KFRI Research Report 197

SOIL MICROFLORA OF SHOLA FORESTS OF ERAVIKULAM NATIONAL PARK

K.V. Sankaran
M. Balasundaran

KERALA FOREST RESEARCH INSTITUTE
PEECHI, THRISSUR

December 2000 Pages: 34

CONTENTS

ABSTRACT

The soil microflora of shola forests and grasslands of Eravikulam National Park (ENP) was studied for a period of three years. The main objective of the study was to prepare an inventory of the soil microorganisms (with special emphasis on fungi) in the shola forest ecosystem which is considered to be ecologically unique.

In general, the density (colony forming units per gram of dry soil) of actinomycetes and bacteria in soils of shola forests and grasslands (>2000 m asl) was lower compared to that in low elevation areas (<500 m asl) in South India. Mitosporic fungi formed the main constituent of soil mycoflora; penicilla, aspergilli and *Trichoderma* dominated the isolations. Species of the genus *Streptomyces* dominated the actinomycete population.

In all, 34 genera and 101 species of fungi were isolated from the soils of shola forests and grasslands. Actinomycetes were represented by only two genera. Interestingly, the species composjtion of fungi in soils of ENP showed close resemblance to that of temperate regions. Shola forests and grasslands yielded floristically dissimilar communities of soil microfungi indicating the variation in the environmental conditions between the two ecosystems.

Soil fungal and actinomyete flora of ENP was low in species diversity compared to that of low elevation areas in Kerala probably due to the higher relative diversity of microhabitats in the latter. The relative abundance of penicillia and mucoraceous fungi in soils of ENP is worth mentioning.

Thirteen species of fungi isolated during the present study formed new records for India. Eleven species of fungi which were rarely recorded from India could also be isolated from soils of ENP. All the fungal isolates (34 genera and 101 species) are conserved *ex-situ* in the culture collection facility at the Kerala Forest Research Institute.

In summary, the soil fungal flora of shola forests and grasslands of ENP appears to be unique in species composition compared to that of low elevation areas in the State. The abundance of rare species of *Penicillium* and other fungi indicates that these two ecosystems may contain fungi with great potential for innovative biotechnology. Efforts are warranted to conserve the microbial diversity of these unique ecosystems through protection from disturbance and exploitation.

1. INTRODUCTION

The tropical forests occupy a great variety of edaphically and climatically heterogeneous sites. They are considered to house the greatest biodiversity on earth. In the case of plants, about two-thirds are believed to occur in the tropics (Raven, 1988). It is estimated that there are 5 to 30 million species of organisms on earth of which less than 1.4% have been described. Tropical rain forests cover about 14% of the world's land surface but may house 70% of the world species (May, 1988).

A comparison of the numbers of known and estimated total species of microorganisms in the world indicates that 95% of fungi, 78% of bacteria and 96% of viruses still remain to be discovered (Bull *et al.,* 1992). Evidences show that a lion's share of this diversity lies in the tropical habitats. For example, an analysis of the newly described fungi during 1981-90 revealed that around 50% were discovered in the tropics (Hawksworth, 1993). Subramanian (1986) has provided evidence of the substantial number of new species of fungi still to be found in India.

Though the magnitude of biodiversity is great, the tropics are grossly under-explored for microorganisms compared to other parts of the world. (May, 1988; Hawksworth,l991). Our information on the density and diversity of actinomycetes, bacteria and fungi occupying various ecological niches in the tropical habitats are very scarce. The present study is an attempt to contribute to the existing information on tropical soil microflora.

The importance of microorganisms in ecosystem function and human progress cannot be over-emphasized. Studies have shown that microbes can serve as an indefinite pool for innovative biotechnology. Concerted efforts are needed to unearth the microbial wealth of the megadiversity areas around the globe so that the various potentials of the microbes could be tapped for human welfare. However, it needs to be mentioned here that management and conservation of biodiversity is not solely an economic issue. Scientifically, biodiversity is essential for the health balance of ecosystems (May, 1988).

Destruction and degradation of tropical forests due to anthropogenic disturbance have probably resulted in extinction of a major part of the microbial diversity in these forests. It is estimated that overall loss of tropical biodiversity occurs at the rate of 1.8% per year (Bull *et al.*,1992); approximately twenty thousand species of organisms become extinct each year (Wilson, 1988).

It is in this context that the present study gains relevance. It was aimed at inventorying the soil microflora (population of actinomycetes, bacteria and fungi) in the shola forests and adjoining grasslands in the Eravikulam National Park (ENP) - a part of the Western Ghat forests which is considered to be a hot-spot of biodiversity (Nayar, 1997).The study involved isolation, enumeration, identification and *ex-situ* conservation of soil microbes (especially fungi), of the shola forests and grasslands.

Shola forests (southern montane wet temperate forests) are considered to be ecologically unique since they harbour many of our endemic species. They are reported to contain very high floristic richness and diversity, probably the highest in the Western Ghat region (Jose *et al.,* 1994). The

characteristically deep fertile soils and high moisture holding capacity of these forests offer excellent conditions for the proliferation of a large number of microorganisms.

Grasslands (southern montane wet grasslands) which exist in close juxtaposition with the shola forests are considered a biotic climax rendered stable by fire and grazing (Bor, 1938). They are interesting as a special ecological niche due to the prevalence of unique micro- and macro-climatic conditions. However, though attempts have been made to understand the diversity of plants in the shola forests and grasslands in the ENP (Jose *et al.*, 1994), efforts have not been made hitherto to study the distribution and diversity of soil microorganisms.

The specific objectives of the present study are :

1. To prepare an inventory of the soil microorganisms in the shola forests and grasslands in the Eravikulam National Park.
2. *Ex-situ* conservation of soil fungi in the form of live culture collection.

2. MATERIALS AND METHODS

2.1. Study area

Eravikulam National Park (10º 05' - 10º 20' N lat. and 77º to 77º 10' E long.)falls on the crest of the Western Ghats, the mountain range running parallel to the west coast of the Indian peninsula.The total area of the park which is located in the high ranges of Idukki District in Kerala State is 99.98 km^2; with sholas and grasslands covering 18% and 60% of the area respectively. The main body of the National Park is comprised of a high rolling plateau with a base elevation of about 2000 m as1 (Jose *et al.*, 1994).

2.1.1. Climate

Mean annual rainfall is 5238 mm, the peak rainy period being June-August. May is the hottest month with a mean maximum temperature of 24.1ºC and a mean minimum of 10.3ºC. January is the coolest month with a mean maximum temperature of 15.3ºC and a mean minimum of 3ºC. Fog and strong wind are prevalent during rainy season. Relative humidity varies between 65 and 82%. Climatic data for the year 1997 is provided in Figures 1 and 2.

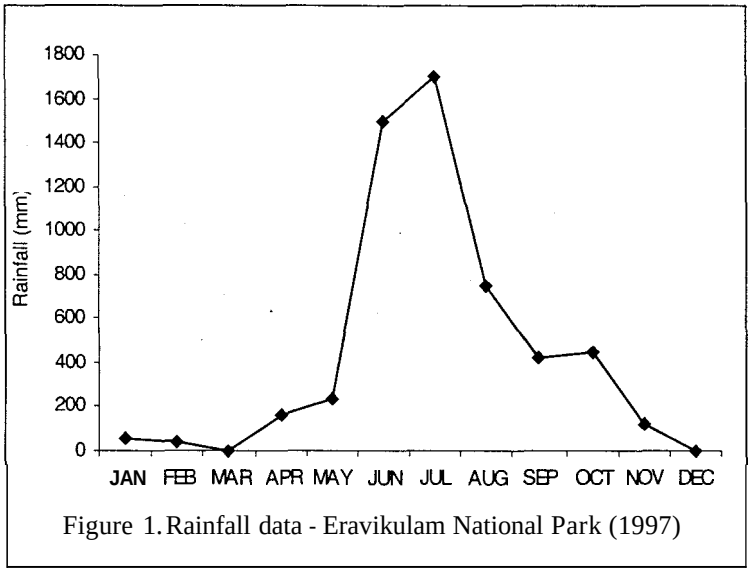

Figure 1. Rainfall data - Eravikulam National Park (1997)

2.1.2. Soils

The underlying rock formation is of archean igneous origin consisting of granites and gneisses. Soils are basically loamy, acidic (pH 5.2 - 5.6), with a high content of organic carbon (18% in grassland and 22.5% in shola) and total N (0.7% in grassland and 1.2% is shola) (Koshy, 1970; Jose *et al.*, 1994).

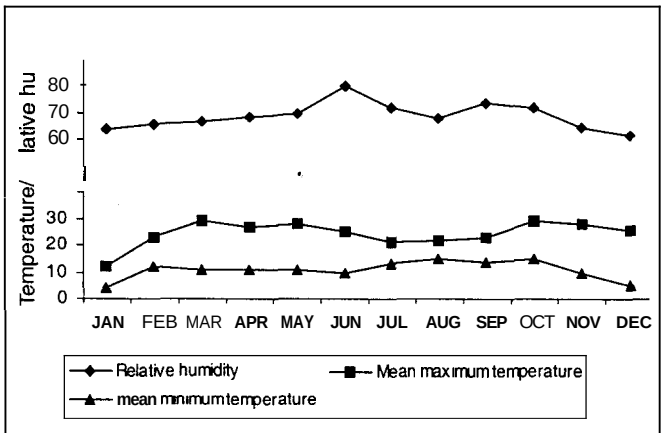

Figure 2. Mean temperature (ºC) and RH(%) ENP-1997

2.1.3. Vegetation

The vegetation is southern montane wet grassland interrupted by southern montane wet temperate forest (shola). The sholas are generally confined to the sheltered valleys, glens, hollows and depressions. They are evergreen forests characterized by stunted trees (height of the forest rarely exceeds 12 m) with dense crown, thick, more or less closed canopy and small coriaceous leaves. The canopy forms a continuum from under shrub to shrubs and then to the relatively large shola trees with

no marked differentiation of the canopy layers. The branches and trunks of the trees are covered with mosses, lichens, orchids and other epiphytes. The major tree species in the shola forests include *Pithecellobium subcoriaceum* Thw., *Ternstroemia japonica* non Thumb., *Ixora notoniaiza* Wall. and *Syzygium arnottianum* Walp. The major grass species in the grasslands are *Andropogon lividus* Thw., *Arundinella vaginata* Bor., *Digitaria wallichiaina* Stapf., and *Arundinella* Nees ex. Steud.

The grasslands are characterized by relatively shallow soils, low nutrient status and low water holding capacity compared to sholas (Jose *et al.*, 1994). Soil organic carbon, total N and available P levels are reported to be higher in the shola forests compared to grasslands (Sharma *et al.*, 1990; Jose *et al.*, 1994).

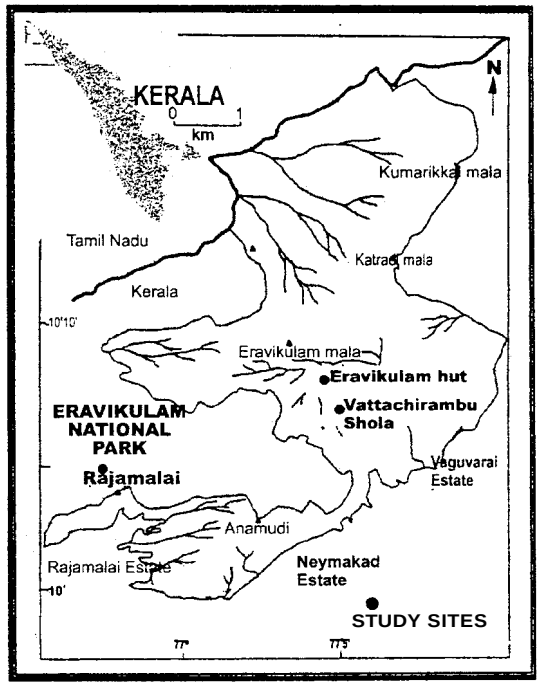

Figure 3. Study area

2.1.4. Study plots

Soil samples were collected at periodic intervals from three sampling plots viz., Rajamalai shola, shola near Eravikulam hut and Vattachirambu shola and adjacent grasslands. Of these, Rajamalai shola lies on the western boundary of ENP. Both Vattachirambu shola and shola near Eravikulam hut lie in the heart of the ENP; the latter lying approximately 4 km away from the former (Figures 3-6).

Figure 4. Shola forest and grassland at Vattachirambu

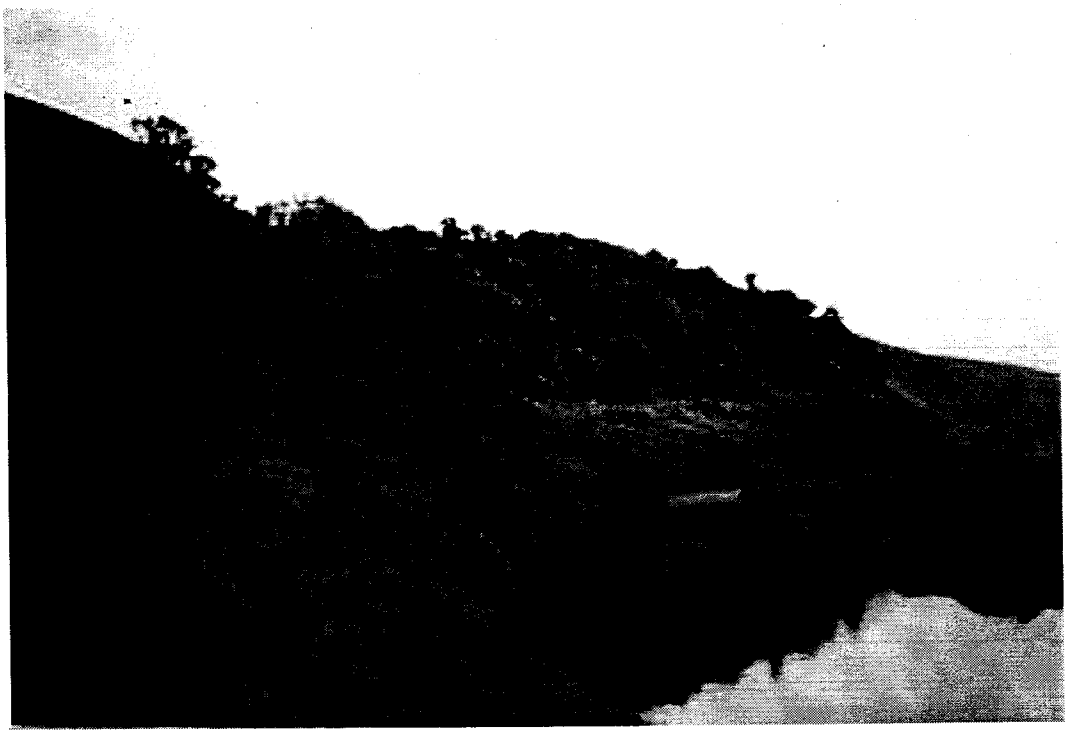

Figure 5. Shola forests and grassland near Eravikulam hut

Figure 6. Shola forests and grassland at Rajamalai

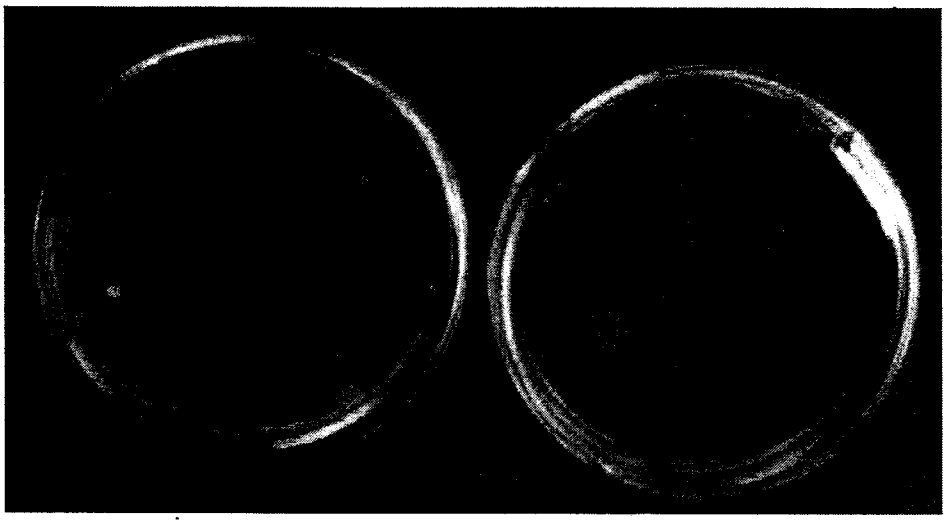

Figure 7. Bacterial colonies on nutrient agar

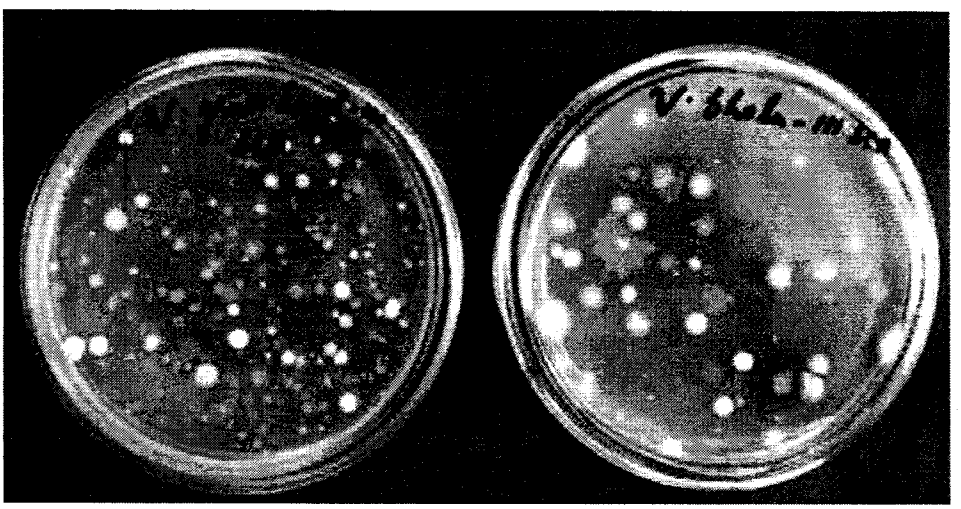

Figure 8. Actinomycete colonies on starch caesin agar

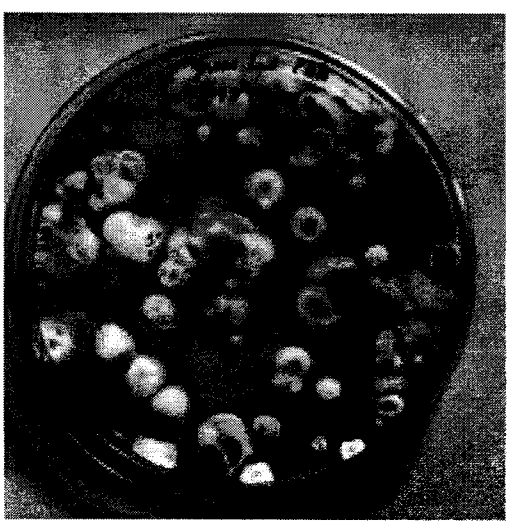

Figure 9. Fungal colonies on potato dextrose agar

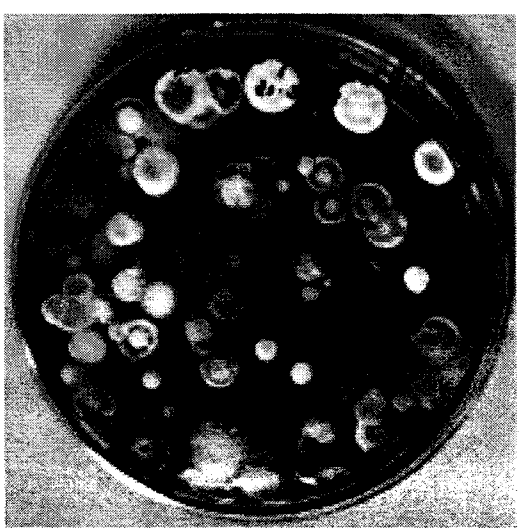

Figure 10. Fungal colonies on rose bengal agar

2.4. Methods

During each sampling, four soil samples were collected at random from a depth of 0-10 cm and mixed together to get one composite soil sample: Three such composite samples were collected from each of the shola and grassland during November-Decembereach year for three consecutive years (1994-1996). The samples were stored at 4°C till they were processed for isolation of actinomyctes, bacteria and fungi. Soil dilution plate method (Waksman, 1922; Timonin, 1940) was used for isolation of microorganisms. For isolations, 10 g of a working sample from each composite sample was transferred to 100 ml sterile water in 250 ml conical flasks. The samples were shaken thoroughly and appropriate dilutions were prepared, ie.,10-3for fungi,10^{-4} for actinomycetes and 10^{-5} for bacteria. Potato dextrose agar (PDA) and rose bengal agar (RBA) were the media used to isolate fungi, while starch caesin agar and nutrient agar were used to isolate actinomycetes and bacteria respectively. One ml of the soil suspension was transferred to individual Petri plates and appropriate media added. Five replicate Petridishes were used for each medium. The Petri plates were incubated in the dark and colonies of different microorganisms enumerated after appropriate time interval (48 h for bacteria, 6 days for fungi and 10-14 days for actinomycetes) (Figures 7-10). These data were used to compute microbes per g of oven dry soil. Attempts were made to identify the fungi and actinomycetes using relevant literature.

Several workers (Warcup, 1955; 1960) have criticized the dilution plate technique on the ground that spores give rise to most of the colonies and vegetatively active forms may be underrated or overlooked. Moreover, culturing techniques are selective and the population they reveal may only be partial. No technique assures that all species have been recognized or isolated. However, it is worth mentioning that this method draws sample populations from a great volume of soil than do most trapping methods, and therefore species restricted to small bits of organic or mineral matter are not so apt to be either missed or grossly over-estimated (Christensen, 1969). In short, despite shortcomings, this method is highly useful for primary characterization and comparison of soil microflora of diverse ecosystems.

2.3. Statistical analyses

The significance of variation in density of soil microorganisms between shola forests and grasslands was brought out using ANOVA. An estimate of similarity in species composition of soil fungal population between shola forests, grasslands and low elevation areas in Kerala was made using Sorensen's index of similarity (Sorensen, 1948) as follows :

$$S = \frac{2c}{a+b} \times 100$$

Where, a is the number of species at one site, b is the number of species at another site and c is the number of species common to both sites. When the sites are similar in species composition, the index of similarity approaches 100. Shannon - Wiener indices of species diversity was also worked out for each ecosystem (Shannon and Wiener, 1963)

$$H' = - \Sigma \; pi \; Inp_i$$

Where 'pi' is the proportional abundance of the i^{th} species = (ni /N), ni = abundance of the individual species and N = total abundance.

3. RESULTS

Observations are summarized in Table 1 and Figures 11 to 13.

3.1. Soil microflora of shola forests

3.1.1. Quantitative features

The density of fungal propagules in the shola forests ranged between 10.23 - 28.78 x 10^3 per g of soil averaging to 16.39 x 10^3 for the whole sampling period. (Table 1, Figure 11). There was no significant difference in density of fungi between different shola forests ($P < 0.05$).

The density of actinomycete population ranged between 120 x 10^3 colony forming units (cfu) per g soil in Vattachirambu shola to 474 x 10^3 cfu per g of soil in Rajamalai shola. Significant difference ($P > 0.05$) between the density of actinomycetes from different shola forests was observed. Bacterial population ranged between 862 x 10^3 to 1720 x 10^3 cfu per g of soil and the difference was statistically significant ($P>0.05$) (Table 1, Figures 12 and 13). The actinomvcete population in soils of Rajamalai shola was significantly higher ($P > 0.05$) than that of Rajamalai grassland.

3.2.2. Qualitative features

The 220 isolates of fungi from soils of the shola forests yielded 68 identified species of fungi belonging to 28 genera. Majority of the species (72%) belonged to the mitosporic group (Table 2). Zygomycota accounted for 19% of the total species and Ascomycota 9%. A list of fungi isolated from the soils at different sampling sites is given in Table 3. Vattachirambu shola (VS) contributed to 18 genera and 23 species while shola near Eravikulam hut (ES) contributed to 14 genera and *25* species. Forty species belonging to 19 genera were isolated from soils of Raiamalai shola (RS). Only four species viz., *Fusarium solani, Mucor heimalis* f. *heimalis, Paecilomyces carneus* and *Penicillium variable* were common to all the three sites. Fourteen species were common to two sites. Fortynine species were restricted in distribution and were isoiated from only one site. Between pairs of sites. 7 species were common to VS and ES, 10 to ES and RS and 9 to VS and RS. The three sampling sites differed significantly in composition of fungal species. The index of similarity ranged between 29 and 31 (Table 4).

Mitosporic fungi which formed the main constituent of the mycoflora belonged to 19 genera and 49 species. *Penicillium* which contributed to 26% (18 species) of the total species was the most dominant genus in soils of shola forests. Among Penicillia, *P. variabile* was the species with highest relative frequency (100%). *Aspergillus* which was represented by 5 species (7%) formed the next dominant genus. (Table 2). *Fusarium* and *Trichoderma* contributed to 4 species each (6% of total species). Among fusaria, *Fusarium solani* was the most common species in shola soils. Zygomycota, which followed mitosporic fungi in dominance, contributed to 6 genera and 13 species. *Absidia* and *Mucor,* represented by 4 species each, were the dominant genera in this groun. *Chaetomium* (represented by *3* species) showed p-edominance over the other genera among Ascomycota. *Emericella* represented by 2 species and *Talaromyces* by 1, were the other genera which represented Ascomycota.

Table 1. Population of fungi, actinomycetes and bacteria (10^3/g oven dry soil) in shola forests and grasslands of Eravikulam National Park (mean of three replicate values)

Study plots	Fungi			Actinornycetes			Bacteria		
	1*	2	3	1	2	3	1	2	3
Vattachirambu shola	10.23	11.18	28.78	120.00	178.67	172.00	862.23	983.33	573.33
Vattachirambu grassland	19.16	33.08	42.04	125.33	180.67	233.00	941.00	1100.00	887.00
Shola near Eravikulam hut	10.51	14.78	16.67	156.70	149.33	302.33	1720.00	1600.00	1147.00
Grassland near Eravikulam hut	25.71	30.55	41.64	133.66	134.67	276.00	840.00	1044.00	1280.00
Rajamalai shola	17.66	20.17	17.59	200.66	302.00	473.66	1133.00	1227.00	1293.00
Rajamalai grassland	14.26	36.02	28.11	153.33	262.66	320.00	887.00	1227.00	1560.00

** 1,2 & 3 - number of isolations from each habitat*

The actinomycetes from the shola forests were sub-cultured on Yeast extract malt extract agar medium. When duplicate isolates were excluded, based on morphological features such as colour of aerial mycelium, substrate mycelium, reverse side pigment, soluble, pigment, melanin production, and spore chain morphology, a total of 96 pure cultures were obtained from shola forests. When the pure cultures were identified up to generic level, 78 to 85% of the cultures from shola forests were identified as species belonging to the genus *Streptomyces*. Identification of the bacterial isolates was not attempted.

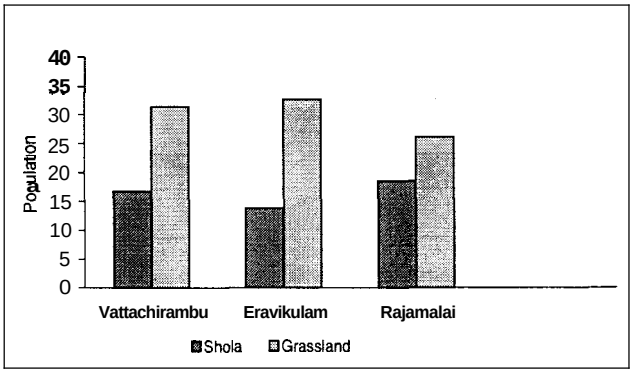

Figure 11. Population of soil fungi (10^3g oven dry soil) in shola forests and grasslands of Eravikulam National Park

3.2. Soil microflora of grasslands

3.2.1. Quantitative features

Fungi per g of dry soil ranged between 14.26 - 42.04 x 10^3 averaging to 30.06 x 10^3 for the whole sampling period (Table 1, Fig 11). There was no significant difference ($P < 0.05$) in density of soil fungi between different sampling sites in the grasslands.

The actinomycete population ranged between 125 x 10^3 to 320 x 10^3 cfu per g of soil, while the bacterial population varied between 840 x 10^3 to 1560 x 10^3 cfu per g of soil. No significant difference ($P< 0.05$) between the population density of actinomycetes and bacteria between grasslands was observed (Table 1 Figures 12 & 13).

3.2.2 Qualitative features

The 286 fungal isolates from the soils of grasslands belonged to 25 genera and 69 species. Mitosporic fungi dominated the isolations, being represented by 12 genera and 50 species (72%

of total species). Zygomycota which followed, accounted for 8 genera and 13 species (19%) and Ascomycota for 5 genera and 6 species (9% of total species) A list of fungi isolated from different grasslands is given in Table 5. Among the different sampling sites, Vattachirambu grassland (VG) contributed to 20 genera and 41 species and Rajamalai grassland (RG) to 20 genera and 40 species. Isolation from soils in grassland near Eravikulam hut (EG) yielded only 14 genera and 35 species.

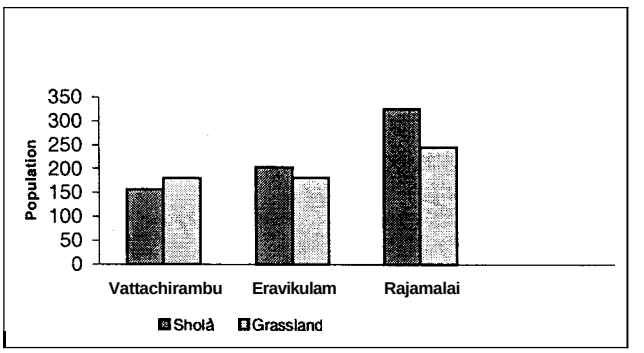

Figure 12 Population of soil actinomycetes (10^3g oven dry soil) in shola forests and grasslands of Eravikulam National Park

Eleven species of fungi which showed the highest frequency of occurrence (l00%), were isolated from all the three sampling sites. They were *Eladia* sp., *Fusarium oxysporum, Gongronella butleri, Mucor heimalis* f. *heimalis, Penicillium chermesinum, P. echinulatum, P. janthinellum, P. simplicissimum, P. variabile, P. velutinum* and *P. waksmanii*. Fifteen species were common to two sites while 45 species were restricted in occurrence. These fungi were isolated only from one of the sites.

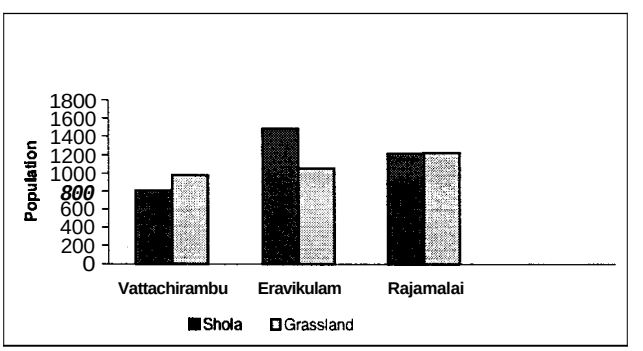

Figure 13. Population of soil bacteria (10^3 g oven dry soil) in shola forests and grasslands of Eravikulam National Park

Between pairs of sites, l7 species were common to VG and EG and 15 to VG and RG. EG and RG had 15 species in common. Though the total number of genera and species between individual sampling sites in the grasslands did not vary significantly, the composition of the fungal flora showed high variation between sites. The indices of similarity in composition of fungal species between individual sites of grasslands ranged between 40 and 45 (Table 4).

Similar to the soil fungal flora of shola forests, *Penicillium*, which was represented by 20 species (29% of total species) formed the most dominant genus in grassland soils. Of these, *Penicillium chermesinum, P. echinulatum, P. janthinellum, P. simplicissimum, P. variabile, P. velutinum and P. waksmanii* were the most frequent. *Aspergillus* which contributed to 8 species (11.5%) followed *Penicillium* in dominance. The genus *Trichoderma* was represented by 5 species, all of which were rather restricted in occurrence. Of the four species of the genus *Absidia, A. cylindrospora* var. *nigra* and *A. glauca* were more common than the rest. *Fusarium, Mucor* and *Paecilomyces* were represented by 3 species each.

Actinomycetes isolated from shola forests and grassland soils belonged to two genera viz., *Streptomyces* and *Streptoverticillum*. The population was dominated by the genus *Streptomyces* which contributed to 75-100 % of the total isolates (Table 6).

3.3. Fungi newly recorded from India

Some fungi isolated from soils of shola forests and grasslands (Table 7a) are new records for India (Bilgrami *et al.*, 1991). Detailed descriptions and global distribution of these fungi are

Table 2. Prevalence of major taxonomic groups of soil fungi in the shola forests and grasslands of Eravikulam National Park and lowlands areas in Kerala

ECO-system	Shola forests			Grasslands			Shola forests & grasslands (>2000m asl)			Lowlands (<500 m asl)		
Group	No.of genera	No.of species	% of total species	No.of genera	No.of species	% of total species	No.of genera	No.of species	% of total species	No.of genera	No.of species	% of total species
Zygomycota	6	13	19	8	13	19	9	19	19	8	18	10
Ascomycota	3	6	9	5	6	9	5	9	9	10	13	7.5
Mitosporic fungi	19	49	72	12	50	72	20	73	72	63	144	82.5
Total	**28**	**68**	**100**	**25**	**69**	**100**	**34**	**101**	**100**	**81**	**175**	**100**
Penicillia	-	18	26	-	20	29	-	29	29	-	34	19.7
Aspergilli	-	5	7	-	8	11.5	-	9	9	-	18	10
Trichoderma	-	4	6	-	5	7	-	7	7	-	2	1

provided below. A perusal of the literature showed that most of these fungi are typical to temperate habitats.

1. Absidia californica

Colonies on PDA at first white, later becoming brownish, fluffy, reverse same colour. Sporangiophores erect, mostly solitary. Sporangia globose, 20-35 µ m diam. Columella globose, pale brown, 14-35 µ m diam. Spores globose, hyaline, smooth, 3 - 5.5 µ m diam.

Distribution : This species has been isolated relatively rarely from soil and little information is available on its distribution (Ellis and Hesseltine, 1965). During the present study, it was isolated from soils in shola forests and grasslands at Rajamalai.

2. Chaetomium megasporum

Colonies on PDA pale brown, reverse same colour. Ascomata developing after 5-6 d., scattered, 140-250 x 123 - 160 µ m, ellipsoidal, ostiole 25-80 µ m, terminal hairs and lateral hairs pale brown, 2-3 µ m diam at the base tapering gradually, delicately roughened. Periphyses not seen. Asci 65-80 x 15- 28 pm, 8-spored, ascospores biseriately arranged, 20 -26 x 7-9 pm, narrowly fusiform but often irregular in shape, pale grey-brown with two apical germ pores.

Distribution : Reported from grassland soils in Japan, forest soils in Spain and bark of *Nothofagus* sp. in Argentina (Cannon, 1986). Recorded from shola forests at Rajamalai.

Table 3. List of fungi isolated from soils of shola forests in the Eravikulam National Park

Vattachirambu Shola	Shola near Eravikulam hut	Rajamalai Shola
Absidia glauca	*Abisidia cylindrospora* var. *nigra*	*Absidia californica*
Alternaria alternata	*Acremonium kiliense*	*A. cylindrospora* var. *nigra*
Aspergillus fumigatus var. *ellipticus*	*Aspergillus niger*	*A. repens*
A. viride-nutans	*Cunninghamella echinulata*	*A. glauca*
Chaetomium funicola	*Cylindrocarpon* sp.	*Acremonium* sp.
Cladosporium cladosporioides	*Emericella nidulans*	*Aspergillus fumigatus* var. *ellipticus*
Cunninghamella elegans	*Fusarium moniliforme*	*A. niger*
Curvularia intermedia	*F. solani*	*A. quadricinctus*
Emericella variecolor	*Geotrichum candidum*	*Beauveria bassiana*
Fusarium dlamini	*Gliocladium catenulatum*	*Chaetomium gracile*
F solani	*G. roseum*	*C. megasporum*
Geotrichum candidum	*Mucor circinelloides* f. *circinelloides*	*Cunninghamella elegans*
Gliocladium roseum	*M. circinelloides* f. *griseocyanus*	*Eladia* sp.
Hyphomucor assamensis	*M. circinelloides* f. *janssenii*	*Fusarium oxysporum*
Metarrhizium anisopliae	*M. heimalis* f. *heimalis*	*F. solani*
Mucor circinelloides f. *janssenii*	*M. heimalis* f. *luteus*	*Gilmaniella humicola*
M. heimalis f. *heimalis*	*M. mucedo*	*Gliocladium catenulatum*
M. heimalis f. *luteus*	*Paecilomyces carneus*	*Humicola fuscoatra*
M. plumbeus	*P.farinosus*	*Metarrhizium anisopliae*
Paecilomyces carneus	*Penicillium aculeatum*	*Mortierella* sp.
Penicillium janczewskii	*P.chermesinum*	*Mucor circinelloides* var. *circinelloides*
Penicillium variabile	*P. globrum*	*M. heimalis* f. *heimalis*
Sesquicillium candelabrum	*P. janthinellum*	*M. plumbeus*
Talaromyces sp.	*P. variabile*	*Myrothecium roridum*
	P. verruculosum	*Paecilomyces carneus*
	Rhizopus microsporus var. *rhizopodiformis*	*Penicillium canescens*
	Trichoderma hamatum	*P. chermesinum*
	T.polysporum	*P. citrinum*
		P. daleae
		P. echinulatum
		P. expansum
		P. lividum
		P. melinii
		P.montanense
		P.restrictum
		P. thomii
		P. variabile
		Rhizopus microsporus var. *rhizopodiformis*
		Trichoderma harzianum
		Trichoderma sp.

Table 4. Indices of similarity of fungal species between different ecosystems*

Paired ecosystems	Index of similarity
Lowland areas *vs* sholas and grasslands	25
Shola forests at Eravikulam *vs* grasslands at Eravikulam	50
Vattachirambu grassland *vs* Grassland near Eravikulam hut	45
Vattachirambu grassland *vs* Rajamala grassland	42
Grassland near Eravikulam hut *vs* Rajamalai grassland	40
Vattachirambu shola *vs* shola near Eravikulam hut	29
Vattachirambu shola *vs* Rajamalai shola	29
Shola near Eravikulam hut *vs* Rajamalai shola	31
Vattachirambu shola *vs* Vattachirambu grassland	34
Shola near Eravikulam hut *vs* grassland near Eravikulam hut	33
Rajamalai grassland *vs* Rajamalai shola	45

* *Isolates identified to species level were only considered for calculating similarity index*

3. Chaetomium virescens* var. *theilavioideum

Colonies on PDA yellowish green, reverse dark brown. Ascomata developing abundantly after 7d, black, scattered over the entire agar surface, 150-300 x 100-200 pm, globose to ellipsoidal, neck absent, ostiole 18-30 pm diam, whole surface of peridium covered with pale brown hairs, hairs flexuous, gradually tapered, 30-120 x 2-3 pm. Periphyses present. Asci cylindrical to clavate, thin-walled, 30-42 x 8-16 pm, evanescent at an early stage, 8-spored. Ascospores arranged biseriately, brownish, broadly fusiform, cylindrical, 11.5-16 x 4.5-8 pm, with one terminal germ pore.

Distribution : Reported from soils in China, Hongkong, Thailand and Malaysia (Cannon, 1986). Recorded from Vattachirambu grassland and grassland near Eravikulam hut.

4. *Fusarium dlamini*

Colonies on PDA initially white, becoming pale brown, floccose to powdery, reverse of colonies initially white becoming pale orange. Conidiogenous cells monophialides formed laterally on the aerial hyphae or rarely on branched conidiophores, hyaline, subulate, 10-30 x 2-3.5 µm. Microconida highly variable in size and shape, napiform, pyriform, globose, ovoid or ellipsoid, 0-1 septate, hyaline, 5-13 x 2-4 µm. Macroconidia rare, hyaline, thin-walled and falcate, with pedicellate basal and curved apical cell, 3-septate, 30-45 x 4-5 µm.

The isolate described here resembles *Fusarium oxysporum* Schlect., but forms some swollen, pyriform to globose or napiform microconidia in addition to normal ovoid-ellipsoid type. The production of napiform conidia is characteristic of *F. dlamini.*

Distribution : First reported from corn *(Zea mays* L.) soils in Butterworth area of the Republic of Transkei, South Africa (Marasus *et al.,* 1985). There are apparently no other published records of this fungus. Recorded from soils of shola forests and grasslands at Vattachirambu.

Table 5. List of fungi isolated from soils of grasslands in the Eravikulam National Park

Vattachirambu grassland	Grassland near Eravikulam hut	Rajamalai grassland
Absidia cylindrospora var. *nigra*	*Absidia cylindrospora* var. *nigra*	*Absidia cylindrospora* var. *cylindrospora*
A. glauca	*A. glauca*	*A. californica*
Aspergillus kanagawaensis	*A. spinosa*	*A. glauca*
A. nidulans	*Acremonium* sp.	*Acremonium sp.*
A. niger	*Aspergillus flavus*	*Aspergillus carneus*
A. wentii	*A. melleus*	*A. niger*
Chaetomium virescens var. *theilavioideum*	*A. viride unutans*	*A. viride-nutans*
Circinella simplex	*Chaetomium virescens* var. *theilavioideum*	*Chaetomium gracile*
Cunninghamella echinulata	*Cylindrocarpon* sp.	*Cunninghamella elegans*
C. elegans	*Eladia saccula*	*Curvularia lunata*
Curvularia intermedia	*Eladia* sp.	*Eladia* sp.
Eladia sp.	*Fusarium oxysporum*	*Eupenicillium* sp.
Emericella variecolor	*Gliocladium roseum*	*Fusarium oxysporum*
Eupenicillium sp.	*Gongronella butleri*	*F solani*
Fusarium dlamini	*Mucor circinelloides* var. *lusitanicus*	*Gliocladium catenulatum*
E oxysporum	*M. circinelloides* var. *circinelloides*	*G. roseum*
Glioclidium catenulatum	*M. heimalis* f. *heimalis*	*Gongronella butleri*
G. roseum	*Neocosmospora vasinifecta*	*Mucor circinelloides* var. *circinelloides*
Gongronella butleri	*Paecilomyces carneus*	*M. heimalis* f. *heimalis*
Hyphomucor assamensis	*P.marquandi*	*Myrothecium roridum*
Micromucor ramannianus	*Penicillium bilaii*	*Neocosmospora vasinfecta*
Mucor circinelloides f. *lusitanicus*	*P. chermesinum*	*Paecilomyces lilacinus*
M. heimalis f.. *heimalis*	*P. citrinum*	*Penicillium chermesinum*
M. racemosus f *chibinenis*	*P. echinulatum*	*P.decumbens*
Myrothecium roridum	*P. janthinellum*	*P.echinulatum*
Paecilomyces marquandii	*P.ochrochloron*	*P. expansum*
Penicillium chermesinum	*P. restrictum*	*P. janthinellum*
P.citrinum	*P. simplicissimum*	*P.purpurogenum*
P.echinulatum	*P.variabile*	*P.restrictum*
P.griseoroseum	*P.velutinum*	*P. simplicissimum*
P.janczewskii	*P. vinaceum*	*P.thomii*
P. janthinellum	*P.waksmanii*	*P.variabile*
P.simplicissimum	*Penicillium* sp.	*P.velutinum*
P.spinulosum	*Trichoderma aureoviride*	*P.vinaceum*
P.variabile	*T. hamatum*	*P.waksmanii*
P. velutinum	*T. pseudokoningii*	*Penicillium* sp.
P.waksmanii		*Periconia* sp.
Penicillium sp.		*Rhizopus microsporus* var. *rhizpodiformis*
Talaromyces sp.		*Talaromyces* sp.
Trichoderma longibracheatum		*Trichoderma* sp.
Trichoderma sp.		

Table 6. Number of *Streptomyces* spp. isolated from the study plots of shola forests and Grasslands

Sl. No.	Study plots	Number of pure cultures	Number of *Streptomyces* spp. and their percentage in parenthesis
1	Vattachirambu shola	23	18 (78.3%)
2	Vattachirambu grassland	22	19 (86.4%)
3	Shola near Eravikulam hut	16	13 (81.3%)
4	Grassland near Eravikulam hut	8	8 (100.0%)
5	Rajamalai shola	28	24 (85.7%)
6	Rajamalai grassland	24	18 (75.0%)

5. *Micromucor ramannianus (Mortierella ramanniana* var. *autotrophica).*

Colonies on PDA reddish to vinaceous brown, reverse yellowish. Sporangiophores 350 - 690 x 3.6 - 6.3 µm with a septum a little below the sporangium. Sporangia globose, 2 -30 µm wide. Columella 7.2 - 13.5 µm diam. Sporangiospores oval, ellipsoidal, variously shaped, 3.6 - 5.4 x 1.8 - 2.7 µm. Chlamydospores abundant, thick walled, rounded or of irregular shape, smooth walled, with dense and oily contents, 8 - 12 µm wide.

Distribution : It is one of the most widespread *Micromucor* species. Reports show a clean preference for cold and temperate zones or cooler zones (higher elevation areas) in tropical habitats (Gochenaur and Woodwell, 1974; Domsch *et al.*, 1980; Arnebrant *et al.*, 1987). Though Domsch *et al.*, (1980) considered it as a typical inhabitant of forest soils, during the present study it was isolated from grasslands at Vattachirambu.

6. *Penicillium bilaii*

Colonies on malt extract agar (MEA) dull green to glaucous grey in colour, surface texture velutinous to funiculose, reverse deep brown, exudates absent. Conidiophores borne on aerial hyphae, mostly solitary, rarely in funicles, stipes 28 - 86 x 2 - 2.5 µ m , smooth walled, straight or sinuous, monoverticillate, phialides crowded, parallel, ampulliform, 5.5-8.5 x 2- 2.5 µ m with short collua. Conidia pale green, subspheroidal to ellipsoidal, 2.5 - 3.0 x 2.0 - 2.5 mm with rugose walls forming well defined columns.

Distribution : This species is widely distributed in soil but not commonly isolated. Most of the records are from temperate regions, eg., soils from Kiev (Russia), Suffolk (Great Britain) New South Wales (Australia) and Mona Island (West Indies) (Pitt, 1979). Recorded from grassland near Eravikulam hut.

7. *Penicillium echinulatum*

Colonies on MEA dark green, surface velutinous to granular, reverse yellowish brown with dark brown centers, exudates absent. Conidiophores borne singly or in fascicles, biverticillate symmetrical or terverticillate, stipes 480-750 x 3.5 - 4.5 µm, rough walled, metulae in verticils of three to five, 7 -12 x 3 - 3.5 mm, phialides ampulliform, 5 - 8 per verticil, 5.5 - 9 x 2 - 2.5µm. Conidia dull green, globose to subglobose, 2.8 - 4 µm diam, walls rugose, borne in long chains.

Distribution : According to Pitt (1979), *P. echinulatum* is a widely distributed species although it appears to be of rare occurrence. The present records are however limited to temperate habitats; contaminent in Petridish from Ottawa (Canada), from air in Yorkshire (Great Britain), from sand in Alberta (Canada) and from an unrecorded source in USA (Pitt, 1979). During the present study, this fungus was recorded from all the three sampling sites in the grasslands and from Rajamalai shola forests.

8. *Penicillium griseoroseum*

Colonies on MEA greyish green to glaucous blue green, velutinous or floccose, reverse yellowish brown, exudates pale. Conidiophores commonly borne on surface hyphae, metulae in verticils of 2-4, appressed to somewhat divergent, 10-20 x 3-4 pm, phialides ampulliform, 7-13 x 2.5-3.0 pm. Conidia globose to subglobose, smooth, 2.5-3.5 mm diam.

Distribution : *P. griseoroseum* has been isolated relatively rarely and information on its distribution is very scarce. During this study, it was isolated from soils of Vattachirambu grassland.

Table 7 a. Fungi newly recorded from India

Absidia californica
Chaetomium megasporum
C. virescens var. theilavioideum
Fusarium dlamini
Micromucor ramannianus
Penicillium bilaii
P. echinulatum
P. griseoroseum
P. janczewskii
P. lividum
P. melinii
P. montanense
Trichoderma polysporum

Table 7 b. New or rarely reported fungi from Indian soil

Absidia repens
Aspergillus kanagawaensis
A. viride- nutans
Paecilomyces carneus
Penicillium canescens
P. daleae
P. ochrochloron
P. restrictum
P. spinulosum
P.vinaceum
Sesquicillium candelabrum

9. *Penicillium janczewskii*

Colonies on MEA blnish green or greenish grey, reverse dark orange, exudates absent. Conidiophores borne from aerial hyphae, stipes highly variable in length, 50-550 x 2.5-3.0 µm; Penicillia biverticillate, asymmetrical, metulae often apically swollen, 8-18 x 2.5-3.0µm, phialides ampulliform, 6 - 9.8 x 2.0 - 3.0 µm. Conidia spheroidal, green, verruculose, 2.0-3.5 µm diam.

Distribution : Penicillium janczewskii is one of the most commonly occurring Penicillium species in temperate regions of the world. It is reported from soils in Poland, Scotland, Northern Ireland, Banbury in Great Britain and New South Wales in Australia. Soil is reported to be its major and perhaps exclusive habitat (Pitt, 1979). Recorded from Vattachirambu shola and Vattachirambu grassland during the present study.

10. *Penicillium lividum*

Colonies on MEA greyish turquoise, velutinous to deeply floccose, reverse pale brown, exudates absent. Conidiophores borne on surface or subsurface hyphae, stipes 200-600 x 2.5-4.0 pm, vesiculate, monoverticillate, phialides crowded, 9-15 x 2.5-3.5 mm. Conidia subspheroidal to ellipsoidal, mostly 3.5- 5.0 x 2.5-3.0 pm, walls roughened.

Table 8. Soil fungal flora of shola forests and grasslands of Eravikulam National Park

Zygomycota

Absidia californica J.J. Ellis & Hesselt.
A. cylindrospora Hagem var. *cylindrospora* Hagem
A. cylindrospora var. *nigra* Hesselt. & J.J. Ellis
A. glauca Hagem
A. repens van Tieghem
A. spinosa Lendner
Circinella simplex van Tieghem
Cunninghamella echinulata (Thaxt.) Thaxt.
C. elegans Lendner
Gongronella butleri (Lendner) Peyronel & Dal Vesco
Hyphomucor assamensis (B.S. Mehrotra & B.R. Mehr.) Schipper & Lunn.
Micromucor ramannianus (A. Moller) Arx.
Mortierella sp.
Mucor circinelloides van Tieghem f. *circinelloides* van Tieghem
M. circinelloides van Tieghem f. *griseo-cyanus* (Hagem) Schipper
M. circinelloides van Tieghem f. *janssenii* (Lendner) Schipper
M. circinelloides van Tieghem f. *lusitanicus* (Bruderlein) Schipper
M. heimalis Wehmer f. *heimalis* Wehmer
M. heimalis Wehmer f. *luteus* Wehmer
M. mucedo L. ex Fr.
M. plumbeus Bon.
M. racemosus Fres. f. *chibinensis* (Neophytova) Schipper
Rhizopus micrsporus var. *rhizopodiformis* van Tieghem
Rhizopus spp.

Ascomycota

Chaetomium funicola Cooke
C. gracile Udagawa
C. megasporum Sorgel ex. Seth.
C. virescens var. *theilavioideum* (Chen.) P.F. Cannon
Emericella nidulans (Eidam) Vuill.
E. variecolor (Fennell & Raper) C.R. Benj.
Eupenicillium sp.
Neocosmospora vasinfecta Smith
Talaromyces sp.

Mitosporic fungi

Acremonium kiliense Grutz.
Acremonium sp.
Alternaria alternata (Fr.) Keissler
Aspergillus carneus (van Teighem) Blochwitz
A. flavus Link
A. fumigatus var. *ellipticus* Raper & Fennell
A. kanagawaensis Nehira
A. melleus Yukawa
A. nidulans (Eidem) Wint.
A. niger van Tieghem
A. quadricinctus Yuill
A. viride - nutans Ducker & Thrower
A. wentii Wehmer
Aspergillus spp.
Beauveria bassiana (Bals.) Vuill
Cladosporium cladosporioides (Fres.) de Vries
Curvularia intermedia Boedijn
C. lunata (Wakker) Boedijn
Cylindrocarpon sp.
Eladia saccula (Dale) Smith
Eladia sp.
Fusarium dlamini Marasas, Nelson & Toussoun
F moniliforme J. Sheld.
F. oxysporum Schltdl.
F solani (Mart.) Sacc.
Geotrichum candidum Link
Gilmaniella humicola Barron
Glicladium catenulatum Gilm. & Abbott
G. roseum Bainier
Humicola fuscoatra Traaen
Metarrhizium anisopliae (Metschn.) Sorok.
Myrothecium roridum Tode ex Fr.
Paeciloniyces carneus (Duche & Heim) Brown & Smith
P. farinosus (Holm ex S.F. Gray) Brown & Smith
P. lilacinus (Thom) Samson
P. marquandii (Massee) Hughes
Penicillium aculeatum Raper & Fennell
P. bilaii Chalabuda
P. canescens Sopp.
P. chermesinum Biourge
P. citrinum Thom
P. daleae Zaleski
P. decumbens Thom
P. echinulatum Raper & Thom
P. expansum Link ex Gray
P. glabrum (Wehmer) Westling
P. griseoroseum Dierckx
P. janczewskii Zaleski
P. janthinellum Biourge
P. lividum Westling
P. melinii Thom
P. montanense Christensen & Backus
P. ochrochloron Biourge
P. purpurogenum Stoll
P. restrictum Gilman & Abbott
P. simplicissimum (Oudem.) Thom
P. spinulosum Thom
P. thomii Maire
P. variabile Sopp
P. velutinum van Beyma
P. verruculosum Peyronel
P. vinaceum Gilman & Abbott
P. waksmanii Zaleski
Penicillium spp.
Periconia sp.
Sesquicillium candelabrum (Bonord.) W. Gams
Trichoderma aureoviride Rifai
T. hamatum (Bonord.) Bain.
T harzianum Rifai
T. longibracheatum Rifai
T. polysporum (Link ex. Pers.) Rifai
T. pseudokoningii Rifai
Trichoderma sp.

Distribution : This species appears to be confined to undisturbed woodlots and forest soils in temperate habitats. Recorded from soils in Wisconsin (USA), Lancashire (Great Britain) Saskatchewan (Canada) and Italy (Pitt, 1979). Other reports are from peat in Sweden, litter in Netherlands and Germany and from roots of eucalypts in Canberra (Australia). During this study it was isolated from soils in shola forest at Rajamalai.

11. *Penicillium melinii*

Colonies on MEA greyish yellow, velutinous or at times floccose, reverse yellowish brown, exudates clear. Conidiophores borne from surface hyphae, stipes 80-530 x 2.5 - 4.0 µ m, walls roughened. Penicillia irregularly monoverticillate to biverticillate, metulae rough walled, 8 - 25 x 2.5 - 4.5 µ m, phialides closely packed and parallel, usually abruptly narrowing to a very short collua, 6 - 11 x 2.5 - 3.0 pm. Conidia dark green, roughened, 3.0 - 4.0 pm diam, borne on short to long chains.

Distribution : *P. melinii* is a soil fungus of wide distribution in temperate habitats. It is recorded from soils in USA, Great Britain and Syria (Pitt, 1979). This fungus was isolated from shola forests at Rajamalai.

12. *Penicillium montanense*

Colonies on MEA with greenish grey center and dull green marign, velutinous, plane or centrally slightly convolute, reverse pale, exudates yellowish. Conidiophores borne on surface hyphae, stipes 380-550 x 4.0-5.5µ m, smooth, thin walled, penicilli monoverticillate, phialides ampulliform, broad, 8-11 x 3.0-3.5 µ m, with long collua tapering to narrow apices. Conidia globose to subglobose, spinose, 3.5 - 4.0 µ m diam.

Distribution : A rarely isolated species, *P. montanense* appears to be confined to habitats in uncultivated soil in temperate regions of the world (Pitt, 1979). It is recorded from soil in Sweden (Arnebrant *et al.,* 1987), Montana (USA), Saskatchewan (Canada) and Austria and also from decomposing leaves of eucalypt in New South Wales (Australia) (Pitt, 1979). During the current study, it was isolated from soils of shola forests at Rajamalai.

13. *Trichoderma polysporum*

Colonies slow growing on PDA characterizedby the formation of discrete white pustules covered with sterile conidiophore ends. Conidiophores arise irregularly but close together to form scattered tufts, each measuring 4-6 pm diam, tips end up in sterile hyphal elongations which are curved, flexuous or whip like. Phialides 4.0 - 6.5 x 2.8 - 3.5 pm, short, plump and almost pear shaped. Conidia ellipsoid to oblong, hyaline, formed in slimy heads, smooth, 2.8 - 2.7 x 1.8 - 2 pm.

Distribution : *T polysporum* is a widely distributed species, though apparently not frequent anywhere. Isolated from soil and a variety of other substrates especially under cool climate. In soils in the USA, it is restricted to those with low temperature (Domsch *et al.,* 1980). Records of the fungus are available from Europe, North America, Nepal, Australia, New Zealand, equatorial West Africa, Central Africa and Japan. (Domsch *et al.,* 1980). During the current study, it was isolated from soils in shola forests near Eravikulam hut.

The following fungi isolated during the present study (Table 7b) are rarely recorded from India. (Gilman, 1957; Raper and Thom 1968; Raper and Fennell, 1977; Pitt, 1979; Domsch *et al.,* 1980; Bilgrami *et al.,* 1991). Some of these fungi constitute new records from Indian soils. Information on the distribution and habitat of occurrence of these fungi are provided below.

1.*Absidia repens* : Recorded from soils in Austria and Switzerland. In India it is recorded from soils in Lucknow and Kanpur in Uttar Pradesh (only two records in all). During the present study it was isolated from shola forest soil at Rajamalai.

2.Aspergillus kanagawaensis : This fungus is very common in forest soils in temperate habitats. Earlier records are from Wisconsin, USA (Christensen, 1969), Northern England (Widden, 1987) and Australia (Raper and Fennell, 1977). In India, it was recorded from soils in Aurangabad (only one record). It was recorded from VG during the present study.

3. Aspergillus viride-nutans : This fungus was isolated originally from rabbit dung in Frameston, Australia (Raper & Fennell, 1977). There are two records from India; i.e., from soil in Madras and Bihar. Isolated from VS, EG and RG during the present study.

4. *Paecilomyces carneus* : *P. carneus* is widely distributed in soils in the temperate regions. Its occurrence in the tropics has been very rare (Domsch *et al.,* 1980). In India, the only record was from air in Uttar Pradesh (Bilgrami *et al.,* 1991). This forms the first record from soil in India (isolated from all the sampling sites in the shola forests and also from grassland near Eravikulam hut).

5. *Penicillium canescens* : This fungus is reported to be widespread in soils in the temperate regions. There are a few records from tropical soils also (Domsch *et al.,*1980). In India, it is recorded from soils in Madhya Pradesh and Uttar Pradesh (only two records in all). Isolated from RS during the current study.

6. *Penicillium daleae* : *P. daleae* is commonly isolated from soils in temperate regions. The only record from India is from paddy field soils in Orissa (Domsch *et al.,* 1980). Isolated from RS during this study.

7. *Penicillium ochrochloron:* Though *P. ochrochloron* is considered to be a soil organism, there is no published record on its occurrence in soil (Pitt, 1979). In India, it was isolated from jute bag from Calcutta (Bilgrami *et al.,*1991). This forms the first record of *P.ochrochloron* from soils. It was isolated from soil in grassland near Eravikulam hut.

8. *Penicillium restrictum* : It is considered to be a soil fungus of worldwide distribution but records from tropical habitat are rare. There is only one record from India; i.e., from soils in Orissa. It was isolated from soils in RS, RG and EG from the Eravikulam National Park.

9. *Penicillium spinulosum* : *P.spinulosum* is of widespread occurrence in soils of temperate regions (Pitt, 1979). In India, the only record is from soils in Andhra Pradesh. It was isolated from soils in VG during the present study.

10 *Penicillium vinaceum* : This fungus has been isolated only rarely from soils. The few records available are from temperate soils. Indian records are from soils in Andhra Pradesh and Madhya Pradesh (two records in all). During the present study it was isolated from EG and RG.

11. *Sesquicillium candelabrum* : This fungus was originally reported from forest and cultivated soils in the Netherlands. Other reports are from soils in Nepal, Japan, USA, Poland, USSR, Syria, and New Zealand. (Domsch *et al.,* 1980) Indian records are from soils in Uttar Pradesh and dead twigs in Rajasthan (Bilgrami *et al.,* 1991). During the current study, it was isolated from VS.

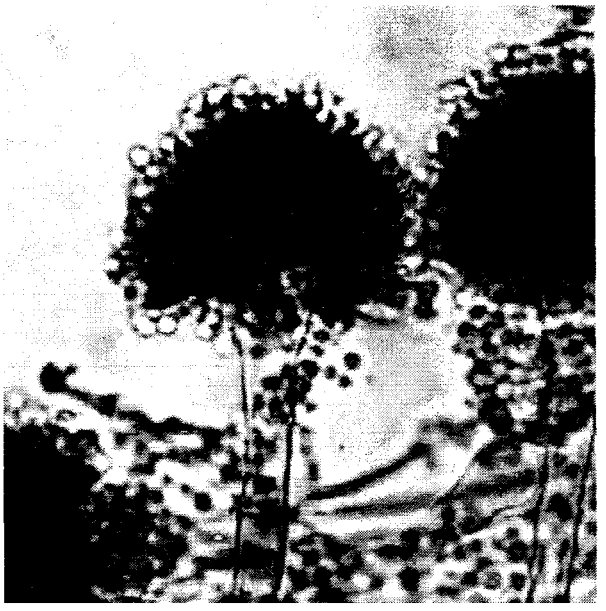

Figure **14** ***Emericella variecolor***

3.4. Comparison between soil mycoflora of shola forests and grasslands.

3.4.1. Quantitative features

The density of fungal propagules in soil was significantly higher (P>0.05) in grasslands compared to shola forests. This was true for all combinations of shola forests and grasslands.

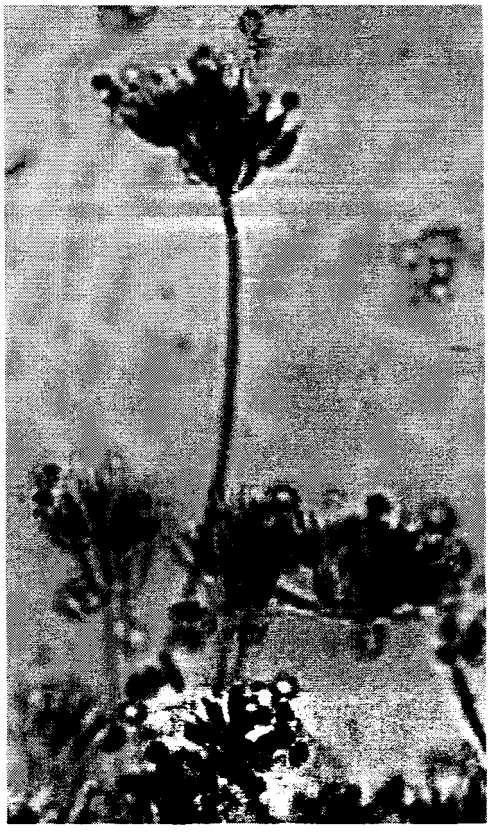

Figure 15. *Penicillium aculeatum*

3.4.2. Qualitative features

In general, the number of genera and species of fungi isolated from shola forests and grasslands did not show significant difference between each other. Twenty eight genera and 68 species were isolated from shola forests; whereas grasslands contributed to 25 genera and 69 species (Figures 14 - 23). However, if considered separately, each pair of grassland and shola exhibited some variation in the number of taxa recovered from soil. VG and EG contained more number of genera and species than the corresponding shola forests. However, RG and RS did not show significant variation in this respect. While 10 species were common to VS and VG and ES and EG, 17 species were common to RS and RG. In short, shola forests and grasslands at Rajamalai showed close similarly in the number of taxa isolated.

Significant variation was observed in composition of species of soil fungi between each sampling site. The overall index of similarity between grasslands and shola forests was 50 (Table 4). About 47% of the species were restricted to either of the ecosystems. One interesting observation was that the similarity in species composition

was higher between grasslands (index of similarity varied between 40-45) compared to shola forests. This can be further illustrated by the fact that while only 4 species of fungi were common to the three sampling sites of sholas, grasslands shared 11 common species. *Penicillium variable* and *Mucor heimalis* f. *heimalis* were the only two species common to all sampling sites in sholas and grasslands. The indices of similarity between individual shola and corresponding grasslands varied between 33 and 45, the highest being between RG and RS (Table 4). Shannon's index of species diversity was almost same for shola forests (4.184) and grasslands (4.168)

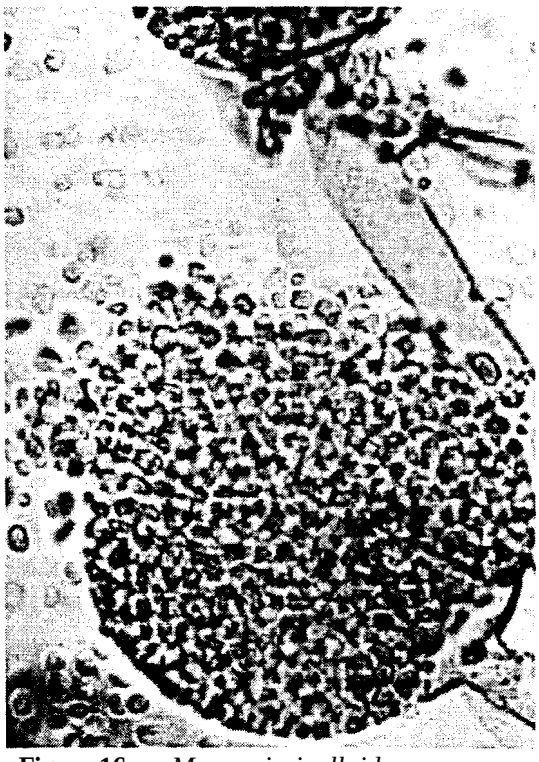

Figure 16. *Mucor circinelloides* var. *lusitanicus*

The prevalence of major taxonomic groups of soil fungi in both the ecosystems remained similar. *Penicillium* was the most dominant genus in both, represented by 18 and 20 species in shola forests and grasslands respectively. *Aspergillus* formed the next dominant genus. Other dominant genera were *Trichoderma, Absidia, Fusarium* and *Mucor* in both the habitats with only slight variation in number of species. (Table 2). Mitosporic fungi formed the largest component of the soil mycoflora in both sholas and grasslands. It is worth noting that among 13 fungi newly recorded from India 4 species viz., *Penicillium lividum, P. melinii, P. montanense* and *Chaetomium megasporum* were restricted to shola forests at Rajamalai. While *Penicillium griseoroseum* and *Micromucor ramannianus* were restricted to VG, P. *janczewskii* and *Fusarium dlamini* were shared solely by VG and VS. Another interesting observation is that the number of *Penicillium* species was rather low at VS and ES compared to the corresponding grasslands.

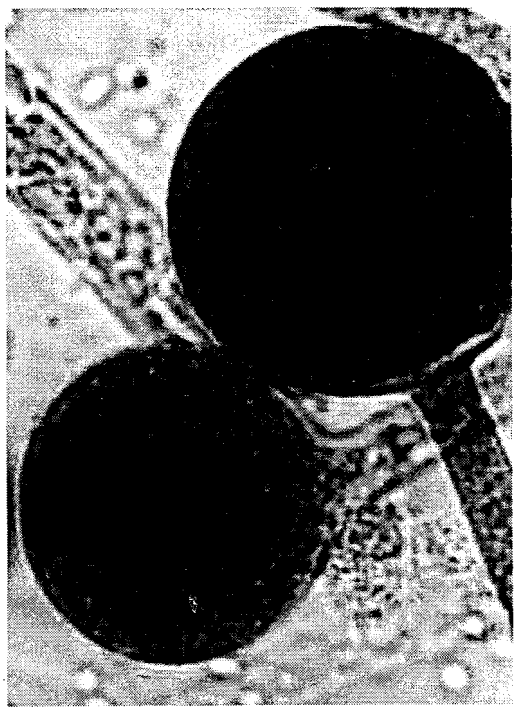

Figure 17. *Circinella simplex*

3.5. Comparison between soil mycoflora of shola forests and grasslands with that of low elevation areas in Kerala

A comparison is attempted between soil fungal flora of shola forests and grasslands (high elevation areas - HEA) (Table 8) with that of low elevation areas (LEA) in Kerala based on data available in the literature (Sankaran, 1981; Zachariah, 1981). The data from LEA (Appendix) were based on intensive studies conducted in a large variety of habitats in the north of Kerala. Compared to this, the data collected from HEA cannot be considered very exhaustive as only a part of the high elevation areas in Kerala were surveyed for soil microflora. Nevertheless, a broad-level comparison may bring out any major variation in species composition between fungal floras.

The total number of species isolated from LEA were 175 which belonged to 81 genera compared to 101 species (belonging to 34 genera) isolated from HEA. Mitosproic fungi constituted a major share of the soil mycoflora of LEA (82.5% of total species) and HEA. The percentage of total species was however lower in the latter (72%). Mitosporic fungi accounted for 63 genera and 144 species in LEA, while 73 species belonging to 20 genera could only be isolated from HEA.

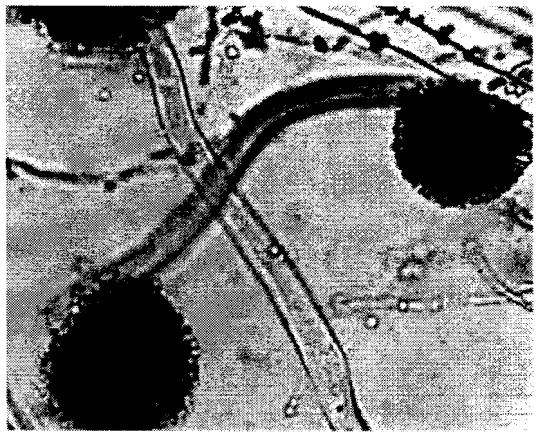

Figure 18. *Aspergillus kanagawaensis*

The preponderance of *Penicillium* is one of the distinguishing features of the soil mycoflora of HEA. The genus constituted 29% of the total species compared to 19.7% in LEA. Ten species were common to both the ecosystems. The index of similarity was 33. *Penicillium variabile* which occurred at high frequency in high elevation sites was also most frequent in low elevation areas. *Penicillium bilaii, P. echinulatum, P.griseoroseum, P..janczewskii, P. lividum, P. melinii* and *P. montananse,* isolated from grasslands and sholas are new records for India.

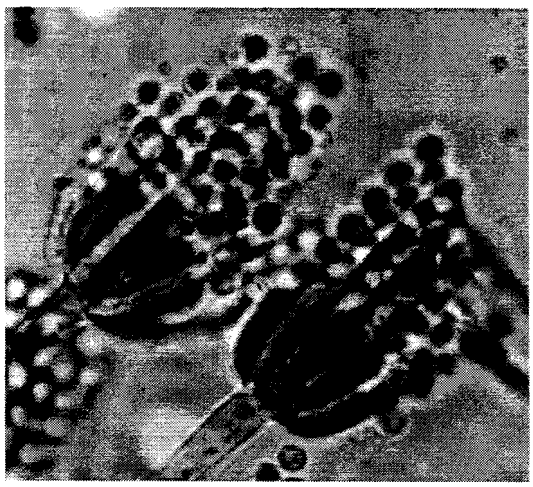

Figure 19. *Penicillium glabrum*

Aspergilli were represented by 18 species in LEA compared to 9 in HEA. Number of species of *Trichoderma* isolated were more (7 species) in HEA compared to 2 in LEA. (Table 2). As regard to Zygomycota, when 8 genera and 18 species (10% of total species) were recorded from low-elevation areas, HEA contributed to 9 genera and 19 species (19%). Diversity of mucoraceous fungi was greater in HEA. The genus *Absidia* was represented by 5 species in HEA compared to 2 in LEA. *Micromucor ramannianus,* usually known to occur in cool and temperate regions was recorded from grasslands. Diversity of members of Ascomycota was more in lowland areas compared to highlands.

In general, species composition of the soil mycoflora in the lowland areas differed significantly from that of shola forests and grasslands. This observation is supported by the low similarity index (25). Shannon's diversity index was higher for LEA (5.087) compared to shola forests (4.184) and grasslands (4.168). These values indicate greater species diversity of fungi in soils of low elevation areas compared to those in high elevation areas. The poor representation of *Fusarium* in high elevation areas (4 species) as against 11 in LEA is also worthy of mention. The absence of genera like

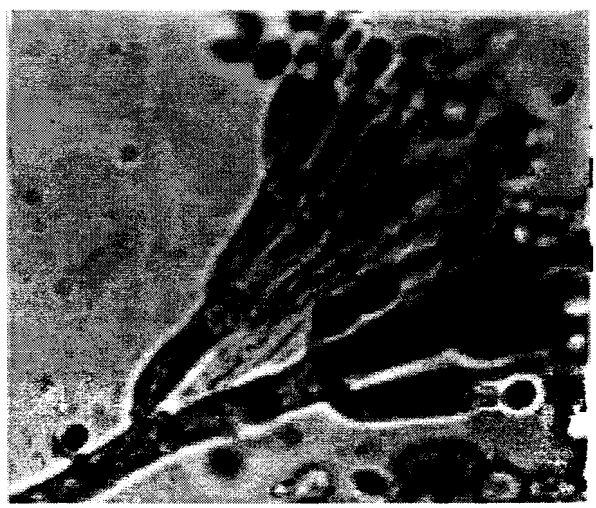

Figure 20. *Penicillium expansum*

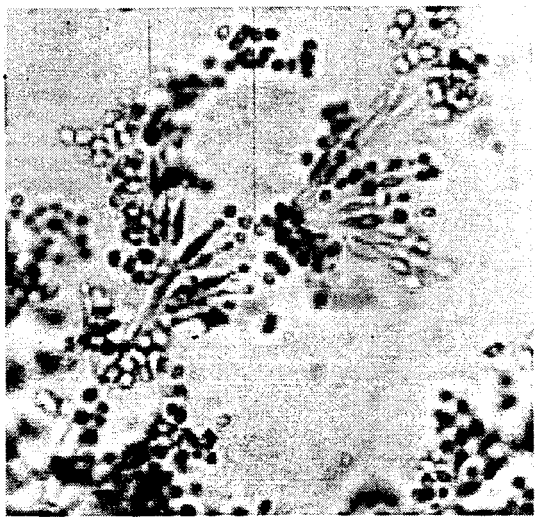

Figure 21. ***Paecilomyces carneus***

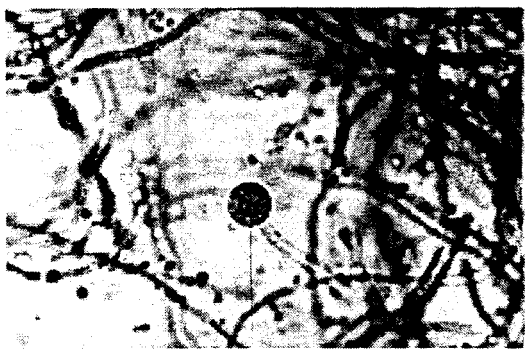

Figure 22. ***Micromucor ramannianus***

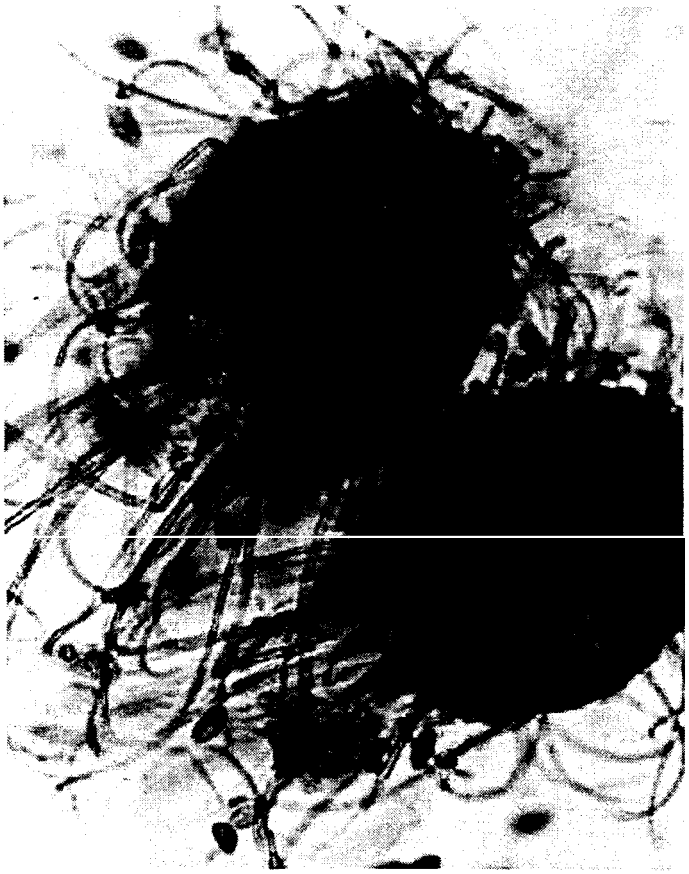

Figure 23. ***Chetomium virescens*** var. ***theilavoideum***

Rhizoctonia, Scolecobasidium and ***Verticillium*** in HEA is another feature at variance from the soil fungal flora of LEA.

3.6. *Ex-situ* conservation of soil fungi

The 34 genera and 101 species of soil fungi isolated from the shola forests and grasslands of ENP are conserved in pure culture in the culture collection facility at the Kerala Forest Research Institute. The fungal cultures (maintained on potato-dextrose agar slants) are examined periodically for purity and subcultured on fresh PDA slants to Facilitate long term storage.

4. DISCUSSION

4.1. Soil mycoflora of shola forests and grasslands

4.1.1. Quantitative features

The density of fungal propagules/g of soil in grasslands and shola forests recorded during this study is comparable to that reported by Reddy (1962) from soils of Nilgiri forests of comparable altitude. It also agrees well with the data recorded by Sankaran (1981) and Zachariah (1981) from soils of Malabar and that by Gochenaur and Whittingham (1967) from soils of willow and cottonwood lowland communities in Southern Wisconsin, USA. However, it is lower than that reported by Upadhyay and Rai (1979) and Saksena (1955) from other parts of India, and also by Wicklow (1973) from praire stands in S. Wisconsin, USA. This variation in density of fungal propagules in soil can be ascribed to the difference in micro- and macro-climatic and edaphic factors prevalent at each site, which are known to influence the fungal population. The lack of variation in soil fungal counts between individual sampling sites of shola and grasslands reflects the similarity in the climatic and edaphic factors referred above.

4.1.2. Qualitative features

In conformity with the general pattern of the soil fungal population in a wide range of geographic regions (Reddy, 1962; Bhatt, 1970; Kamal and Bhargava, 1973; Papendorf, 1976; Gochenaur and Whittingham. 1967; Zachariah, 1981; Widden, 1986,1987), the mitosporic fungi were found to be the largest, most varied and best representedgroup in the soils of shola forests and grasslands. The dominance and high frequency of penicillia, asperigilli, *Fusarium* and *Trichoderma* observed in these two ecosystems is in agreement with the reports of several earlier workers (Warcup, 1957; Reddy, 1962; Moubasher and Moustafa, 1970; Singh, 1976; Sankaran, 1981; Zachariah, 1981; Widden, 1987). The predominance of these fungi in soils of diverse geographical regions may be attributed to their high sporulating ability and rapid growth. According to Upadhyay and Rai (1979) these genera of fungi have a wide ecological spectrum.

The preponderance of penicillia in soils of cool and temperate forests has also been reported by several workers (Warcup, 1951; Miller *et al.,* 1957; Widden, 1987). Reddy (1962) recorded *Penicillium* as the dominant genus in soils of Nilgiri high altitude forests. Aspergilli are generally considered to be abundant in warmer climates and in tropical soils (Miller *et al.,* 1957; Warcup, 1951; Rama Rao, 1970). The occurrence of aspergilli in temperate soils is reported to be sporadic (Miller *et al.,* 1957). Results of the present study are in agreement with these observations.

Thornton (1960) reported abundance of zygomycetous fungi in forest and grassland soils in England and New Zealand. According to Papendorf (1976) who studied the soil mycoflora of *Acacia karroo* community in Western Transvaal, S. Africa, high surface temperature, low moisture content and limited energy sources available are too rigorous for the survival of generally hyaline and delicate mucoraceous forms. The climatic and edaphic factors in temperate soils are thus considered to be favourable for the proliferation of mucoraceous fungi. Data from soils of the Eravikulam National Park (ENP) confirm this view.

A significant number of fungi recorded from shola forests and grasslands appear to be cosmopolitan in distribution, reported from tropical and temperate habitats around the globe (Chesters, 1949; Saksena, 1955; Rama Rao, 1970; Wicklow and Whittingham, 1974; Papendorf, 1976; Widden, 1987; Gochenaur, 1978; Zachariah, 1981). However, in general, the flora shows close resemblance to fungal flora of temperate soils. Thirteen species of fungi recorded from soils in the ENP were common to soils along an elevation gradient in northern England (Widden, 1987). Likewise, 23 species of fungi were common to ENP and sandbarwillow stands in southern Wisconsin (Gochenaur and Backus, 1967). Close similarly was also observed between soil fungal flora of ENP and that of conifer-hardwood forests in northern Wisconsin, USA (Wicklow and Whittingham, 1978) and norway spruce stands in southern Qubec (Canada) (Widden, 1986).

Among the fungi recorded from shola forests and grasslands of ENP, *Absidia cylindrospora, Aspergillus kanagawaensis, Beauveria bassiana, Geotrichum candidum, Mucor circinelloides, Metarrhizium anisopliae, Micromucor ramannianus, Paecilomyces carneus, Penicillium aculaeatum, P. canescens, P. daleae, P. janthinellum, P.lividum, P. melinii, P. purpurogenum, P. simplicissimum, P. spinulosum, P. variabile, P.verruculosum, P. thomii, P. waksmanii, Trichoderma hamatum, T harzianum* and *T polysporum* are reported to be either restricted to temperate soils or recorded only during winter months in subtropical/tropical areas. (Christensen *et al.,* 1962; Danielson & Davey, 1973; Gochenaur and Woodwell, 1974; Gochenaur, 1978; Widden, 1986, 1987). The foregoing discussion provides ample proof for the similarity of soil fungal flora of ENP with that of temperate soils.

The similarity in soil mycoflora of different regions with very diverse plant cover and highly varied micro- and macro-ecological characteristics may be attributed to the fact that the soil environment is physically better buffered than the sub aerial environment, so that the microbes do not suffer such extremes as higher plants do (Garrett, 1955). It is also true that microbes in general are more tolerant to environmental extremes than higher plants. This tolerance may be ascribed in part to their capacity for prolonged dormancy.

The results of this study prompt the authors to agree with the views of Garrett (1955) and Griffin (1972) that in general terms, the mycoflora of soils even of greatly different geographical areas are striking for their similarity rather than dissimilarity.

A large number of investigations on fungal flora of grasslands have been published but still it is difficult to find distinct patterns of fungal distribution. Studies from New Zealand (Thornton, 1960), USA (Orpurt and Curtis, 1957) and England (Warcup, 1951) showed that Fusarium is the most characteristic genus of the grassland soils and is virtually always present among the isolates from grasslands. Other important genera isolated from grasslands are *Penicillium, Absidia, Trichoderma, Mortierella* and *Cladosporium.* Results of the present study are broadly consistent with these reports. However, *Fusarium* was represented by only three species in this study and these were all isolated from shola forests also. So, *Fusarium* cannot be considered quite characteristic of grasslands everywhere. The absence of *Cladosporium* and *Mortierella* may be a matter of chance rather than due to any specific ecological reason.

The wide variation in species composition of soil fungi between shola forests probably reflects the slight variation in plant species composition at individual sites. The presence of larger number of fungal species at Rajamalai shola and the abundance of *Penicillium* at this site compared

to other shola forest sites makes one think whether anthropogenic disturbances contributed to this change. This hypothesis is supported by the fact that the difference in species composition between grassland and shola forest at Rajamalai was not very much pronounced. It is possible that the shola forest at Rajamalai is loosing its uniqueness due to disturbance.

Individual grassland sites at ENP also varied greatly in species composition. But, the variation in this regard was much less compared to shola forests. A total of 14 species were common to all the three sampling sites in the grasslands. This observation shows the relative uniformity in the vegetation and edaphic characteristics between grassland sites.

4.2. Comparison between soil mycoflora of shola forests and grasslands

4.2.1. Quantitative features

The density of fungal propagules in the soil was significantly higher in grasslands compared to shola forests. These results are contrary to the widely held dogma that forest soils will hold higher density of microorganisms due to the high organic matter content, and a multitude of other positive factors. The occurrence of higher density of fungal propagules in grassland soils can be dttributed to the fact that grasslands provided favourable micro- and macro-climatic conditions for multiplication of fungi than shola forests. Thornton (1960) reported that grass-clover pasture soils in England contained higher number of mycelia than oakwood and pine forests.

Allelopathic effect of leaf litter of certain trees and build up of frost inside shola forests are probable reasons for the reduction in number of soil fungal propagules in these forests.

4.2.2. Qualitative features

Though a good number of the cosmopolitan species were common to both grasslands and shola forests, 47% of the total species were restricted to either of the ecosystems showing that they yielded floristically dissimilar communities of soil microfungi. The index of similarity between shola forests and grasslands was 50 (Table 4). Many of the fungi restricted to each ecosystem can be considered as narrow amplitude species as their frequency of occurrence was low (45 species in grasslands and 49 in shola forests). The dominance of such species leaves no scope for identifying indicator species for sholas and grasslands. This also indicates a large environmental diversity involving soil physical and chemical properties and nature of organic matter accumulation. Jose *et al.*, (1994) have reported that shola forests in ENP are superior to grassland soils in terms of edaphic characteristics, nutritional status and water holding capacity.

A critical appraisal of the soil fungal flora of grasslands and shola forests probably indicates that there is a fungal flora of cosmopolitan species and that each habitat is characterized by a few characteristic species (Nicholls, 1956). However, floristic surveys like the one conducted here is insufficient to identify the species characteristic for each site. It requires more intensive studies spread over a much longer period. As far as the cosmopolitan species are concerned, they show no apparent ecological specificity in terms of presence, their frequencies and densities vary from habitat to habitat; probably each species exhibits an Optimum development under specific vegetational and edaphic conditions (Christensen, 1969). The fact that there is no significant difference in number of fungal species isolated from both the habitats show that grassland soils are rich enough to favour growth of diverse species. Shannon's diversity indices indicate similar species diversity in both the ecosystems.

4.3. Comparison between soil mycoflora of low elevation areas (LEA) and shola forests and grasslands

The higher species richness in low elevation areas (LEA) compared to HEA may be due to the higher relative diversity in microhabitats and abundance of physical environmental resources in the former. The main factors contributing to the species richness being, organic matter derived from a great variety of plant species, congenial climatic conditions like high temperate and high humidity and nutrient -rich soils in LEA.

In general, number and diversity of mitosporic fungi were greater in LEA because most of these fungi prefer high temperature and high humidity for proliferation. Dematiaceous and sphaeropsidaceous forms possess morphological and/or physiological properties permitting them to survive in the harsh conditions provided by tropical warm humid climate. The abundance of aspergilli in these soils compared to soils in HEAis an example. Penicillia, *Trichoderma* and members of Zygomycota appear to prefer less harsh atmospheric and soil conditions for proliferation (Papendorf, 1976) and hence were abundant in soils in HEA compared to LEA. It may be noted here that most of the fungi which are recorded as new addition to Indian fungi during this study, are typical of temperate habitats. Majority of the rarely recorded fungi isolated during the current study (Table 7b) are also characteristic of temperate soils. In summary, the species richness and diversity of fungi in LEA is mainly due to the tropical warm humid climate prevailing in the study sites. As sites in HEA are situated in high elevation areas (>2000 msl), the climate is typically cool and temperate.

Figure 24. *Spirales* conidial chain morphology of *Streptomyces*

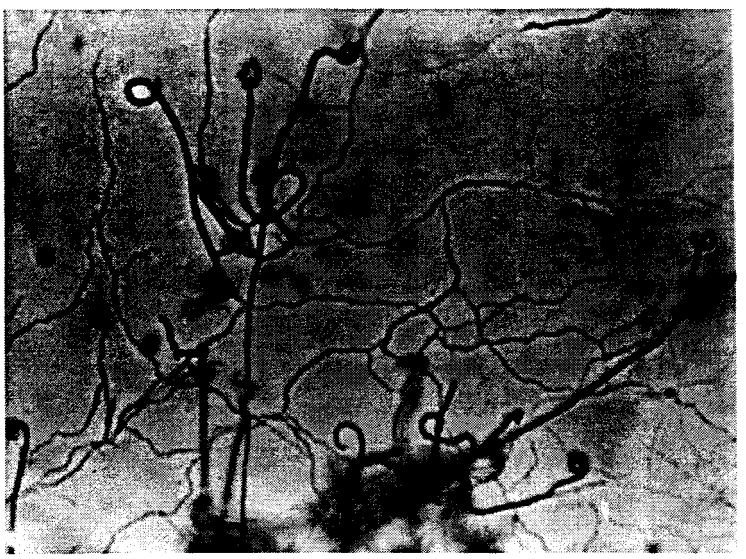

Figure 25. *Retinaculiaperti* conidial chain morphology of *Streptomyces*

Some of the cosmopolitan species were common to LEA and HEA; but LEA appears to have a characteristic soil fungal flora of its own, largely decided by the natural plant cover, existing ecological conditions and interactions among various fungal

species (Christensen, 1969; Upadhyay and Rai, 1979). It is worth mentioning here that in contrast to the low species richness of soil fungal flora, shola forests and grasslands in ENP (HEA) has a rich plant flora perhaps the richest in the whole of Western Ghats (Jose *et al.*, 1994).

4.4. Actinomycetes and bacteria from shola forests and grasslands

The density of population of bacteria and actinomycetes reported from soils of the shola forests and the grasslands in the present study are less than those reported from lowland South Indian soils (Rangaswami *et al.*, 1967; Balasundaran, 1992). The low population density may be due to the cool weather condition prevalent in high altitudes of shola forests and grasslands. Alexander (1978) reported that abundance of microbial population in various soils is a reflection of several environmental factors.

The role of actinomycetes in decomposition of organic matter and their importance in nutrient cycling is stressed by various soil microbiologists and ecologists (Waksman, 1959; Alexander, 1978). Among the actinomycetes, the preponderance of *Streptomyces* spp. observed in the present study was expected as they are the most dominant genus in this group of organisms. A study conducted on actinomycetes from the forest soils of Ponmudi which is also a high altitude area in Kerala State, showed that most of the 40 pure cultures of actinomycetes isolated were *Streptomyces* spp. (Philip and Ray, 1976). The dominance of *Streptomyces* spp. among the soil actinomycetes in all types of soil including desert soil (Elwan and Diab, 1976) was reported earlier (Waksman, 1959; Lechevalier and Lechevalier, 1981; Balasundaran, 1992). Rangaswami *et al.* (1976) also reported that *Streptomyces* spp. accounted for 87 to 97% of the actinomycetes from the soils of South India.

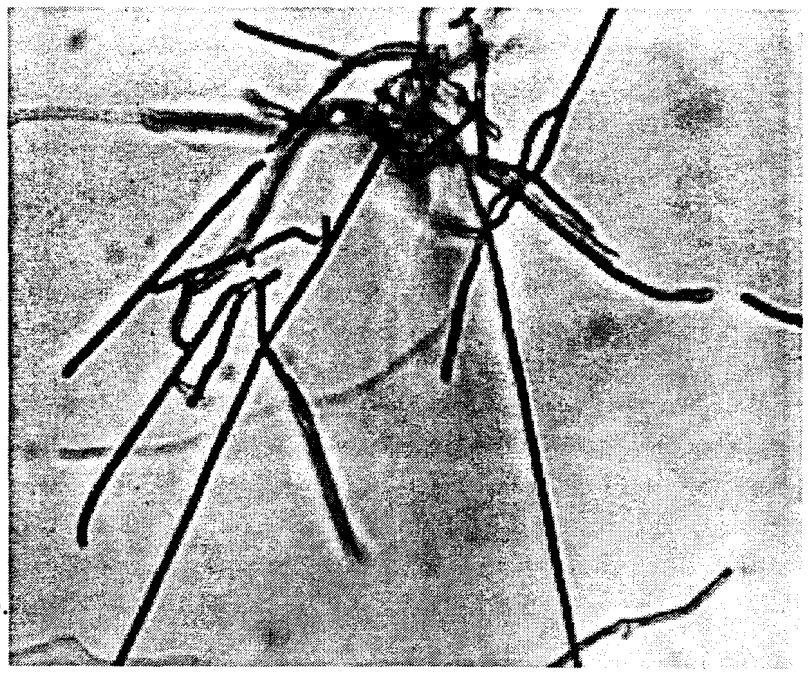

Figure 26. *Rectiflexibiles* conidial chain morphology of *Streptomyces*

The diversity of soil actinomycetes appears to be low in shola forests and grasslands compared to lowland areas in Kerala. Majority of the species isolated from soils of these two ecosystems belonged to the genus *Streptomyces*. When as many as 8 genera were recorded from soils in the lowland areas (Philip and Ray, 1976; Balasundaran, 1992), only 2 genera *(Streptomyces* and *Streptoverticillium)* could be recorded from soils in the shola forests and grasslands of ENP. The *Streptomycetes* were in different colours and hues, all the three types of spore chain morphology viz. *Rectiflexibiles, Retinaculiapertii* and *Spirales* forms were observed (Figures 24-26).

5. CONCLUSIONS

1. The mitosporic fungi were the largest, most varied and best represented group among fungi in the soils of shola forests and grasslands in the Eravikulam National Park (ENP). Penicillia, aspergilli and *Trichoderma* dominated the isolations. Mucoraceous (members of Zygomycota) fungi followed mitosporic fungi in dominance.

2. The soil fungal flora of shola forests and grasslands in the ENP showed close resemblance to soil mycoflora of temperate regions. The preponderance of penicillia and mucoraceous fungi in soils in the ENP supports this observation.

3. The shola forests and grasslands yielded floristically dissimilar communities of soil microfungi indicating the environmental diversity between the two ecosystems which involves variation in soil physical and chemical properties and organic matter accumulation.

4. The study indicates that there is a soil fungal flora of cosmopolitan species (which may occur worldwide irrespective of difference in climatic and edaphic factors) and that each habitat is characterised by a few distinctive species. Intensive studies on the fungal flora spread over a longer period is mandatory to identify the indicator species of each ecosystem.

5. The species richness of soil microfungi in shola forests and grasslands was almost similar. The Shannon's diversity index was 4.184 and 4.168 for sholas and grasslands respectively. The results thus show that grassland soils can also support a rich fungal flora despite the low nutrient status and organic matter content.

6. Soil fungal flora of shola forests and grasslands was less diverse and species rich compared to that of lowland areas in Kerala probably due to the higher relative diversity in microhabitats and abundance of physical environmental resources in the latter. The Shannon's diversity index for soil fungi for lowland areas was 5.086. The diversity of soil actinomycetes was also low in the soils of shola forests and grasslands compared to that of lowland areas in Kerala.

7. The difference in species composition of soil fungi between shola forests and grasslands at Rajamalai was not very pronounced compared to other shola forests and grasslands. This, as well as the relatively higher number of fungal taxa isolated from these two sites indicate a definite variation in the soil mycoflora compared to other sampling sites. This variation could be probably due to the anthropogenic disturbance at Rajamalai.

8. Thirteen species of fungi isolated during this study are new records from India. Eleven species of fungi which were only rarely recorded from India could also be isolated.

9. The soil fungal flora of shola forests and grasslands is unique in terms of species composition compared to lowland areas. The preponderance of rare species of penicillia and other fungi indicates that soils of these two ecosystems may contain fungi with great potential for innovative biotechnology. Efforts should be made to protect these ecosystems from any sort of disturbance/ exploitation so that the microbial diversity can be conserved.

6. REFERENCES

Alexander, M. 1978. Introduction to Soil Microbiology (Second Edtion) Wiley Eastern Ltd., New Delhi, 467 p.

Arnebrant. K., E. Baath & A. Nordgren. 1987. Copper tolerance of microfungi isolated from polluted and unpolluted forest soil. Mycologia 79 : 89-95.

Balasundaran, M. 1992. Studies on the actinomycetes from the rhizosphere soils of some crop plants. Doctoral thesis. University of Kerala. 169 p.

Bhatt. G.C. 1970. The soil microfungi of white cedar forests in Ontario. Can. J. Bot. 48 : 333-339.

Bilgrami. K.S., Jamaluddin & M.A. Rizwi. 1991. Fungi of India: List and References. Today & Tommorrow Printers and Publishers, 798 p.

Bor, N.L. 1938. The vegetation of the Nilgiris. Indian For. 64 : 600 - 609.

Bull, A.T., M. Goodfellow & J.H. Slater. 1992. Biodiversity as a source of innovation in biotechnology. Ann. Rev. Microbiol. 46: 219-292.

Cannon, P.F. 1986. A revision of *Achaetomium. Achaetomiella* and *Subramaniula* and similar species of *Chaetomium*. Trans. Brit.MyCol. Soc. 87:45-76.

Chesters, C.G.C. 1949. Concerning fungi inhabiting soil. Trans. Brit. Mycol. Soc..32:197-216.

Christensen, M. 1969. Soil microfungi of dry to mesic conifer-hardwood forests in Northern Winconsin. Ecology 50:9-27.

Christensen, M.. W.F. Whittingham & R.O. Navak. 1962. The soil microfungi of wet-mesic forests in Southern Wisconsin. Mycologia 54 : 374-388.

Danielson, R.M. & C.B. Davey. 1973. The abundance of *Trichoderma* propagules and the distribution of species in forest soils. Soil Biol. Biochem. 5 : 485-494.

Domsch, K.H., W. Gams & T.H. Anderson. 1980. Compendium of Soil Fungi. Academic Press, New York. 859 p.

Ellis, J.J.& C.W. Hesseltine.1965. The genus *Absidia:* Globose spored species. Mycologia 57 : 222-235.

Elwan, S.H. & A. Diab 1976. Actinomycetes of an Arabian desert soil. Egyptian J. Bot. 19: 111-114.

Garrett, S.D.1955. Microbial ecology of the soil. Trans. Brit. Mycol. Soc. 38 :1-9.

Gilman, J.C. 1957. A Manual of Soil Fungi. 2nd ed. Oxford IBH Publishing Co., New Delhi, 450 p.

Gochenaur, S.E. 1978. Fungi of a long island oak-birch forest. I. Community organization and seasonal occurrence of the opportunistic decomposers of the A horizon. Mycologia 70975-994.

Gochenaur, S.E. & M.P. Backus. 1967. Mycoecology of willow and cottonwood lowland communities in Southern Wisconsin. II. Soil microfungi in the sandbar willow stands. Mycologia 59 : 893 - 901.

Gochenaur, S.E. & W.F. Whittingham. 1967. Mycoecology of willow and cottonwood lowland communities in Southern Wisconsin. Soil microfungi in the willow - cottonwood forests. Mycopathol. Mycol. Appl. 33 : 123 - 129.

Gochenaur, S.E. & G.M.Woodwel1. 1974. The soil microfungi of a chronically irradiated oak-pine forest. Ecology 55: 1004-1016.

Griffin, D.M. 1972. Ecology of Soil Fungi. Chapman & Hall, London, 193 p.

Hawksworth, D.L. 1991. The fungal dimension of biodiversity, magnitude, significance and conservation. Mycol. Res. 99 : 641-655.

Hawksworth. D.L. 1993. The tropical fungal biota: census. pertinence. prophylaxis and prognosis. in: S. Isacc. J.C. Frankland, R. Watling & A.J.S. Whalley (eds.). Aspects of Tropical Mycology: Proc. Symp. British Mycol. Soc.. Cambridge University Press, London: 265-293.

Jose. S.. A. Sreepathy. B. Mohankumar & V.K. Vcnugopal. 1994. Structural. floristic and edaphic attributes of the grassland shola forests of Eravikulam in Peninsular India. For. Ecol. Manage. 65: 279-291.

Kamal & K.S. Bhargava. 1973. Studies on soil fungi from teak forests of Gorakhpur. X. Edaphic factors and distribution of soil microfungi in teak stands of different ages. Proc. Nat. Acad.Sci. India 43 (B) : 9-16.

Koshy. M.M. 1970. Some important soil groups of Kerala. II. The forest soil. An extension lecture delivered at the Agricultural College and Research Institute, Coimbatore.11 September,l970., S.B. Press, Trivandrum, 10 p.

Lechevalier. H.A. & M.P. Lechevalier. 1981. Introduction to the order Actinomycetales. In: H.P. Starr. H. Stolp, H.G. Truper. A. Balows and H.G. Schlegel (eds.). The Prokaryotes. A Handbook on Habitats, Isolation and Identification of Bacteria, Vol.II. Springer-Verlag. Berlin : 3915 - 1922.

Marasus. W.F.O., P.E. Nelson & T.A. Tousson. 1985. *Fusarium dlamini.* a new species from Southern Africa. Mycologia 77:971-975.

May. R.M. 1988. How many species arc there on earth? Science, 241 : 1441- 1449

Miller. J.H., J.E. Giddens & A.A. Foster. 1957. A survey of the fungi of forest and cultivated soils of Georgia. Mycologia 49 : 779 - 808.

Moubasher. A.H. & A.F. Moustafa. 1970. A survey of Egyptian soil fungi with special reference to *Aspergillus, Penicillium* and *Penicillium* related genera. Trans. Brit. Mycol. Soc. 53 : 35-44.

Nayar, M.P. 1997. Biodiversity challenges in Kerala and science of conservation biology. In : P. Pushpangadan. & K.S.S. Nair (eds.). Biodiversity and Tropical Forests. The Kerala Scenario. STEC. Kerala: 17-18.

Nicholls, V.O. 1956. Fungi of chalk soils. Trans. Brit. Mycol. Soc. 39 : 233-238.

Orpurt, P.A. & J.T. Curtis. 1957. Soil microfungi in relation to prairie continuum in Wisconsin. Ecology 38 : 628-637.

Papendorf, M.C. 1976. The soil mycoflora of an *Acacia karroo* community in the Western Transvaal. Bothalia 12 : 123-127.

Philip, S.& J.S. Ray. 1976. Studies on the antagonistic actinomycetes of the forest soils of Ponmudi. Agricultural Res. J. of Kerala. 14 : 9-12.

Pitt, J.I. 1979. The Genus *Penicillium* and its Teleomorphic States *Eupenicillium* and *Talaromyces*. Academic Press. London, 634 p.

Rama Rao, P. 1970. Studies on soil fungi Ill. Seasonal variation and distribution of microfungi in some soils of Andhra Pradesh. Mycopathol. Mycol. Appl. 40 : 277-298.

Rangaswami, G., G. Oblisami & R.Swaminathan. 1967. Antagonistic actinomyectes in the soils of South India. University of Agricultural Sciences, Bangalore and USDA, FERRO, P.L. 480. 156 p.

Raper, K.B. & C. Thom.1968. A Manual of the Penicillia. Hafner Publishing Company, New York and London, 875 pp.

Raper, K.B. & D.I. Fennel1.1977. The Genus *Aspergillus*. Rober E. Krieger Publishing Co., New York, 686 p.

Raven, P.H. 1988. The cause and impact of deforestation. In : H.J. de Blij (ed.). Earth 88. Changing Geographic Perspectives, National Geographic Society, Washington DC, USA.: 212-227.

Reddy, T.K.R. 1962. Role of plant cover in distribution of fungi in Nilgiri forest soils. Proc. Indian Acad Sci Sect. B. 56 : 185 - 194.

Saksena. S.B. 1955. Ecological factors governing the distribution of soil microfungi in some forest soils of Sagar. Ind.J. Bot. Soc. 34 : 267 - 297.

Sankaran. K.V. 1981. Studies on the rhizosphere mycoflora of black pepper *(Piper nigrum* L..). Doctoral thesis, University of Calicut, 208 p.

Shannon. C.E. & W. Wiener. 1963. The Mathematical Theory of Communication. Univ. of Illinois Press, Urbano, 320 p.

Sharma. B.D.. A.K. Bawa & 1.C. Gupta. 1990. Physico-chemical changes of soil as influenced by natural tree and grass covers in arid range lands. Ann. Arid-zone 29: 15-18.

Singh. P. 1976. Some fungi in the forest soils of Newfoundland. Mycologia 68 : 881-890.

Sorensen, T. 1948. A method of establishing groups of equal amplitude in plant sociology based on similarity of species content and its application to analyse of the vegetation in Danish commons. Kongel. Danske Vidensk. Selsk. Biol. Skr. 5: 1-34.

Subramanian, C.V. 1986. The progress and status of mycology in India. Proc. lnd. Acad. Sci., Plant Sciences 96:379-392.

Thomton. R.H. 1960. Growth of fungi in some forest and grassland soils. In: D. Parkinson & J.S. Waid (eds.). Ecology of soil Fungi. Liverpool Univ. Press: 85-91.

Timonin, M.I. 1940. The interaction of higher plants and soil microorganisms I. Microbial population of the rhizosphere of seedlings of certain cultivated plants. Can.J.Res. Sect..C 18: 307-317.

Upadhyay, R.S. & B. Rai. 1979. Ecological survey of Indian soil fungi with special reference to *aspergilli, penicillia* and *Trichoderma.* Rev. Ecol. Biol. Sol.16 : 39 - 49.

Waksman, S.A. 1922. A method of counting the number of fungi in soil. J. Bacteriol. 7: 303-309.

Waksman, S.A. 1959. The Actinomycetales. Vol. 1. Nature, Occurrence and Activities. The Williams and Wilkins Co., Baltimore, USA. 420 p.

Warcup, J.H. 1951. The ecology of soil fungi. Trans. Brit. Mycol. Soc. 34 : 376-399.

Warcup. J.H. 1955. On the origin of colonies of fungi developing on soil dilution plates. Trans. Brit. Mycol.Soc. 38: 298-301.

Warcup, J.H. 1957. Studies on the occurrence and activity of fungi in a wheat field soil. Trans. Brit. Mycol. Soc. 40 : 237-262.

Warcup, J.H. 1960. Methods for isolation and estimation of activity of fungi in soil. In : D. Parkinson, & J.S. Waid (eds.). Ecology of Soil Fungi. Liverpool Univ. Press, Liverpool: 3 - 21.

Wicklow, D.T. 1973. Microbial populations in surface soils of manipulated praire stands. Ecology 54 : 1302-1310.

Wicklow. D.T. & W.F. Whittingham. 1974. Soil microfungal changes among the profiles of disturbed conifer hardwood forests. Ecology 55: 3 - 16.

Wicklow, D.T. & W.F. Whittingham. 1978. Comparison of soil microfungal populations in disturbed and undisturbed forests in Northern Wisconsin. Can. J. Bot. 56 : 1702 - 1709.

Widden, P. 1986. Seasonality of forest soil microfungi in Southern Qubec. Can. J. Bot. 64 : 1413-1423.

Widden, P. 1987. Fungal communities in soils along an elevation gradient in northern England. Mycologia 79 : 298-309.

Wilson, E.O.(ed.). 1988. Biodiveristy. Natl.Acad.Press, Washington, DC., 521 p.

Zachariah, S. 1981. Soil fungi of Malabar. Doctoral thesis, University of Calicut, 196 p.

APPENDIX

Soil fungal flora of lowlands (<500 msl) in north Kerala*

Zygomycota

Absidia glauca Hagem
A. spinosa Lendner
Choanephora sp.
Cunninghamella bertholletiae Paine
C. echinulata Thaxter
C. elegans Lendner
Gongonella butleri (Lendn.) Peyr. & Dalvesco
Mucor abundans Povah
M. circinelloides van Tieghem
M. fragilis Bainier
M. microsporus Namyslowski
Rhizopus arrhizus Fischer
R. nigricans Ehrenb
R. nodosus Namyslowski
R. oryzae Went & Geerligs
Syncephalastrum racemosum (Cohn.) Schroeter
Zygorhynchus moelleri Vuill.
Zygorhynchus sp.

Ascomycota

Byssochlamys nivea Westling
Chaetomium dolichotrichum Ames
Chaetomium sp.
Farrowia longicollea (Krzem & Badura) D. Hawksw.
Gelasinospora sp.
Melanospora sp.
Nectaria sp.
Neocosmospora vasinfecta Smith
Petriellidium boydii (Shear) Malloch
Pseudeurotium indicum (Chattopadhay & Das Gupta) Chattopadhyay
Thielavia minor (Rayss & Borut) Malloch & Cain
Theilavia terricola (Gilman & Abbott) Emmons
Theilavia sp.

Mitosporic fungi

Acremonium sp.
Acrophialophora fusispora (Saksena) M.B. Ellis
Alternaria alternata (Fr.) Keissler
Arthrobotrys sp.
Aspergillius candidus Link
A. awamori Nakazawa
A. brunneo-unseriatus var. nanus Sankaran & Zachariah
A. conicus Blochwitz
A. flavipes (Bain. & Sart.) Thom & Church
A. flavus Link
A. fumigatus Fresenius
A. japonicus Saito
A. lanosus Kamal & Barghava
A. nanus Montagne
A. nidulans (Eidem) Wint.
A. niger van Tieghem
A. niveus Blochwitz
A. phoenicis (Corda) Thom
A. sydowi (Bain & Sart.) Thom & Church
A. terreus Thom
A. versicolor (Vuill.) Tiraboschi
A. wentii Wehmer
Aureobasidium pullulans (de Bary) Arnaud
Bahusakala sp.
Beltrania rhombica Penz.
Botryodiplodia theobromae Pat.
Botryotrichum piluliferum Sacc. & March
Chaetomella circinoseta Stalk
Chaetomella sp.
Cladosporium resinae (Lindau) de Vries
C. cladosporioides (Fresen.) de Vries
C. oxysporum Berk. & Curt.
Chaetomella raphigera Swift
Colletotrichum capsici (Syd.) Butler & Bisby
C. *gloeosporiodies* (Penz.) Sacc.
Corynespora sp.
Curvularia eragrostidis (P. Henn) J.A. Meyer
C. lunata (Wakker) Boedijn
C. pallescens Boedijn
C. verruciformis Agarwal & Sahni
Cylindrocarpon tenue Bugn.
C. tonkinense Bugn.
Cylindrocarpon sp.
Cylindrocladium camelliae Venkataramani & Venkata Ram
Dictyoarthrinium rabaulense Matsushima
Diplococcium spicatum Grove-
Drechslera holmii (Luttrell) Subram. & Jain.
Drechslera sp.
Fusarium acuminatum Ellis & Everhart
F dimerum Penz.
F fusarioides (Frag. & Cif.) Booth
F merismoides Corda
F moniliforme Scheldon
F oxysporum Schlecht. ex Fr.
F. semitectum Berk. & Rav.
F. solani (Mart.) Sacc.
E udum Butler
E ventricosum Appel & Wollenw.
Fusarium sp.

Fusidium sp.
Geotrichum candidum Link
Gliocephalotrichum bulbilium J.J. Ellis & Hesseltine
Gliocladium catenulatum Gilman & Abbott
G. penicillodies Corda
G. roseum Bainer
Gliomastix murorum (Corda) Hughes
Gonytrichum macrocladum (Sacc.) Hughes
Heteroconium chaetospira (Grove) M.B. Ellis
Humicola fuscoatra Traaen
Humicola sp.
Hyalodendron sp.
Hyalostachybotrys sacchari Sriniv.
Libertella sp.
Metarrhizium anisopliae (Mesch.) Sorok. var. *anisopliae*
Monacrosporium bembicoides (Drechsler) Subram.
Monilia sitophila (Mont.) Sacc.
Myrothecium roridum Tode ex Fr.
M. verrucaria (Alb. & Schw.) Ditm. ex Fr.
Nigrospora oryzae (Berk. & Br.) Petch.
Nodulisporium gregarium (Berk. & Curt.) Meyer.
Oidiodendron sp.
Paecilomyces fusisporous Saksena
Paecilomyces sp.
Penicillium chermesinum Biourge
P. citreo-viride Biourge
P. citrinum Thorn.
P. corylophilum Dierckx
P. decumbens Thom
P. diversum Raper & Fennell
P. egyptiacum Van Beyma
P. frequentans Westling
P. funiculosum Thorn
P. javanicum Van Beyma
P. jenseni Zaleski
P. lanosum Westling
P. lapidosum Raper & Fennell
P. lilacinus (Thorn) Samson
P. maydicus (Sacc.) M.B. Ellis
P. megasporum Orpurt & Fennell
P. miczynskii Zaleski
P. novae-zeelandiae Van Beyma
P. parvum Raper & Fennell
P. pulvillorum Turfitt
P. purpurogenum Stoll
P. raistrickii Smith
P. rubrum Stoll
P. simplicissimum (Oud.) Thom
P. soppi Zaleski
P. tardum Thorn
P. thomii Maire
P. turbatum Westling
P. variabile Sopp
P. variabilis Tiwari, Agarwal & Sutton
P. varioti Bainier
P velutinum van Beyma
P. verruculosuni Peyronel
P. waksmani Zaleski
Pestalotiopsis versicolor (Speg.) Steyaert
Phoma sp.
Phomopsis sp.
Pithomyces chartarum (Berk. & Curt.) M.B. Eliis
Polyschema indica Behera, Mukerjii & Sharma
Rhizoctonia bataticola (Taub.) Butler
R. solani Kuhn.
Robillarda depazeoides (W & C) Sacc.
Robillarda sp.
Scolecobasidiuni huniicola Barron & Busch
S. terreum Abbott
Septonema verrucosum Zachariah, Sankaran & Leelavathy
Stachybotrys atra Corda
Staphylotrichum coccosporum Meyer & Nicot
Stilbum nanum Massee
Torula terrestris Misra
Trichocladium variosporum Zachariah, Sankaran & Rahman
Trichoderma koningii Oud.
T. viride Pers. ex. Fr.
Trimmatostroma sp.
Tritirachium oryzae (Vincens) de Hoog
Ulocladium sp.
Veronaea simplex Papendorf
Verticillium candelabrum Bonorden
V. terrestre (Link) Lindau
Wardomyces inflatus (Marchal) Hennebert

* From Sankaran (1981); Zachariah (1981)