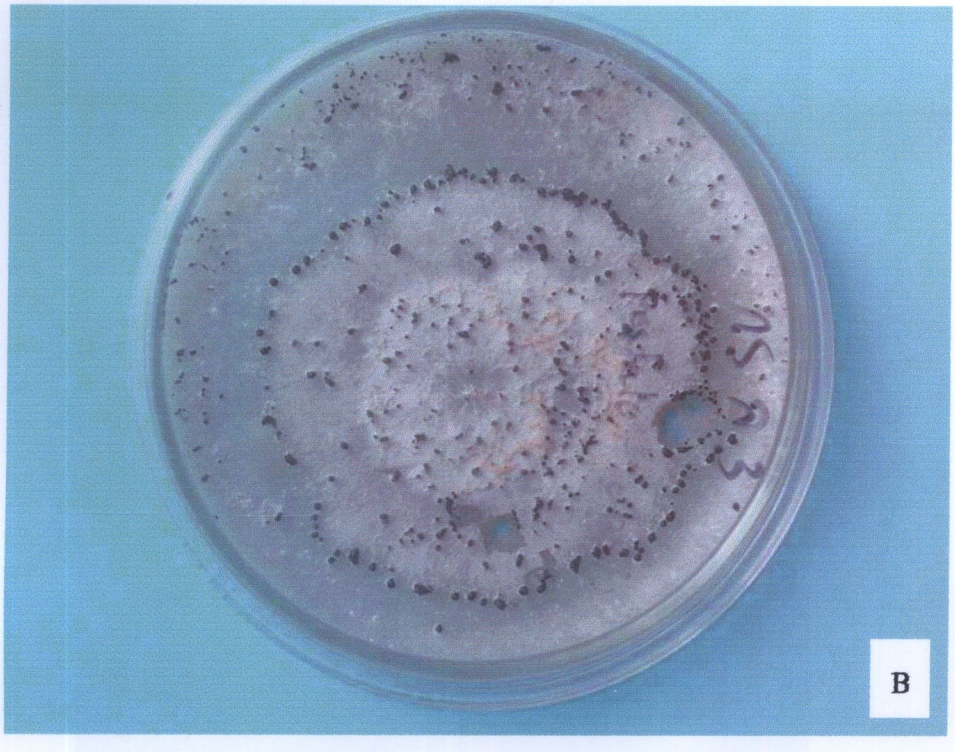




Appendix Figure 29 *Phoma nebulosa* ; A : Colony on V-8, 14 days, at 30°C,

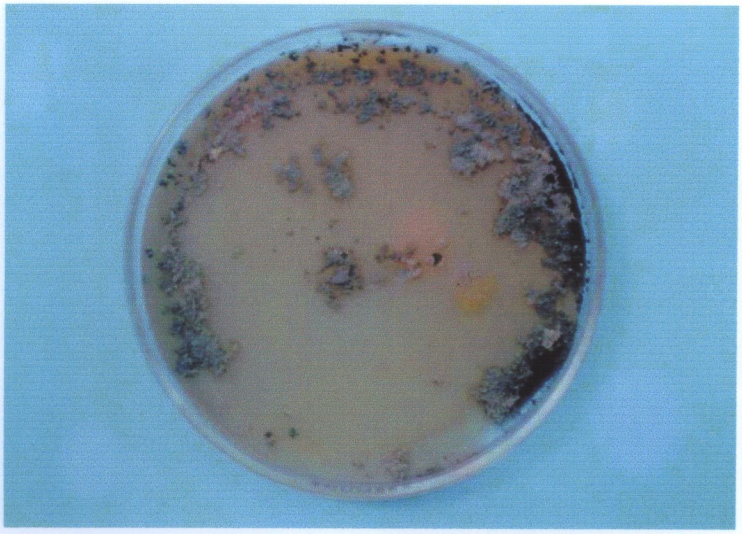
B : Reverse on V-8, 14 days, at 30°C

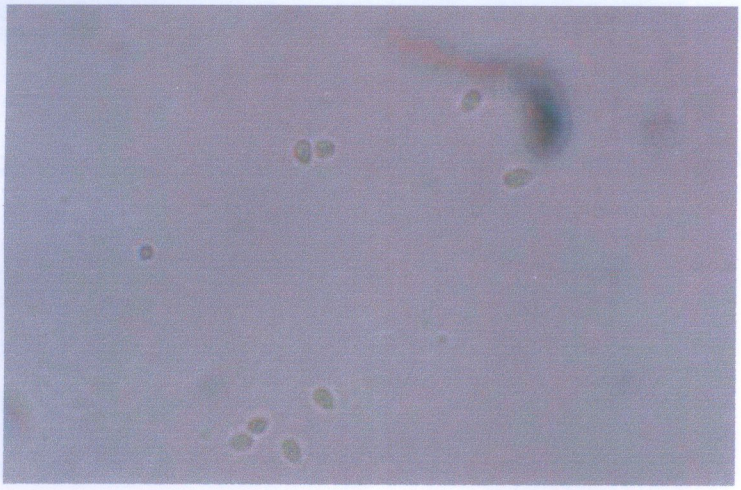


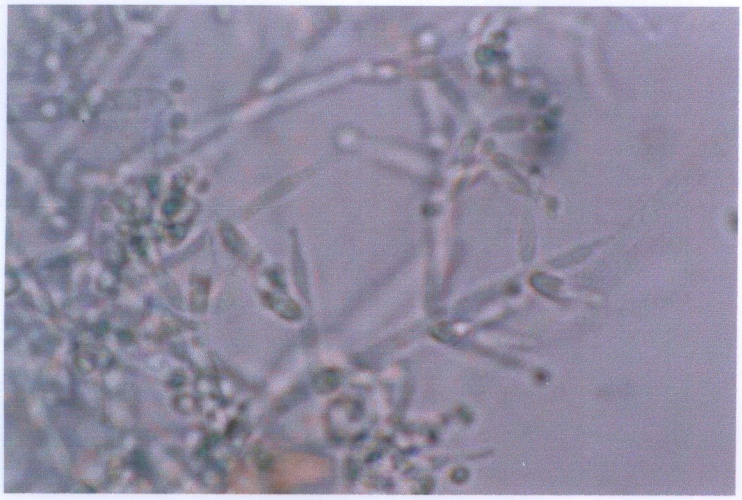


Appendix Figure 30 *Pestalotiopsis guipinii* ; A : Conidia 1000 x,

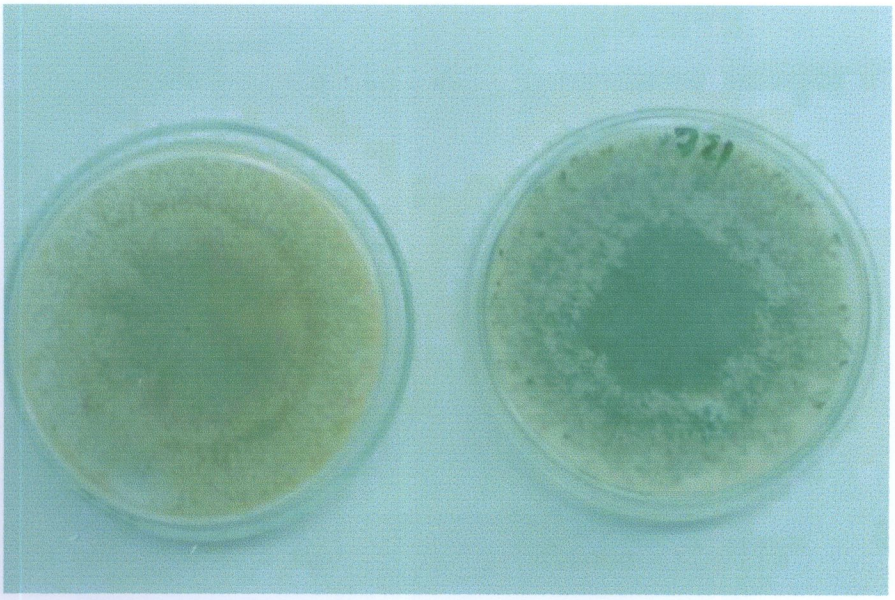
B : Colony on CMA, 14 days at 30°C



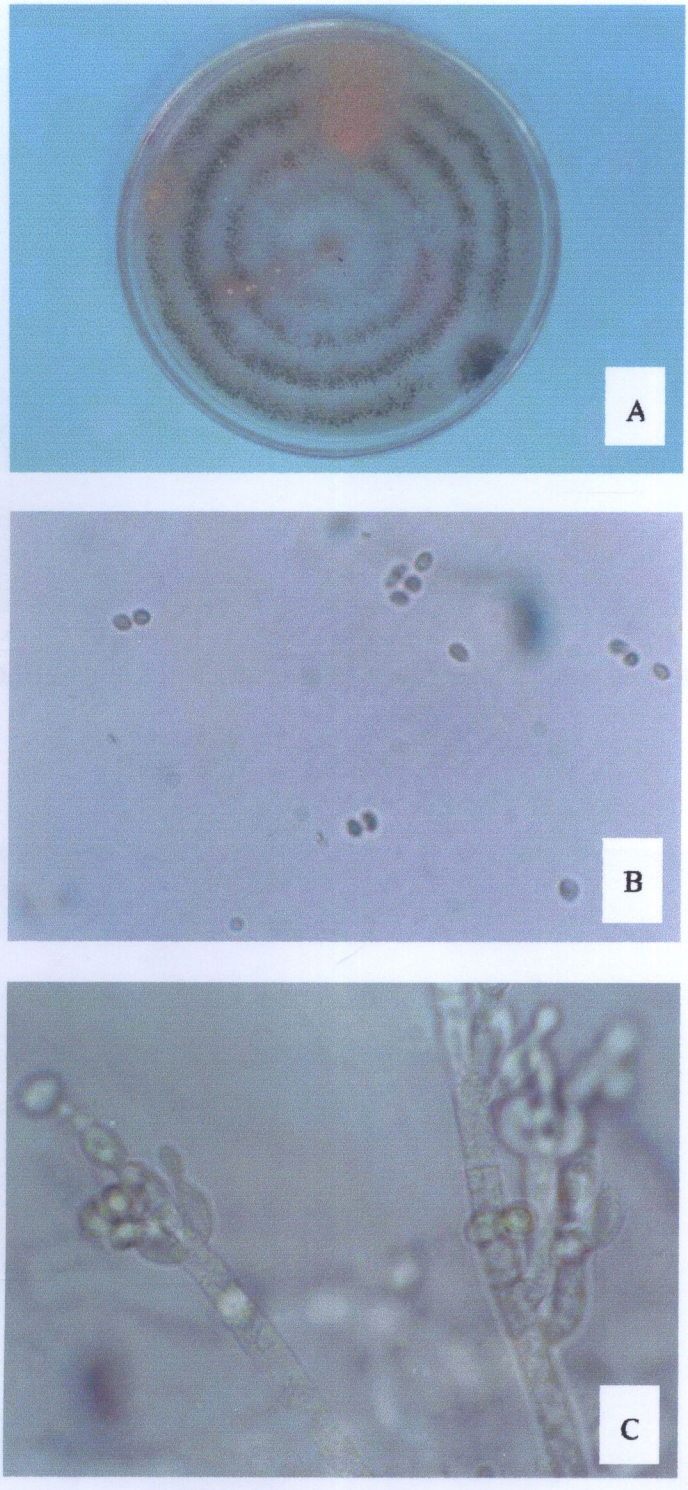




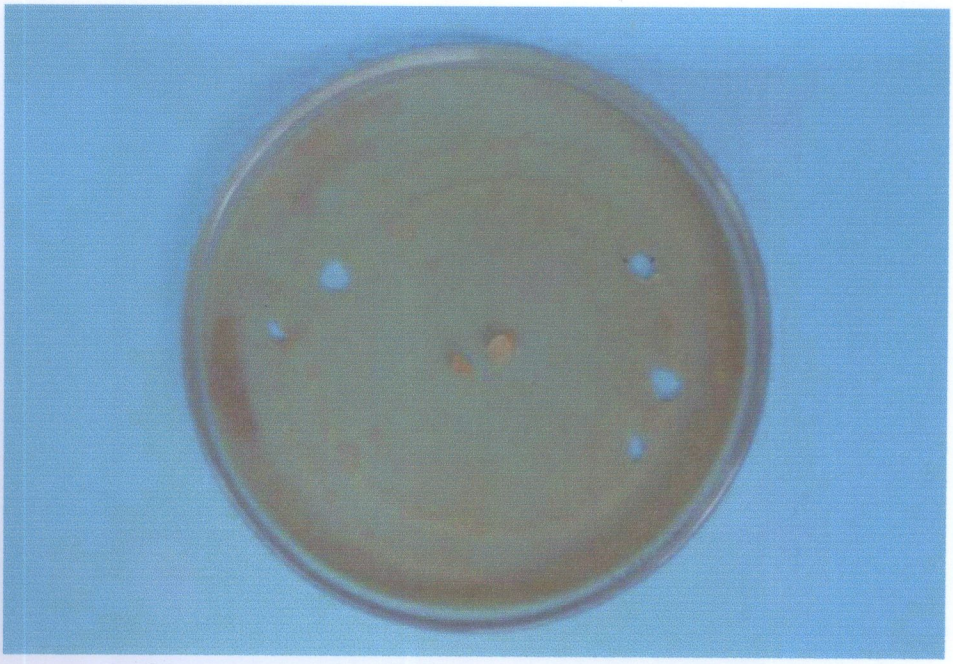
Appendix Figure 31 *Trichoderma aureoviride* ; A : Colony on CMA, 21 days, B : Conidia 1000 x, C : Phialide 1000 x



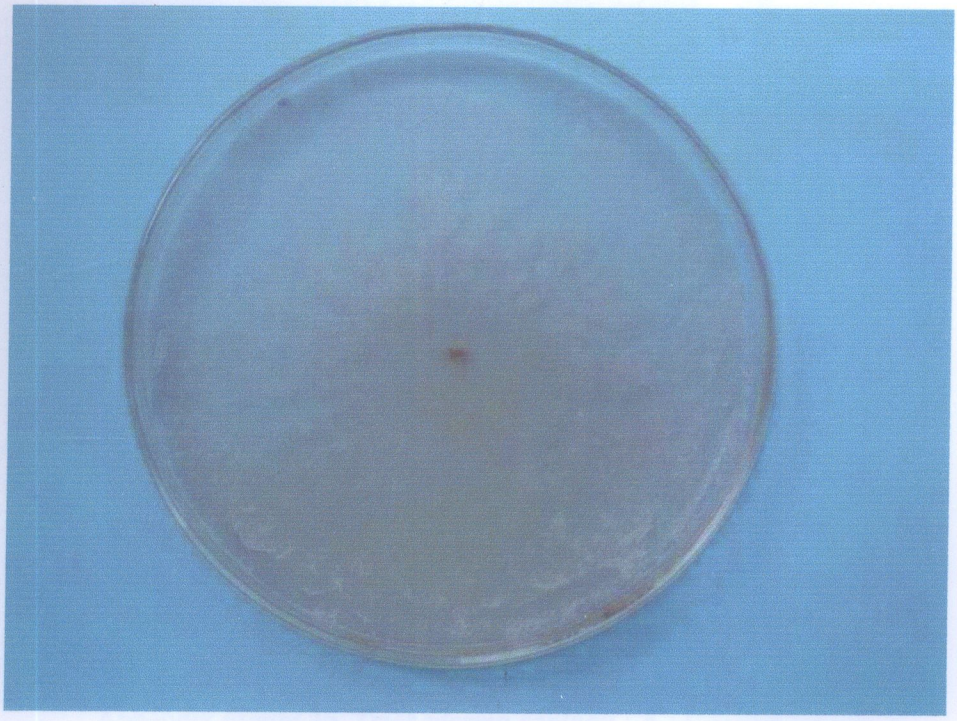
Appendix Figure 32 *Trichoderma hamatum* ; Colonies on CMA, 14 days, at 30°C



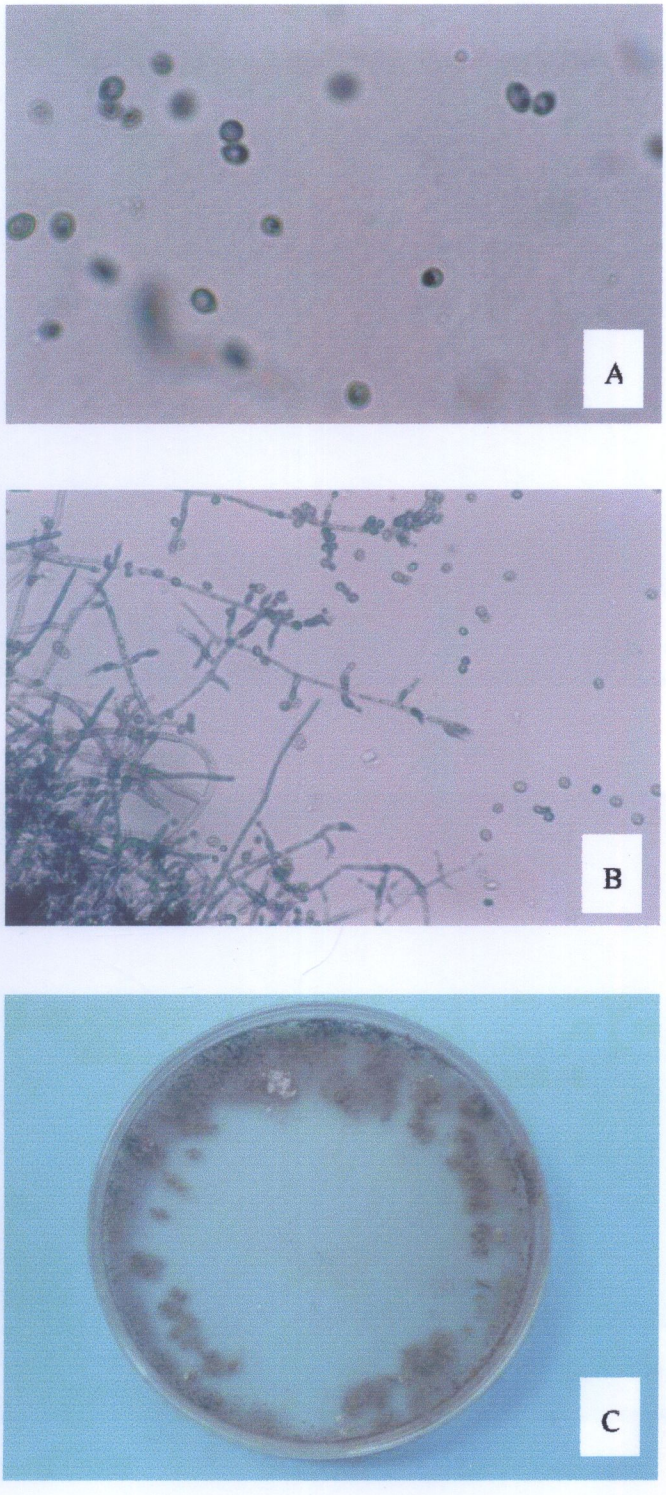
Appendix Figure 33 *Trichoderma harzianum* : A : Colony on CMA, 14 days, B : Conidia 400 x, C : Phialide 1000 x



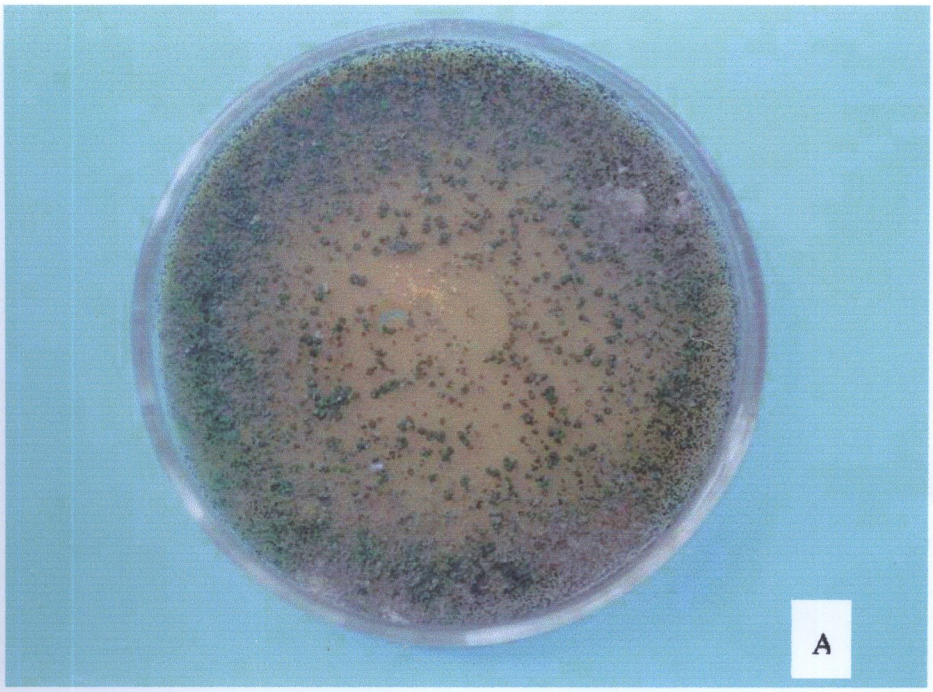
Appendix Figure 34 *Trichoderma polysporum* ; Colony on CMA, 14 days, at 30°C



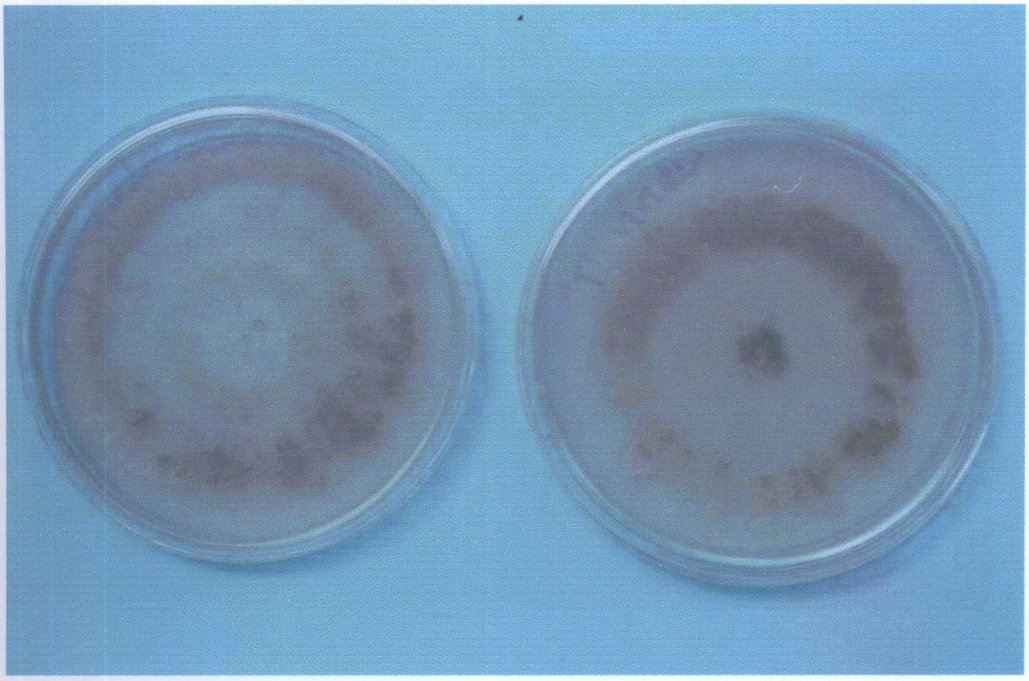
Appendix Figure 35 *Trichoderma poluliforum* ; Colony on CMA, 14 days, at 30°C



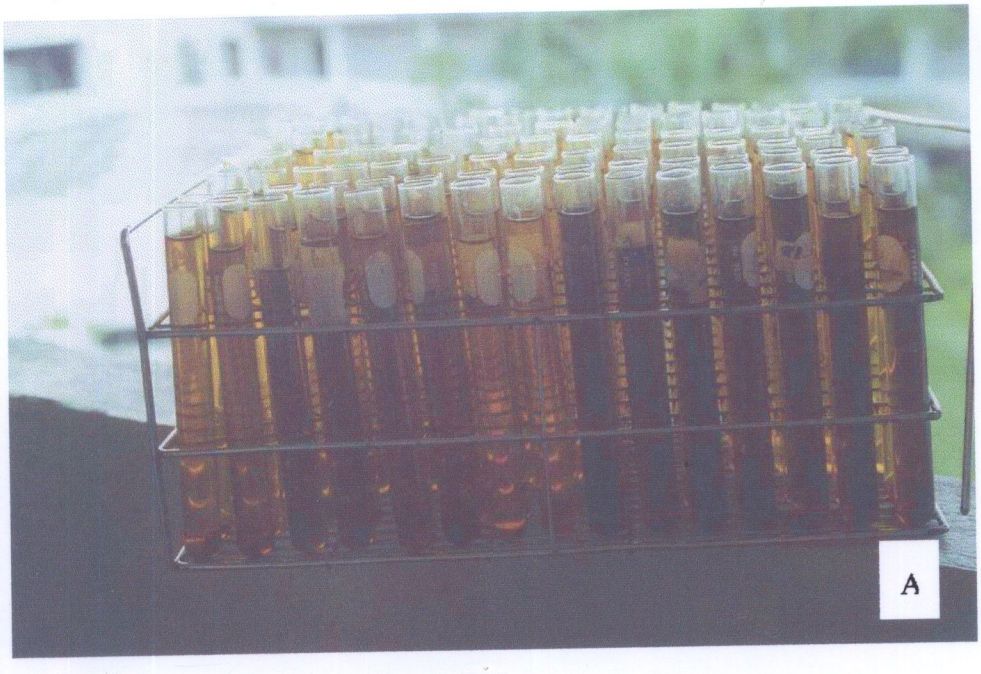
Appendix Figure 36 *Trichoderma koningii* ; A : Conidia 1000 x, B : Phialide 400 x, C : Colony on CMA, 21 days



Appendix Figure 37 *Trichoderma pseudokoningii* ; A : Colony on CMA, 14 days, B : Phialide 1000 x



Appendix Figure 38 *Trichoderma viride* ; Colony on CMA, 14 days, at 30°C



Appendix Figure 39 A : Glucose Production from Cellulose Powder, Filter Paper, Xylan, Lingin and Cellulose on *A. alba* and *R. apiculata* Leaves Degraded by Various Fungal Species at 15 and 30 ppt Salinity as Compare to the Control Bank,
B : Spectrophotometer UV 1601