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A Comparative Account of the Diversity and Distribution of Fungi in Tropical Forest Soils and Sand Dunes of Orissa, India

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ABSTRACT An investigation was carried out to estimate micro fungal population and its relationship with physico-chemical properties in natural tropical forest soil, deforested soil, deforested-cum-cultivated soil, barren sand dune, sand dune with monoculture plantation of *Casuarina* and sand dune with monoculture plantation of *Anacardium*.. Microbial isolation and soil analysis was performed using standard procedures. The micro fungal population ranged from 35.5 to 1276.2 g^{-1} dry soil in different study sites. They corresponded to the fluctuation of prevailing temperature, moisture and total organic carbon content of the said habitat. . A total of 285 species of fungi belonging to 113 genera were enumerated. The majorities were from the genus *Aspergillus*; the next two in order of dominance were *Penicillium* and *Trichoderma*. The diversity values (H) show an increase as we move from barren sand dune to deforested-cum-cultivated soil. Shannon's diversity index is reasonably high varying from 3.528 to 4.144 correspondingly the dominance values are low varying from 0.0242 to 0.0499. The evenness values, however, show a different trend. The surface soil of forest has the highest species richness where as sub-surface soil of barren sand dunes shows lowest richness. The study revealed that the conversion of natural forest led to a reduction of soil organic matter. Considering the importance of microbial component in soil, we conclude that the conversion of natural forest to different land uses leads to the loss of biological stability of soil. Introduction of predominant decomposing microorganisms isolated from the present study can help to increase the nutrient status of the sandy sterile mass under focus is suggested.

INTRODUCTION

Fungal species are especially important component of biodiversity in tropical forests**.** Colonization and decomposition of leaf litter in soil is carried out by a wide range of microbes; particularly fungi and bacteria are crucial as they change and release many nutrients playing a vital role in nutrient cycling (Feller and Beare 1997; Parotta 1999; Sall et al. 2003; Szott et al. 1999) and sustenance of vegetation. Their function is often compared to a station through which, sooner or later, all carbon (C) originating from dead organic matter passes (Paul and VanVeen 1978; Jerkinson and Ladd 1981). From the late 1940s there has been a growing interest in soil mycology and soil borne fungal diseases of plants and this too has motivated the studies on soil fungi and their ecology (Subramanian 1986). Defining the number of fungi on earth has always been a point of discussion and several studies have focused on enumerating the world's fungal diversity (Crous 2006). It is very well experimented and concluded that soil fungal diversity and population density are invariably the reflections of the methods used to recover the fungi (Brock 1987; Schlegal and Jannasch 1991). Identification of fungi is complicated as the fungal life cycle in natural habitat is quite different from the laboratory (Domsch and Gram 1972). Furthermore, fungi are so nutritionally diverse that there is no one medium that can isolate all of them. There are over 1.5 million fungal species distributed widely throughout the globe (Hawksworth 2004) .Recent evidence suggests that out of 1.5 million fungi, about one-third exist in India and of this only 50% are identified until now (Monoharachary et al. 2005; Swapna et al. 2008). It is disappointing that despite a long period of research, many fungi are yet to be discovered. The patent literature on fungal diversity concluded that different habitat exhibited variation, among different plant systems and also both environment and edaphic factors greatly influence the growth and development of microbes (Gentry 1988; Behera et al. 1991; Nilima et al. 2007).

In spite of the ecological significance of the

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tropical forest in the context of present day environmental crisis, the tropical forests are being cleared, denuded and degraded at an alarming rate (Parrota 1992). Tropical forest degradation adversely affect soil physico-chemical and microbiological characteristics (Henrot and Robertson 1994; Hajabassi 1997) and thereby alters the nutrient status of the soil that lead to the genesis of barren degraded wasteland (Mroz et al. 1985; Lal 1989). In contrast to tropical forest, coastal sand dune ecosystem is considered as one of the most unproductive and sterile habitats of the world where the rate of primary productivity is very low. Both chemical fertility and physical stability in this soil is weak (Pieri 1992). Plantations present on coastal sand dunes vary in structure and composition and these variations may alter soil microbial communities (Warren and Zou 2002). It is especially true in Orissan coast of about 480 kms of stretched coast line filled with sand dunes only. Some years ago, phase wise monoculture plantations of *Casuarina equisetifolia* and *Anacardium occidentale* were created along the coastline to minimize the effect of cyclonic sea storms, a regular phenomenon due to its geographical location. Although it has solved the problem to some extent, but the role of beach plantation in determining the abundance and diversity of fungal flora has not been thoroughly studied. Previous studies of Ghosh and Dutta (1960), Dutta and Ghosh (1965) revealed that some 98 species of soil fungi were identified from rice fields of Sambalpur, Orissa.

In this context, lack of research in coastal sand dunes and forest soils of South Orissa is surprising in comparison to forest soils of Western Orissa (Basu and Behera 1992; Basu and Behera 1993; Prasad et al. 1994; Behera and Sahani 2003).In view of the above fact, the present project was undertaken to find out the distribution and diversity pattern of fungi in six different type of soils in Southern Orissa and also to investigate the role of beach plantation in determining the fungal abundance and the factors which affect their ecophysiology

MATERIALS AND METHODS

The present investigation was carried out in two different localities of South Orissa, India.First one is a moist deciduous forest (19º43'N and 84º21'E) with an area of 922.714 sq. kms situated at an elevation of 100-150m above MSL and at a distance of 80kms from sea shore i.e. Bay of Bengal. The major part of the forest occupies the slopes of Eastern Ghat Mountains. Three sites with different vegetation cover were selected to study the effect of deforestation and its conversion to cultivated land on the soil fungi. First one is a natural undisturbed forest area with thick undergrowth of annual and perennial herbs and shrubs together with trees and the soil is rich in litter and humus. Second site is a deforested area comprising of few grasses and herbaceous plants. Third site (deforested-cum-cultivated) is a big patch of land situated adjacent to forest area which is cleared by the tribal people for seasonal cropping like millets, gourd and sweet potato. The average annual rainfall of the sites is about 130cm.

The second locality (19º15'N and 84º50'E) having 60km of coastline along the Bay of Bengal is at a height of 6-8m above MSL.The climate of the region is monsoonal with coastal characteristics. The average annual rainfall is about 130cm. The region is subject to cyclones during the wet seasons and coastal areas are affected by the resulting strong winds and intense rainfall. Some of the unproductive uplands and coastal sand dunes are extensively covered by *Casuarina equisetifolia* and Cashew (*Anacardium occidentale*) plants. Cashew plantation at the inner belt study site covers an area of about 1500 hectares extending 4-5 km with a width of 250-450 m, varying at places and a shelter belt cum wind break vegetation of *Casuarina* about 30-40 rows covering 15-20 m in the outer belt along the coast of the sea. Both the plants have been preferred over many others because of their physiological adaptation to tolerate extreme drought conditions, good growth in nutritionally poor soils. Three sites of about one hectare each were selected for the investigation. First one is barren sand dune without any vegetation; the second with plantation of *Anacardium* without any undergrowth and the third with plantation of *Casuarina* without any undergrowth. The study was conducted for a period of 13 months in first locality and for two years in second locality. First series of soil samples were collected from all the sites in sterilized test tubes by randomly sampling at monthly intervals by inserting sterile glass tubes at depths of 0.3cm (surface) and 8-15cm (sub-surface) for microbial analysis. Each tube was allowed to contain 10-15 g of soil and stoppered tightly. Second series of samples was collected for estimation of physico-chemical properties. Samples were brought to the laboratory in sterilized polythene packets along with identification tags in sealed condition. The samples were temporarily stored in an ice chest prior to isolation of microbes. The micro fungi were isolated by dilution (Waksman 1927) and pour plate (Warcup 1950) techniques using PDA medium. Fungi were studied after 3-7 days of incubation. Fungi were identified by adopting standard procedures (Barnett and Hunter 1972; Ellis 1971, 1976; Gilman 1966; Sarabhoy1983; Subramanian 1971). Physico-chemical properties of soils were estimated as per Jackson (1967).

STATISTICAL ANALYSIS

The following indices of diversity were calculated based on species level identification (Krebs 1989; Ludwig and Reynolds 1988).

Shannon –Wiener index $H = -\Sigma_{i=0}^{S} Pi\ln Pi$

where *Pi* is the proportion of the individual found in the i^{th} species, *ln* denotes natural logarithm and H is the Shannon –Wiener index.

Simpson's index $D = \Sigma_{i=0}^{S} (Pi)^2$

Where is the proportion of the individual found in the i^{th} species and D Simpson's index

Evenness index (E) = H/S

Where H is the Shannon –Wiener index of diversity, S total number of species and is the natural logarithm.

Richness index (Margalef 1963) R =S-1/N

Where S is the total number of species and N is the sampling number.

RESULTS

Major differences were reported among the soils under this study. While having an intercomparison of data among the sites on fungal growth profile to that of the nutrient it revealed that sites with low temperature, high moisture and better nutrient status harbored more fungi (Table 1). On the other hand, fungal population in barren sand dune is poor and there is substantial drop in nutrient composition (Table 1). The poor colonization of fungi on this soil may be due to low moisture and high temperature which serve as an important defense against fungal attacks and/or colonization. The fungal population of the soils followed the order, forest > deforested > deforested-cum-cultivated > sand dune with *Anacardium* plantation> sand dune with *Casuarin*a plantation > barren sand dune.

Fungal population in all the sites and both the layers had positive correlation with soil moisture, total nitrogen and total organic carbon, while the temperature was negatively correlated. The seasonal variations seem to influence the density of an individual fungus and population as a whole. The rainy carried higher population followed by winter and summer. Higher moisture content and temperature of soils corresponding to the rains and summer might be the reason for such fluctuation. The species composition at six sites shows marked difference with change in habitat and surface vegetation. A total of 285 species of fungi belonging to 113 genera were enumerated of which forest surface soil had a share of 50 genera and 118 species. While subsurface soil produced 41 genera, 91 species;

Table 1: Edaphic factors and fungal population at study sites

Sites	*Layers*	*Temp(°C)*	*Moisture content (%)*	*pH*	*Total organic carbon (%)*	*Total nitrogen (%)*	*Fungal population/ gdwx10²*
Forest soil	Surface soil	33.7	11.4	6.7	0.947	0.118	1276.2
	Sub-surface soil	31.7	11.1	6.1	0.472	0.111	693.9
Deforested soil	Surface soil	36.2	8.2	7.1	0.253	0.106	684.3
	Sub-surface soil	32.7	7.8	6.0	0.189	0.105	403.6
Deforested-cum-cultivated soil	Surface soil	34.4	8.9	6.7	0.328	0.106	974.9
	Sub-surface soil	32.1	10.8	6.1	0.328	0.105	631.8
Barren sand dune without vegetation	Surface soil	32.3	0.38	7.5	0.2	0.0108	36.5
	Sub-surface soil	30.8	0.96	7.5	0.17	0.0105	35.5
Sand dune with *Casuarina* plantation	Surface soil	30.3	0.57	7.1	0.32	0.0143	41.8
	Sub-surface soil	28.9	1.21	7.4	0.24	0.0106	38.5
Sand dune with *Anacardium* plantation	Surface soil	30.28	1.26	6.9	0.403	0.0246	64.7
	Sub-surface soil	28.74	2.03	6.3	0.275	0.0195	44.7

Table 2: Total count of surface fungi isolated in different samples

Samples	*Barren sand dune without vegetation*		*Sand dune with Casuarina plantation*		*Sand dune with Anacardium plantation*		*Forest soil*		*Deforested soil*		*Deforested-cum-cultivated soil*	
	Genus	*Sp.*	*Genus*	*Sp.*	*Genus*	*Sp.*	*Genus*	*Sp.*	*Genus*	*Sp.*	*Genus*	*Sp.*
Zygomycotina	06	06	05	07	05	12	05	11	04	09	07	14
Ascomycotina	06	08	03	05	05	07	07	07	06	09	07	07
Deuteromycotina	42	77	28	66	33	95	38	100	28	85	39	102
Moniliales	32	67	24	62	23	85	26	88	18	75	24	87
Sphaeropsidales	07	07	03	03	06	06	09	09	07	07	12	12
Melanconiales	01	01	01	01	02	02	02	02	02	02	02	02
Mycelia sterilia	02	02	-	-	02	02	01	01	01	01	01	01
Total	54	91	36	78	45	114	50	118	38	103	53	123

deforested surface soil 38 genera , 103 species, sub-surface soil 37 genera, 86 species; deforested-cum-cultivated surface soil 53 genera, 123 species, subsurface 50 genera , 110 species; sand dune with *Anacardium* plantation surface 45 genera , 114 species, subsurface 41 genera, 93 species; sand dune with *Casuarina* plantation surface 36 genera, 78 species, subsurface 38 genera, 85 species ;barren sand dune surface 54 genera and 91 species, subsurface 46 genera and 80species.The media in our study appear to favor Dueteromycotina the most, followed by Ascomycotina and Zygomycotina (Table 2 and 3). The order of occurrence might be due to ability of the fungi for survival of adversity and adjustment with the environment. A distinct pattern of fungal community structure was observed in all the samples during the study period. The percentage composition and rank abundances of different fungal species fluctuated (Table 4 and 5). The majority was from the genus *Aspergillus*; the next two in order of dominance were *Penicillium* and *Trichoderma*. Considering the dominant species, it is clear that fungal succession in plantation site greatly differed from without plantation. The occurrence of good number of sugar fungi in plantation site may be accounted for their greater affinity towards the simple carbohydrates. Twenty fungal species were detected common to all the soils under study (Table 6). Total number of restricted species in forest soil was 18, deforested 10, deforested-cum-cultivated 26, sand dune with *Anacardium* plantation 31, sand dune with *Casuarina* plantation 07 and barren sand dune 13 (Table 6). The diversity values (H) show an increase as we move from barren sand dune to deforested-cum-cultivated soil. Shannon's diversity index is reasonably high varying from 3.528 to 4.144 correspondingly the dominance values are low varying from 0.0242 to 0.0499 (Table 7). The evenness values however show a different trend. It is highest in sub-surface soil of barren sand dune and lowest in soil with *Casuarina* plantation. The surface soil of forest has the highest species richness where as sub-surface soil of barren sand dunes shows lowest richness.

DISCUSSION

Sandy soils have diverse physical, chemical and biological constraints: poor structural stability, poor nutrient holding capacity and low mi-

Table 3: Total count of sub-surface fungi isolated in different samples

Samples	*Barren sand dune without vegetation*		*Sand dune with Casuarina plantation*		*Sand dune with Anacardium plantation*		*Forest soil*		*Deforested soil*		*Deforested-cum-cultivated soil*	
	Genus	*Sp.*	*Genus*	*Sp.*	*Genus*	*Sp.*	*Genus*	*Sp.*	*Genus*	*Sp.*	*Genus*	*Sp.*
Zygomycotina	03	04	04	05	6	9	05	09	03	07	06	11
Ascomycotina	05	06	04	06	5	9	07	07	07	08	07	07
Deuteromycotina	38	70	30	74	30	75	29	81	27	71	37	92
Moniliales	30	62	19	63	22	67	18	70	18	62	30	85
Sphaeropsidales	06	06	07	07	5	5	08	08	07	07	05	05
Melanconiales	02	02	02	02	01	01	01	01	01	01	01	01
Mycelia sterilia	-	-	02	02	2	2	02	02	01	01	01	01
Total	46	80	38	85	41	93	41	97	37	86	50	110

Table 4: Percentage contribution (above 2.0%) and ranks of some dominant surface fungi isolated from samples at study sites

Samples	*Barren sand dune without vegetation*		*Sand dune with Casuarina plantation*		*Sand dune with Anacardium plantation*		*Forest soil*		*Deforested soil*		*Deforested-cum-cultivated soil*	
Fungi	*%*	*Rank*	*%*	*Rank*	*%*	*Rank*	*%*	*Rank*	*%*	*Rank*	*%*	*Rank*
Absidia butleri	-	-	2.2	15	5.3	04	-	-	-	-	-	-
A.glauca	-	-	-	-	2.7	10	-	-	-	-	-	-
A.spinosa	-	-	-	-	2.0	20	-	-	-	-	-	-
Aspergillus awamori	9.0	01	3.2	10	6.7	01	-	-	2.4	09	-	-
A.candidus	-	-	2.1	17	-	-	-	-	-	-	-	-
A.flavus	2.0	16	6.9	03	2.8	09	3.7	04	2.3	11	3.1	05
A.fonsecoceous	-	-	-	-	2.5	11	2.2	13	2.4	09	-	-
A.fumigatus	6.9	03	3.3	09	3.0	08	2.4	10	2.1	12	-	-
A.luchuensis	-	-	-	-	2.1	16	-	-	-	-	-	-
A.nidulans	15.0	01	-	-	-	-	-	-	-	-	-	-
A.niger	5.4	05	6.1	04	5.8	03	8.2	01	8.3	01	7.5	01
A.terreus	2.8	13	3.8	07	-	-	2.6	07	2.4	10	4.3	03
Chaetomium homopilatum	3.4	11	-	-	-	-	-	-	—	-	-	-
Cladosporium cladosporoides	6.7	04	3.5	08	2.4	12	-	-	3.5	06	-	-
C.oxysporum	2.3	14	2.9	11	-	-	-	-	2.1	13	-	-
Curvularia eragrostidis	4.3	08	-	-	-	-	-	-	-	-	-	-
C.lunata	4.8	07	2.6	12	-	-	3.9	02	5.1	02	5.4	02
Cytosporella sp.	3.6	09	-	-	-	-	-	-	-	-	-	-
Drechslera austaliensis	-	-	2.3	14	-	-	-	-	-	-	-	-
D. hawaiiensis	-	-	-	-	-	-	2.6	08	-	-	-	-
Fusarium oxysporum	-	-	5.2	06	2.4	13	2.9	06	4.8	03	4.0	04
Paecilomyces varioti	3.5	10	-	-	-	-	-	-	-	-	-	-
Penicillium citrinum	4.9	06	5.8	05	5.2	05	3.9	03	3.4	07	2.4	07
P.javanicum	-	-	-	3.8	07	-	-	-	-	-	-	-
P.minioleuteum	-	-	-	2.3	14	-	-	-	-	-	-	-
P.nigricans	-	-	-	2.1	17	-	-	-	-	-	-	-
P.oxalicum	-	-	-	-	-	-	2.6	09	4.1	04	3.0	06
P.rubrum	-	-	2.4	13	2.1	18	-	-	-	-	-	-
P.rugulosum	-	-	-	2.3	15	-	-	-	-	-	-	-
P.verruculosum	2.2	15	7.0	02	6.2	02	2.4	11	-	-	-	-
Rhizopus nigricans	-	-	2.2	16	2.1	19	-	-	-	-	-	-
*R.*sp.	-	-	-	-	-	-	2.4	12	-	-	-	-
R.stolonifer	-	-	-	-	-	-	-	-	3.9	15	-	
Trichoderma viride	3.0	12	7.2	01	5.2	06	3.2	05	2.8	08	2.1	08

crobial community (Parotta 1999; Pieri 1992; Sall et al. 2003; Szott et al. 1999). In these soils organic matter is the main determinant of fertility, nutrient storage and microbial activities. It is the main source of ecosystem energy and plays a major role on soil plant relationship; especially in sand dunes (Buresh and Tian 1997; Diallo et al. 2005; Feller and Beare 1997; Lavelle 1997; Lavelle and Spain 2001). But in natural forest, most of the organic matter produced by the vegetation compartment is returned to the soil; whereas in crop field and grassland much of it is removed for human and animal consumption and relatively small proportion to the total productivity find their way aback to the soil (Srivastava and Singh 1989,1991). Soil organic matter plays an important role in the formation of micro and macro aggregates (Tisdall and Oades 1982) and brings structural stability to the soil(Gupta and Germinda 1988). In the present study, a decline in available nutrients as a result of cultivation agrees with the finding of Basu and Behera (1993) Bauer and Black (1981), Srivastava and Singh (1991).One of the major reasons of this decline is the disturbance of soil by cultivation practices such as ploughing. Relatively lower

Table 5: Percentage contribution (above 2.0%) and ranks of some dominant sub-surface fungi isolated from samples at study sites

Samples	*Barren sand dune without vegetation*		*Sand dune with Casuarina plantation*		*Sand dune with Anacardium plantation*		*Forest soil*		*Deforested soil*		*Deforested-cum-cultivated soil*	
Fungi	*%*	*Rank*	*%*	*Rank*	*%*	*Rank*	*%*	*Rank*	*%*	*Rank*	*%*	*Rank*
Absidia butleri	-	-	2.4	13	5.1	04	-	-	-	-	-	-
A.glauca	-	-	-	-	2.6	15	-	-	-	-	-	-
A.spinosa	-	-	-	-	2.9	10	-	-	-	-	-	-
Arachniotus terrestris	-	-	-	-	-	-	2.1	11	-	-	-	-
Aspergillus awamori	5.5	01	6.6	05	6.5	01	2.0	14	3.0	07	-	-
A.carbonarius	-	-	-	-	-	-	-	-	3.3	06	-	-
A.flavus	-	-	2.1	14	2.4	16	2.6	07	6.3	02	2.4	07
A.fonsecoceous	-	-	-	-	-	-	-	-	-	-	2.4	08
A.fumigatus	4.2	04	5.1	06	2.8	12	3.2	06	3.0	08	2.3	09
A.nidulans	5.0	02	-	-	-	-	2.1	12	-	-	-	-
A.niger	3.5	08	8.2	03	6.2	02	8.9	01	10.3	01	11.1	01
A.sydowi	-	-	-	-	-	-	-	-	-	-	3.2	04
A.terreus	2.8	12	7.9	04	2.2	18	3.8	05	2.8	10	4.0	03
Chaetomium homopilatum	4.0	05	-	-	-	-	-	-	-	-	-	-
Cladosporium cladosporoides	4.3	03	-	-	3.5	09	-	-	2.9	09	2.1	11
C.oxysporum	-	-	-	-	4.0	08	-	-	-	-	2.2	10
Curvularia eragrostidis	-	-	-	-	2.2	19	-	-	-	-	-	-
Curvularia lunata	3.3	09	3.2	08	2.0	20	4.8	04	5.6	04	5.6	02
Cytosporina sp.	-	-	-	-	-	-	-	-	2.6	12	-	-
Drechslera austaliensis	-	-	-	-	-	-	2.1	13	-	-	-	-
Fusarium oxysporum	-	-	4.5	07	2.4	17	2.4	09	6.1	03	2.8	05
Paecilomyces varioti	3.9	07	-	-	-	-	-	-	-	-	-	-
Penicillium citrinum	4.0	06	2.5	11	4.5	05	5.6	03	2.8	11	2.6	06
P.cyaneum	-	-	-	-	2.0	21	-	-	-	-	-	-
P.javanicum	-	-	-	-	4.3	06	-	-	-	-	-	-
P.minioleuteum	-	-	2.6	10	2.8	13	-	-	-	-	-	-
P.oxalicum	-	-	-	-	3.0	11	-	-	2.1	15	2.1	12
P.roseopurpureum	-	-	-	-	-	-	-	-	2.5	13	-	-
P.rubrum	-	-	2.5	12	2.7	14	-	-	-	-	-	-
P.verruculosum	2.9	11	9.7	02	5.9	03	-	-	3.6	05	-	-
Pycnidial form	-	-	-	-	-	-	-	-	2.3	14	-	-
Rhizopus nigricans	-	-	3.0	09	-	-	2.6	08	-	-	-	-
Trichoderma canadense	-	-	-	-	-	-	2.2	10	-	-	-	-
Trichoderma viride	3.1	10	11.0	01	4.3	07	7.1	02	-	-	-	-

microbial growth in sand dunes, deforested soil and cultivated land can be explained through the lower input of organic carbon to the soil (Schnurer et al. 1985). A decrease in microbial population/biomass after cultivation of natural ecosystems has also been reported by Anderson and Domsch (1989) Dalal and Mayer (1987), Gupta and Germinda (1988) . Thus, denudation and cultivation of natural forest exhibited impact on both the nutrient status and microbial growth of the soil. The colonization of fungi in diversified habitats is of much significance as their secondary metabolites are of much relevance to the human welfare. The qualitative and quantitative differences of microbial populations at six sites indicate that surface vegetation as well as nutrient composition influences micro fungal populations of the soil. Plantations are often linked to a strong increase in the total soil organic matter content and soil microorganisms of the soil (Battles et al. 2001; Buresh and Tian 1997; Corre 1991; Ganry 2001; Kubat et al.1979; Manley et al. 2000;

Table 6: List of fungi isolated from different soils at study sites

Samples	*Barren sand dune without vegetation*		*Sand dune with Casuarina plantation*		*Sand dune with Anacardium plantation*		*Forest soil*		*Deforested soil*		*Deforested-cum-cultivated soil*	
Fungi	A_1	A_2	A_1	A_2	A_1	A_2	A_1	A_2	A_1	A_2	A_1	A_2
Zygomycotina												
Absidia butleri	+	+	+	+	+	+	+	+			+	+
Absidia glauca	-	+	+	+	+	+	+	+	+	+	+	+
A.spinosa			+		+	+	+	+	+		+	+
Blackslea trispora											+	
Choanephora cucurbitarum	+				+	+					+	+
Cunninghamella bertholletiae							+	+				
C. echinulata	+		+		+	+			+		+	+
Mucor circinelloides							+	+	+	+	+	+
M. fragilis											+	
M. hiemalis	+		+	+	+	+	+	+	+	+	+	+
M.javanicus							+					
M.ramannianus									+	+		
*M.*sp.					+							
Rhizopus conhii					+		+	+			+	+
R.nigricans	+	+	+	+	+	+			+	+	+	+
R.oryzae					+	+						
*R.*species							+	+	+	+	+	+
R.stolonifer							+		+	+	+	
Syncephalastrum recemosum	+	+	+	+	+	+	+	+			+	+
Thamilidium sp.					+							
Ascomycotina												
Amauroascus sp.							+	+				
Arachniotus terrestris	+	+	+	+			+	+		+	+	+
Botryosphaeria sp.									+	+		
Chaetomium fimeti				+		+	+	+	+	+		
C.funicola			+	+					+			
C.homopilatum	+	+			+	+			+	+		
C.magnum	+	-	+	-		+						
C.murorum					+				+			
C. nigricolor	+	+	+	+								
C. olivacium						+						
C. sp.					+							
Cleistothecial form							+	+	+	+	+	+
Coniochaetidium sp.											+	+
Emericella sp.											+	+
Emericillopsis humicola	+	+			+	+						
E.terricola						+						
E.repens	+	-	-	+		+						
Melanospora zamiae	+				+	+						
Monascus species									+	+		
Neocosmospora affricana							+	+			+	+
N.vasinlfecta									+	+		
Neopeckia fulcita		+			+							
Preussia sp.							+					
Pseudonectaria rousseliana											+	+
Theilavia terricola	+	+	+	+	+	+	+	+	+	+	+	+

Table 6: Contd........

Samples	*Barren sand dune without vegetation*		*Sand dune with Casuarina plantation*		*Sand dune with Anacardium plantation*		*Forest soil*		*Deforested soil*		*Deforested-cum-cultivated soil*	
Fungi	A_1	A_2	A_1	A_2	A_1	A_2	A_1	A_2	A_1	A_2	A_1	A_2
Xylogone sphaerospora								+				
Deuteromycotina (Moniliales)												
Acremonium alternatum	+	+	+	-								
Acrophialophora fusispora											+	+
Alternaria alternata	+	+			+	+	+	+	+	+	+	+
A.geophila											+	+
A.humicola											+	+
A.longipes					+							
A.padwickii	+				+							
A.solani	+	+										
A.tenuis											+	+
A.tenuissima									+	+		
Alysidium resinae		+		+		+	+	+	+	+	+	
Aphanocladium album	+	+	+	+								
Arthrinium sacchari			+									
Aspergillus awamorii	+	+	+	+	+	+	+	+	+	+	+	+
A.caepitosus	+	+	+	+								
A.candidus			+	+	+	+	+	+	+	+	+	+
A.carbonarius				+	+	+	+	+	+	+	+	+
A.clavatus			+	+								
A.fischeri			+	+			+	+	+	+	+	+
A.flavipes					+		+	+	+	+	+	+
A.flavus	+	+	+	+	+	+	+	+	+	+	+	+
A.fonsecaceus				+	+	+	+	+	+	+	+	+
A.fumigatus	+	+	+	+	+	+	+	+	+	+	+	+
A.funiculosus	+	+			+	+						
A.humicola				+		+	+	+	+	+	+	+
A.japonicus											+	+
A.koningi		+	+	+								
A.luchuensis	+		+	+	+	+	+	+	+		+	+
A.nidulans	+	+	+	+			+	+			+	+
A.niger	+	+	+	+	+	+	+	+	+	+	+	+
A.niveus						+		+	+		+	
A.quadrilinaetus	+											
A.repens	+	+				+						
A.rugulosus											+	+
A.sparsus			+									
A.sulphureus			+			+	+	+	+		+	+
A.sydowii		+	+	+	+		+	+	+	+	+	+
A.tamarii				+			+	+				
A.terreus	+	+	+	+	+	+	+	+	+	+	+	+
A.terricola	+	+	+	+	+		+					
A.ustus			+	+								
A.variecolor				+								
A.versicolor	+	+	+	+			+	+	+	+	+	+
Asperosporium sp.											+	+
Aurobasidium sp.											+	+
Beltrania rhombica	+	+	+	+								
B. querna							+					
Beltraniopsis sp.	+											
Bispora butulina						+						

Table 6: Contd.......

Samples	*Barren sand dune without vegetation*		*Sand dune with Casuarina plantation*		*Sand dune with Anacardium plantation*		*Forest soil*		*Deforested soil*		*Deforested-cum-cultivated soil*	
Fungi	A_1	A_2	A_1	A_2	A_1	A_2	A_1	A_2	A_1	A_2	A_1	A_2
B.punctata	+	+	+	+								
Botryoderma lateritium											+	
Botryotricheum piluliferum										+		
Botrytitis cinera												
Candida albicans	+	+	+	+			+		+			+
Cephalosporium acremonium	+	+			+	+						
C.roseogriseum											+	
Chloridium sacchari					+	+						
Chrysosporium tropicum	+	+										
C. sp.							+					
Cladosporium cladosporoides	+	+	+	+	+	+	+	+	+	+	+	+
C.oxysporum	+	+	+	+	+	+	+	+	+	+	+	+
C.sp haerospermum					+						+	+
C.tennuissium									+	+		
C.variable							+				+	
Curvularia brachyspora					+	+						
C.clavata	+											
C.eragrostidis	+		+	+	+	+	+	+			+	
C.lunata	+	+	+	+	+	+	+	+	+	+	+	+
C.lunata var aeria	+						+				+	+
C.oryzea							+					
C.ovoidae	+	+		+					+	+		
C.pallescens				+	+	+	+	+	+	+	+	+
C.tuberculata			+									
Dichomera sp.	+	+										
Diheterospora chlamydosporia							+	+	+		+	
Drechslera avenaceae					+							
D.australiensis	+	+	+	+	+	+	+	+	+	+	+	+
D. hawaiiensis	+	+	+	+	+	+	+	+	+	+	+	+
D. holmii									+		+	
D. halodes	+	+										
D.miyakei											+	+
Ellisiopsis sp.					+		+					
Endocalyx indica	+	+										
Fusarium chlamydosporum									+		+	
F.hypocastani						+	+	+	+		+	+
F.liseola					+							
F.monoliformae									+			
F.oxysporum	+	+	+	+	+	+	+	+	+	+	+	+
F. solani				+	+		+		+	+	+	+
*F.*sp.					+		+					
F.vasinfectum											+	
Geotrichum candidum							+		+			
Gilmoniella humicola	+	+	+	+	+			+		+		+
Hansfordia biophila							+					+

Table 6: Contd.......

Samples	*Barren sand dune without vegetation*		*Sand dune with Casuarina plantation*		*Sand dune with Anacardium plantation*		*Forest soil*		*Deforested soil*		*Deforested-cum-cultivated soil*	
Fungi	A_1	A_2	A_1	A_2	A_1	A_2	A_1	A_2	A_1	A_2	A_1	A_2
Haplosporangium parvum	+				+	+						
Humicola fuscoatra	+	+	+	+							+	
H.grisea							+					
Isaria pulcherrima		+				+						
Lacellina graminicola	+	+	+									
Meria coniospora					+	+						
Monilia sp.	+	+										
Monocillium indicum												+
Monodictys antique	+	+										
M. fluctuate		+	+									
M.putredinis		+										
Myrothecium advena											+	+
M. roridum	+		+				+	+	+	+	+	+
Nigrospora oryzae	+	+			+							
N.sacchari	+	+										
N.sphaerica	+	+	+	+	+	+	+	+			+	+
Neurospora sp.							+	+			+	
Oidiodendron kalari			+									
O.maeius						+						
O.rhodogenum					+	+						
Peacilomyces fusisporus					+	+						
P. varioti	+	+	+	+	+	+	+	+	+	+	+	+
P.violacia							+	+				
Popularia sp.												+
Penicillium adamentezi				+	+				+	+		
P. atromerotosum							+					
P.brefaldianum					+	+			+	+		
P.cacemberti							+	+	+	+	+	+
P.canadens					+							
P.carneolutescens							+	+				
P.chermissinum			+		+				+		+	+
P.chrysogenum			+		+							
P.citrinum	+	+	+	+	+	+	+	+	+	+	+	+
P.citroviride					+							
P. corylophyllum					+	+	+	+	+	+	+	+
P. cyaneum			+	+	+	+	+	+	+	+	+	+
P.decumbens			+	+	+	+	+	+	+	+	+	+
P.digitatum							+		+			
P.diversum					+	+						
P.ehrlichii					+							
P.expansum	+	+										
P.fellutatum			+	+	+		+		+	+	+	+
P.funiculosum					+		+	+	+	+	+	+
P.fuscum									+	+		
P.glabrum			+	+	+		+	+	+	+	+	+
P.granulatum			+									
P.harquei							+	+				
P.implicatum					+		+	+	+			
P.islandicum	+	+	+	+		+	+	+			+	+
P.janthocitrinum					+						+	+
P.javanicum	+	+			+	+	+	+	+	+	+	+
P.lanosum	+	+	+	+	+	+	+	+	+	+	+	

Table 6: Contd.......

Samples	*Barren sand dune without vegetation*		*Sand dune with Casuarina plantation*		*Sand dune with Anacardium plantation*		*Forest soil*		*Deforested soil*		*Deforested-cum-cultivated soil*	
Fungi	A_1	A_2	A_1	A_2	A_1	A_2	A_1	A_2	A_1	A_2	A_1	A_2
P. leuteum					+							
P.levitum						+						
P.lilacinum							+					
P.minio-leuteum		+	+	+	+	+	+	+	+	+	+	+
P.minutissima					+							
P.nigricans	+	+	+	+	+	+	+	+	+	+	+	+
P.oxalicum	+	+	+	+	+	+	+	+	+	+	+	+
P.purpurogenum	+	+			+	+	+	+	+	+	+	+
P.restrictii						+						
P.restrictum							+	+	+	+		
P.resticulosum		+		+								
P.roseopurpureum	+	+	+	+					+	+	+	+
P.rubrum	+	+	+	+	+	+	+	+	+	+	+	+
P.rugulosum	+	+	+	+	+	+	+	+	+	+	+	+
P.simplicissimum							+	+	+	+	+	+
P.spiculisporum								+				
P.stoloniferum									+			
P.tardum							+					
P.terrestre											+	+
P.turbatum					+							
P.variable				+	+	+	+	+	+	+	+	+
P.varians											+	+
P.verruculosum	+	+	+	+	+	+	+	+	+	+	+	+
P.waksmanii					+	+						
P.wortmonii											+	
Periconia byssoides		+	+	+							+	
P.cambrensis					+				+	+		
P.cookii					+				+			
P.digitata				+			+	+				
P.glycericola						+						
P. hypsidula							+				+	+
P.minutissima					+							
P.saraswatipurensis					+	+	+	+				
*P.*sp.						+	+					
P. tirupatiansis									+	+		
Pithomyces sacchari	+											
Phialophorophoma sp.	+											
Phyllosticta acetosa				+								
Scopulariopsis brumpti	+	+										
Scolicobasidium constrictum					+	+					+	+
S.humicola									+	+	+	+
Sepedonium sp.					+	+						
Spegazzinia ornate		+										
Sporotrichum canescens								+				+
S.pruinosum								+	+			
Staphylotrichum cocosporium	+											
Stilbum inconsipicum										+		
Tetraploa aristata											+	+
Theilaviopsis paradoxa				+			+	+	+			+

Table 6: Contd.......

Samples	*Barren sand dune without vegetation*		*Sand dune with Casuarina plantation*		*Sand dune with Anacardium plantation*		*Forest soil*		*Deforested soil*		*Deforested-cum-cultivated soil*	
Fungi	A_1	A_2	A_1	A_2	A_1	A_2	A_1	A_2	A_1	A_2	A_1	A_2
Torula calligans	+	+	+	+	+	+			+	+	+	+
T.herbarum	+			+			+		+	+	+	+
T. sp.									+			
Trichocladium canadense		+			+		+	+			+	
Trichoderma album				+	+	+	+				+	
T.glabrum					+	+						
T.glaucum							+	+			+	+
T.koningii					+	+	+					+
T.lignorum							+	+				
T.viride	+	+	+	+	+	+	+	+	+	+	+	+
Trichurus spiralis					+							
Verticillium dahlia	+										+	
V.glaucum					+							
Zygosporium mycophila												+
Sphaeropsidales												
Amerosporium sp.							+	+			+	+
Ampleomyces sp.											+	+
Aposphaeria sp.											+	
Asteromella andrewsi				+			+	+				
*A.*sp.						+						
Botryodiplodia theobromae							+		+	+		
Brown pycnidial form					+	+	+	+	+	+	+	+
Catinula thuja	+			+			+	+	+	+	+	
C. sp.					+	+						
Chaetophoma sp.											+	
Cytosporina indica	+	+	+	+					+	+		
C.sp.					+	+						
Cytosporella sp.	+	+	+	+								
Dendrophoma sp.							+					
Diplodina macrospora		+						+				
D. sp.					+							
Fusicoccum sp.	+		+									
Leptostroma sp.									+	+	+	
Pyrenonella sp.	+	+					+	+	+	+		
Pyrenocheata sp.	+	+		+	+						+	+
Phoma sp.	+	+		+	+	+	+	+			+	+
Phomopsis sp.											+	
Rabenhorstia sp.											+	
Rhynchophoma raduloid				+							+	
Yellow pycndial form							+	+	+	+		
Melanconiales												
Epicoccum andropogonis					+		+	+	+	+		
E. nigrum		+		+			+	+			+	+
Pestalotia	+	+	+	+	+	+	+		+		+	
Mycelia sterilia												
Black sterile	+			+	+	+		+				
White sterile	+			+	+	+	+	+	+	+	+	+

A_1 =Surface, A2 =Sub-surface, (+) =Presence, Blank=Absence

Table 7: Dominance, diversity, evenness and richness indices of fungi in different samples at study sites

Samples	*Layers*	*D*	*1- D*	*H*	*E*	*R*
Barren sand dune without vegetation	Surface	0.0323	0.968	3.718	0.881	21.08
	Sub-surface	0.035	0.965	3.528	0.921	14.16
Sand dune with *Casuarina* plantation	Surface	0.0356	0.964	3.7098	0.852	24.23
	Sub-surface	0.0499	0.95	3.54	0.797	26.43
Sand dune with *Anacardium* plantation	Surface	0.032	0.968	3.744	0.869	23.28
	Sub-surface	0.0333	0.967	3.608	0.904	16.68
Forest soil	Surface	0.0242	0.976	4.143	0.899	38.6
	Sub-surface	0.0307	0.969	3.918	0.892	39.1
Deforested soil	Surface	0.029	0.971	3.88	0.896	29.24
	Sub-surface	0.0356	0.964	3.703	0.908	22.61
Deforested – cum- cultivated soil	Surface	0.0229	0.977	4.144	0.916	34.48
	Sub-surface	0.0303	0.97	3.973	0.899	31.97

D= Simpson dominance index, H= Shannon diversity index, E= Evenness, R= Richness

Monoharachary 2008). Thus, in this ecological context, stability of edaphic factors is one of the important factor governing the activity and diversity of fungi. Mycoflora differs in its composition from an ecological niche to the other have also been reported by Christensen (1969) and Monoharachary (2008). The correlation between the fungal population and soil moisture and temperature accord to Eicker (1970), Behera et al. (1991). The pH and other factors proved insignificant. Marginal variations in pH at sites fail to influence the fungal population due to its trifle role (Menon and Williams 1957**;** Behera et al. 1991).

The surface mycoflora was richer in comparison to sub-surface mycoflora. The majority was from the genus *Aspergillus*; the next two in order of dominance were *Penicillium* and *Trichoderma* . Earlier reports have indicated that these genera appeared abundantly in Indian soils dominating both in the frequency and in relative density(Behera and Mukherji 1985; Behera et al. 1991; Bhagat and Pan 2010; Mamtaz and Mishra 1991; Manoharachary et al. 2005; Upadhyay and Rai 1979) and had important role in leaf litter decomposition (Umadevi and Manoharachary 1987a; Umadevi and Manoharachary 1991; Panda et al. 2009). This may be due to the faster growth rate of these fungi in addition to their better intrinsic prolific sporulating capacity to utilize the substrate. Considering the dominant species it is clear that fungal succession in plantation site greatly differed from site without plantation. The occurrences of good number of sugar fungi in plantation site may be accounted for their greater affinity towards the simple carbohydrates. Species of Deutoromycotina were maximum followed by Zygomycotina and Ascomycotina. Their occurrence might be due to ability of the concerned group of fungi for survival in adverse condition and adjustment with the environment. Restricted appearance of different fungi at study sites was also observed. This is possibly due to the effect of surface vegetation of the sites corroborating Panda et al. (2009). The evenness index indicates that species were fairly evenly distributed. The D value and H value in both the soil indicates many species with maximum diversity. The evenness index indicates that species were fairly evenly distributed.

CONCLUSION

It can be concluded from the present study that the above ground vegetation in different habitats is essential to maintain a productive environment to enhance microbial growth. The nutrient status of the sands can be enhanced either through introduction of the predominant microbes isolated from the present study biotechnologically or through proper mixing of litter with sands by intermittent ploughing or by the application of both. The study revealed that the conversion of natural forest led to a reduction of soil organic matter. Considering the importance of microbial component in soil, we conclude that the conversion of natural forest to different land uses leads to the loss of biological stability of soil. Vegetation is a major factor controlling the distribution and diversity of fungal species and subsequently deforestation can lead to loss of biological diversity as a whole.

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