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Ecological factors governing the distribution of soil microfungi in some forest soils of Pachmarhi Hills, India

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Abstract

An ecological study of the microfungi occurring in the various forest soils of Pachmarhi Hills, India has been carried-out by the soil plate technique. Soil samples from 5 different forest communities viz., moist deciduous forest dominated by tree ferns, *Diospyros* forest, *Terminalia* forest, *Shorea* forest and scrub forest dominated by *Acacia* and *Dalbergia* sp. were collected during October, 1983. Some physico--chemical characteristics of the soil were analysed and their role in distribution of fungi in 5 soil types was studied and discussed. 43 fungal species were isolated, of which *Asperigillus niger* I and *Penicillium janthinellum* occurred in all the 5 soil types. Statistically, none of the edaphic factors showed positive significant correlation with the number of fungi.

Key words: ecological factors, microfungi, forest soils

INTRODUCTION

The soil is a complex substrate considered as reservoir of microorganisms. The activity of fungi in soil, soil conditions and the influence of higher plant cover have been examined in various seasons by many workers (Cobb 1932, Tresner et al. 1954, Saksena 1955, Thornton 1956, 1960, Chesters and Thornton 1956, Chauhan and Sinha 1966, Rama Rao 1970, Manoharachary 1977, Joshi and Chauhan 1981). The activity of soil-inhabiting microorganisms is chifly controlled besides the biological competition by soil conditions. The different types of soils exhibit different spectra of fungi species. In the present studies an attempt has been made to analyze various physico-chemical factors governing the distribution of soil microflora in 5 different forest communities of Pachmarhi Hills, India.

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MATERIAL AND METHODS

During the vegetation studies of Pachmarhi Hills during October 1983, five different forest communities were selected and 5 sites were marked in each forest types for the collection of soil samples from different depths of soils, i.e. from 5 cm to 15 cm. Different-depht samples were mixed to form a uniform composite soil sample. The selected forest communities were as follows:

1. Moist deciduous forest, dominated by tree ferns.
2. *Diospyros* forest.
3. *Terminalia* forest.
4. *Shorea* forest.
5. Scrub forest dominated by *Acacia* and *Dalbergia* sp.

The soil samples were marked as SI, SII... SV and brought to the laboratory for the analysis of physico-chemical factors and isolation of soil fungi. The fungi isolations were done by soil plate method (Warcup 1950) using streptomycin rose bengal medium (Martin 1950). The identification of fungi was confirmed by Commonwealth Mycological Institute, Kew, England. The percentage frequency and abundance of individual species and their different scales were calculated according Saksena (1955) as follows:

$$\% \text{ Frequency} = \frac{\text{Number of replication with a species present}}{\text{Total number of replications}} \times 100.$$

Scale — Class 1 — species occurring 1-20% of the plates,
Class 2 — species occurring 21-40% of the plates,
Class 3 — species occurring 41-60% of the plates,
Class 4 — species occurring 61-80% of the plates,
Class 5 — species occurring 81-100% of the plates.

$$\% \text{ Abundance} = \frac{\text{Number of colonies of particular species}}{\text{Total number of colonies of all the species}} \times 100.$$

Scale — Class 1 — species forming 1-3% of colonies,
Class 2 — species forming 4-8% of colonies,
Class 3 — species forming 9-15% of colonies,
Class 4 — species forming 16-25% of colonies,
Class 5 — species forming 26-100% of colonies.

The various edaphic factors viz., moisture, water-holding capacity, pH, organic carbon, total nitrogen, C/N ratio and organic matter were determined using methods suggested by Piper (1966). Exchangeable Ca, K and Na were determined with flame photometer and available phosphorus with Klett and Somerson's colorimeter following instructions given by Jackson (1968). The soil colour was determined by comparing the samples with the Munsell soil colour chart (Munsell 1975). The data were subjected the statistical analysis (Wilde et al. 1979) for getting precise conclusions. The correlation coefficient was calculated as:

$$r = \frac{SSxy}{\sqrt{SSx \cdot SSy}} \geqslant \pm 1,$$

where SSx is the variance of x, SSy is the variance of y and $SSxy$ is their covariance.

RESULTS

Table 1 illustrates the distribution of fungi in 5 different soil types of Pachmarhi Hills. The number of fungi per soil unit varies considerably from one study area to another. The five soil types are represented by distinct forest types from moist deciduous forest with vegetation of tree ferns (soil type I) to the scrub type of forest dominated by the trees of *Acacia* and *Dalbergia* (soil type V). The other communities (soil types II, III and IV) are dominated by species of *Diospyros, Terminalia* and *Shorea*, respectively. The soil samples of *Shorea* forest (soil type IV) showed maximum fungal number (215 per mg of soil) and the soil samples of moist deciduous forest (soil type I) were characterized by the minimum fungal number (91.66 per mg of soil).

Table 1

Distribution of soil fungi in 5 soil types of Pachmarhi Hills

Species name	Soil sample types				
	I	II	III	IV	V
Phycomycetes					
Absidia licntheimii	−	+	−	−	+
Cunninghamella verticillata	−	−	−	−	+
Mortierella ramanniana	+	−	+	−	−
Mucor recemosus	+	−	−	−	−
Rhizopus nigricans	−	+	+	+	+
Syncephalastrum racemosum	−	−	−	+	+
Ascomycetes					
Gelasinospora brasiliensis	+	−	−	−	−
Hyphomycetes					
Acremonium sp.	+	−	−	−	−
Alternaria alternata	−	−	−	+	−
Aspergillus flavus	−	+	−	+	−
A. fumigatus	+	−	+	+	−
A. glaucus	−	−	+	−	−
A. nidulus	−	+	+	−	−
A. niger St. I	+	+	+	+	+
A. niger St. II	−	+	+	−	−
A. ustus	−	+	+	+	−
Cylindrocladium parvum	−	−	−	+	−

Species name	Soil sample types				
	I	II	III	IV	V
Fusarium oxysporum	–	–	+	+	+
F. solani	–	+	–	–	–
Humicola fusco-atra	–	+	+	+	+
Paecilomyces varioti	–	–	+	–	–
Paecilomyces sp.	+	–	+	–	–
Penicillium brefeldianum	–	+	–	–	+
P. decumbens	–	–	+	–	–
P. digitatum	–	–	–	+	–
P. funiculosum	+	–	–	+	+
P. herquei	–	+	+	–	–
P. janthinellum	+	+	+	+	+
P. javanicum	–	+	+	–	–
P. parvum	–	+	+	–	–
Penicillium sp. I	–	+	+	–	–
Penicillium sp. II	–	–	–	+	+
Scopulariopsis brevicaulis	–	+	–	–	–
Trichoderma viride	+	–	+	–	+
Trichoderma sp.	+	–	–	+	–
Verticillium puniceum	–	–	–	–	+
Verticillium sp. I	–	–	–	–	+
Verticillium sp. II	–	–	–	+	+
Sterile I	+	–	–	–	–
Sterile II	+	–	–	+	+
Sterile III	–	–	+	–	–
Sterile IV	–	–	+	+	–
Sterile V	–	–	+	–	–
Number of species	13	16	22	18	16

– = present. – = absent.
Soil type I — moist deciduous forest dominated by tree ferns.
Soil type II — *Diospyros* forest.
Soil type III — *Terminalia* forest.
Soil type IV — *Shorea* forest.
Soil type V — scrub forest dominated by *Acacia* and *Dalbergia* spp.

Of the 43 isolated species, 6 belonged to *Phycomycetes*, 1 — to *Ascomycetes*, 31 — to *Hyphomycetes* and 5 — to *Mycelia sterila* (Table 1). The common soil fungi were represented by the species of *Aspergillus*, *Penicillium*, *Rhizopus*, *Humicola*, *Trichoderma* and *Verticillium*. Only 2 fungal species, i.e. *Aspergillus niger* I and *Penicillium janthinellum*, occurred in all the soil types. *Humicola fusco-atra* and *Rhizopus nigricans* formed the second category of dominants, as they were isolated from all the soil samples except soil type I, while the rest of fungal species showed restricted distribution. The data presented in Table 2 contain frequency and abundance of some of the dominating fungi in different soil types.

Table 3 show various physico-chemical characteristics of the soil and the number of fungi per mg of soil dry weight as well as correlation coefficients *r* calculated for them. The soil moisture varied greatly from

1.68% (soil type IV) to 21.42% (soil type I). There is a significant negative correlation between soil moisture and average number of fungi per soil unit. The water-holding capacity ranged from 39.51% (soil type V) to 67.09% (soil type I); a significant negative correlation exists between water-holding capacity and average number of fungi per soil unit.

Table 2

Distribution of frequency and abundance classes of some of the dominant fungi species in different soil types (after Saksena 1955)

Species name	Soil sample types									
	I		II		III		IV		V	
	F	A	F	A	F	A	F	A	F	A
Penicillium janthinellum	5	3	4	3	5	2	5	3	4	3
Aspergillus niger St. I	4	2	5	5	5	5	5	4	4	2
Humicola fusco-atra	—	—	2	1	2	1	5	1	2	1
Rhizopus nigricans	—	—	2	1	2	1	2	1	2	1
Trichoderma viride	5	4	—	—	2	1	—	—	4	1
Sterile II	2	2	—	—	—	—	5	5	5	4

F = frequency; A = abundance.
Soil type I — moist deciduous forest dominated by tree ferns.
Soil type II — *Diospyros* forest.
Soil type III — *Terminalia* forest.
Soil type IV — *Shorea* forest.
Soil type V — scrub forest dominated by *Acacia* and *Dalbergia* spp.

A positive correlation between pH and average number of fungi per soil unit in the different forest soils exists though the various soil types show a narrow range of pH values, i.c. from 4.9 to 6.0. The oorganic matter is one of the very important soil components. The soil type III showed the highest content of organic matter (4.61%) and was also characterized by maximum number of fungal species (2 species, Table 1). However, it is evident from the Table 3 that there was also a negative correlation between organic matter content and average number of fungi per soil unit. All the soil types are rich in nitrogen. However, in the present study no positive correlation could be established between total nitrogen content and average number of fungi per soil unit. Similarly the C/N ratio also showed a negative correlation with the number of fungi. The exchangeable calcium was fairly variable in the different soil types and it ranged from 38.75 to 16.25 mg per 100 g of soil. There was no simple relation between exchangeable calcium and average number of fungi or number of fungal species (Tables 1 and 3). The exchangeable potassium followed the same trend, whereas exchangeable sodium showed the positive correlation with the average number of fungi per soil unit. All mentioned above correlations are not significant. The available phosphorous was highly variable in the 5

Table 3

Number of fungal colonies in the soils of 5 forest types and correlation coefficients between it and various physico-chemical characteristics of these soils

Physico-chemical characteristics	Soil type I	Soil type II	Soil type III	Soil type IV	Soil type V	Correlation coefficient 'r'
Average number of colonies of fungi per mg of soil dry weight	91.66	148.33	156.66	215.00	181.66	
Colour	dark brown (ue 10YR 3/3)	very dark greyish brown (Hue 10YR 3/2)	dark brown (Hue 10YR 3/3)	dark brown (Hue 10YR 3/3)	dark reddish brown (Hue 5YR 3/4)	
Moisture, %	21.42	4.92	4.34	1.68	3.95	−0.90 negative
Water holding capacity, %	67.09	51.52	51.49	41.74	39.51	−0.94 negative
pH	4.9	5.4	5.5	5.6	6.0	+0.81
Organic carbon, %	2.64	2.58	2.67	2.19	1.20	−0.51
Total nitrogen, %	0.09	0.11	0.13	0.08	0.07	−0.30
Organic matter	4.55	4.45	4.61	3.78	2.07	−0.51
Exchangeable Ca, mg per 100 g soil	33.75	38.75	30.00	17.50	16.25	−0.75 +
Exchangeable K, mg per 100 g soil	19.00	24.50	20.50	13.50	12.00	−0.57
Exchangeable Na, mg per 100 g soil	15.00	30.00	18.75	20.00	13.75	+0.08
Available phosphorus, ppm	36.00	17.55	20.25	8.55	2.25	−0.90 negative

$n = 5$, $p = 0.05$.

Soil type I — moist deciduous forest dominated by tree ferns.

Soil type II — *Diospyros* forest.

Soil type III — *Terminalia* forest.

Soil type IV — *Shorea* forest.

Soil type V — scrub forest dominated by *Acacia* and *Dalbergia* spp.

soil types (36.00-2.25 ppm). The results of present study showed that significant inverse relationship does exist between available phosphorus contents and total number of fungi per soil unit.

DISCUSSION

The plant cover and soil conditions are amongst the most important ecological factors which govern the distribution of soil fungi. The soil samples of five forest types named after the dominant plant species have been analysed for important edaphic factors and for the distribution of microfungi on the grounds of calculated correlation coefficients *r*. Soil moisture plays an important role and, as a rule, is favourable for the growth of fungi till there is no waterlogging (Saksena 1955). Results of present study have shown a significant negative correlation between soil moisture and average number of fungi per soil unit. Similar observations have been made by Ramakrishnan (1955), Rama Rao (1970) and Manoharachary (1977). On the other hand water-holding capacity which is another important soil factor shows positive relationship with the distribution of fungi in different soils. It appears that the fungal flora of soils with higher water-holding capacity is better equipped against drying (Saksena 1955, Mishra 1966). A significant negative correlation observed in the present study confirms Joshi's and Chauhan's (1981) observations.

A positive correlation has been noticed between pH and average number of fungi per soil unit in different forest types. Some earlier workers (Jensen 1931, Cobb 1932, Eggleton 1938, Kaufman and Williams 1964) have thought that pH has no significant influence on the average number of fungi, whereas, Coleman (1916), Waksman (1922), Warcup (1951) and Saksena (1955) have proved, that soil microorganisms are greatly influenced by differences in soil reaction (pH) and thrive both in acidic and alakaline soils. This has been later confirmed by number of workers (Chauhan and Sinha 1966, Rama Rao 1970, Manoharachary 1977, Joshi and Chauhan 1981).

Organic matter directly derives from decomposition of plant litter. Therefore, plant cover plays an important role in increasing the organic matter contant in soils. Mclenan and Ducker (1954), Saksena (1955), Eicker (1969) and Rama Rao (1970) have observed that organic matter has a great influence on the abundance of soil microorganisms. It is quite evident from the data obtained in the present study that the analyzed soils are rich in organic matter and their dark brown colour is due to high humus content. Here, a great amount of litter is deposited due to the thick plant cover. However, a negative correlation exists between organic matter content and average number of fungi (Table 3). This has been also observed by Joshi and Chauhan (1981) in ravine soils. Swart (1958) has recorded a positive correlation between the total amount of carbon and average number of fungi in soils. Saksena (1955) has calculed that the quality of nitrogen seems to correspond with the quality of organic matter in various soils, thus affecting distribution of fungi flora. From the present study it may be concluded that total nitrogen as well as C/N ratio may not show a positive correlation, although these parameters may affect the distribution of fungal species (Kaufman and Williams 1963, Joshi and Chauhan 1981).

The exchangeable calcium, potassium and sodium have been regarded as important soil factors for the development of vegetation. They promote the aggregation of soil colloids and influence soil aeration and drainage. Calcium reduces the toxicity in soils by neutralizing acids produced by microorganisms, thus creating atmospheric conditions which favour the growth of microorganisms and plants (Saksena 1955). The data obtained in the present study show that calcium and potassium exhibit negative correlation with average number of fungi and number of fungal species (Tables 1 and 3). Mishra (1966) has also come to the same concludions while studing distribution of soil microfungi in relation to ecological factors. A similar trend was noticed in the case of available phosphorus. Dwivedi (1959) and Mishra (1966) have observed a direct correlation of soil phosphates with a number of fungi, while Joshi and Chauhan (1981) have observed a negative correlation while analyzing soils of Chambal ravines.

The distribution of various species of soil microfungi depends upon type and components of plant community. Five different types of forests have had different ecological conditions and therefore, each forest soil has had more or less its own characteristic fungal flora (Waksman 1916, Tresner et al. 1954).

Rao (1965), Rama Rao (1970), Domsch and Gams (1972) have suggested that species of *Aspergillus* are more common in tropical soils and species of *Penicillium* are more predominant in the winter season. But the present work showed that both *Penicillium* (10 spp.) and *Aspergillus* (7 spp.) dominanted in the tropical forest soils collected in October 1983. Manoharachary (1977) has also observed higher number of *Penicillium* species in the forest soils. Due to the variation in edaphic factors, samples of different forest soil types are characterized by different microbial communities (Table 3). This diversity of soil parameters may also lead to the dominance of a fungal species in a particular soil type and to its restricted distribution in the other soil types (Alexander 1971).

Summing-up, distribution of soil microfungi in different soil types is governed by the combined effect of soil factors. The dominance, frequency and abundance of different fungal species in various soils is not based on one or two specific soil factors but often they operate in a complex manner. Therefore, the soil still remains one of the most interesting and mysterious milieu for soil microbiologists to explore.

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Czynniki ekologiczne regulujące dystrybucję mikroflory grzybowej gleby w niektórych lasach Pachmarhi Hills w Indiach

Streszczenie

Ekologiczne badania mikroflory grzybowej występującej w różnych glebach leśnych w Pachmarhi Hills w Indiach wykonano metodą płytek glebowych. W październiku 1983 roku zbierano próbki gleby z 5 różnych zbiorowisk leśnych: z wilgotnego zrzucającego liście lasu, w którym dominują paprocie drzewiaste; z lasu z *Diospyros*; z lasu z *Terminalia*; z lasu z *Shorea* oraz z lasu, w którym dominują *Acacia* i *Dalbergia* spp. Zanalizowano niektóre cechy fizyko--chemiczne gleby oraz zbadano i przedyskutowano ich rolę w dystrybucji grzybów w 5 rodzajach gleby. Wyizolowano 43 gatunki grzybów, spośród których *Aspergillus niger* I i *Penicillium janthinellum* występowały w wszystkich 5 typach gleby. Statystycznie, żaden z czynników edaficznych nie wykazał pozytywnej istotnej korelacji z liczbą grzybów.