POPULATION STUDIES AND PHENOLOGY OF FUNGI IN SCRUB JUNGLE FOREST SOILS OF ANDHRA PRADESH, INDIA

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Abstract

Soil samples of two forest localities of Andhra Pradesh collected at monthly intervals for a period of one year (1985-86) were analysed for their mycopopulations and qualitative composition in relation to soil temperature, soil pH and moisture. The aspects concerning phenology, percentage occurrence of special groups of fungi and their distribution have been discussed. Altogether 69 species belonging to 35 genera of fungi were isolated. A new species of *Hendersonia* Sacc. has been isolated besides recording three new additions and many interesting fungi.

Introduction

The importance of myco-ecological studies of terrestrial habitats have been emphasized by Alexander (1971), Garrett (1970), Griffin (1972), Park (1968), Pugh (1974), Saksena (1967), Subramanian (1973), Waksman (1944) and Warcup (1967). The ecological approach to the study of soil fungi has only recently begun and originated in the systematic studies. There are quite a few studies on the myco-ecology of cultivated and forest soils from various countries (Ahrins & Sattci, 1985; Wicklow & Carrol, 1981; Widden, 1981, 1986; Witkamp, 1960). However, scrub jungle forest soils received only meagre attention (Manoharachary, 1977; Ramarao, 1970). An attempt has been made in the present investigation to study the phenology, qualitative composition and distribution pattern of fungi in two scrub jungle forest soils of Andhra Pradesh, India.

Material and methods

Composite soil samples were collected from two forest localities of Andhra Pradesh at 4-weekly intervals, starting from June 1985 and continues to May 1986. Sampling sites were designated as soil-A and soil-B.

Soil-A was taken from scrub jungle forest at Amrabad (606 metres above mean sea level) which covers an area of 1142 sq. km. The following angiosperms were common in this area : *Acacia catechu* Willd,. *Albizia procera* Benth., *Bassia latifolia* (Roxb.) Macbr., *Butea frondosa* Koen., *Cymbopogon* sp., *Dodonea viscosa* (Linn.) Jacq., *Euphorbia antiquorum* Linn. *Feronia elephantum* Corr., *Indigofera glandulosa* Willd., *Lantana camara* Linn. *Saccharum spontaneum* Linn., *Vitex negundo* Linn.

Soil-B was taken from Mannanur forest area (636 metres above mean sea level). It extends about 580 sq. km. The following are the dominant angiosperms in the area: *Acacia arabica* Willd., *Aegle marmelos* Corr., *Asparagus racemosus* Willd., *Bassia latifolia* (Roxb). Macbr., *Bauhinia racemosa* Lam., *Bambax malabaricum* DC., *Cassia fistula* Linn. *Hardwickia binata* Roxb., *Legerstroemia parviflora* Roxb., *Saccharum spontaneum* Linn., *Sapindus emerginatus* Vahl., *Wrightia tinctoria* R. Br.

Soil-A is a sandy clay loam type (coarse sand 33%, fine sand 26.5, silt 16%, clay 24%, moisture 0.5%) and had 22% of water holding capacity. Soil-B also is a sandy clay loam (coarse sand 46%, fine sand 17%, silt 17%, clay 19%, moisture 0.8%) and had 24% of water holding capacity Soil samples were collected with a steril-

Geophytology, **19**(2): 131-139, 1989. Issued: September 1990

metal soil sample tube. At least five samples were taken at random. Quantitative and qualitative composition of fungi was estimated by Waksman's soil dilution plate technique and Warcups soil plate technique as detailed by Johnson and Curl (1972), respectively. Boiled hemp seeds and grass blades were also employed. Quantitative data is based on number of colonies per 1gm moisture free soil as estimated by dilution plate method.

The pH was read directly with a "Optronics" pH meter, while the soil temperature was recorded with a soil thermograph. The moisture content was determined by heating 10 gm. of soil at 105°C in an oven for 11 hours until a constant weight was obtained. The general laboratory techniques followed during the course of investigation were as outlined by Booth (1971).

The present investigation is confined to two forest localities of Mahaboobnagar district only. The average rain-fall for the year 1985-86 was 74.2 mm with a monthly maximum of 281.5 mm in August 1985, with a monthly minimum being 1.2 mm in March 1986. The air temperature increased to a maximum of 44°C in summer and decreased to a minimum of 15°—20°C in winter. There are three marked seasons., *viz.*, monsoon (June-September), winter (October-January) and summer (February-May). Fungi were identified with the help of keys provided by Barron (1968), Booth (1971a). Ellis (1971, 1976), Guba (1961), Kin-Ichiro Sakaguchi and Shigeo Abe (1957). Onions and Barron (1967), Raper and Fennell (1965), Raper and Thom (1949), Rifai (1969), Seth (1970), Subramanian (1971), Tulloch (1972) and Waterhouse (1968). Fungi were grown on different media as per the requirement of specific identification.

Results

Monthly changes in soil temperature, soil pH, soil moisture and fungal numbers are presented in Table 1.

Aspergilli appeared to be the most dominant group followed by other deuteromycotina members (Table 2). The highest fungal numbers were encountered in November 1985 for soil-A and in October and November for Soil-B, while the lowest was recorded in summer months in both the soils. However, members of Aspergilli and other Deuteromycotina formed the most predominant group during summer season. More fungal species were found during winter than in monsoon and summer. There were more fungi in soil-A (pH range of 6.6-6.9) than soil-B (pH range of 6.8-7.3). The isolated fungal species are represented by *Acremonium*, *Acrophialophora*, *Allomyces*, *Alternaria*, *Aspergillus*, *Aureobasidium*, *Chaetomium*, *Cladosporium*, *Cunninghamella*, *Curvularia*, *Drechslera*, *Epicoccum*, *Fusarium*, *Humicola*, *Memnoniella*, *Monodictys*, *Mucor*, *Myrothecium*, *Nigrospora*, *Peecilomyces*, *Penicillium*, *Pestalotiopsis*, *Pithomyces*, *Pythium*, *Rhizopus*, *Robillarda*, *Syncephalastrum*, *Thielevia*, *Trichoderma* and *Zygorhynchus*. Altogether 69 fungal species were isolated from both the forest soils. The percentage occurrence of fungi has been given in Table 3.

Discussion

Monthly fluctuations in mycoflora of two forest soils were similar in monsoon and winter; the fungal population decreased during summer months. The regular low fungal counts during summer and high fungal counts during winter followed by monsoon revealed the effect of the season. Similar results have also been obtained for forest soils (Ahrins & Sattci, 1985; Manoharachary, 1977; Ramchandra Reddy, 1962; Ramarao, 1970; Wicklow & Carrol, 1981; Widden 1981, 1986). The winter peaks during the present work are due to low temperatures both in soil and air and average moisture content, besides the required nutrient status. The monsoon peaks are due to the availability of moisture and average temperatures, while the high temperatures and non availability of moisture are the limiting factors in summer.

Of the 69 species belonging to 35 genera of fungi isolated, 30 fungal species were common to both the soils and others were restricted. Some species appeared sporadically, while others were predominent in all the months. All the fungi were the inhabitants of the soil habitats investigated. Domsch and Gams (1972), Manoharachary (1977), Waksman (1944) and Wicklow and Carrol (1981) have suggested that species of Aspergilli and Deuteromycotina were more common in tropical soils, while the Penicillia and other fungi dominated the temperate soils. In the present investigation species of *Aspergillus* were not only domi-

Table 1—Soil temperature, pH, percentage moisture content and fungal numbers as 10^3 per 1g moisture free soil

	MONSOON				WINTER				SUMMER			
	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May
	1985							1986				
Soil temperature °C	42	30	25	37.5	35	27	28	27	32	32	37	41
pH	6.8	6.6	6.6	6.6	6.7	6.6	6.7	6.8	6.9	6.8	6.7	6.8
% of moisture	9.3	8.24	8.9	10.4	2.4	8.8	1.9	6.85	1.4	1.25	0.3	1.05
Fungal numbers	90	100	100	80	120	200	100	50	50	30	42	20
						Soil-B						
Soil temperature °C	26	27	24	27	29	26.5	26	22.5	24	37	44	30
pH	7.3	7.3	7.1	7.2	7.1	6.9	7.0	6.8	6.9	7.0	7.0	7.3
% of moisture	14.4	11.3	10.3	6.2	5.6	7.5	2.3	2.7	2.9	3.35	2.0	2.9
Fungal numbers	80	60	60	100	110	110	60	20	40	50	60	40

Table 2—Percentage occurrence of particular groups of fungi in the two soils

Particular groups of fungi	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May
					Soil—A							
Mucorales	—	—	11.1	15.5	—	6.7	10	18.7	10	16.7	6.7	—
Asocomycetes	—	—	—	—	—	—	—	—	—	—	—	33.3
Aspergilli (including sexual types)	77.6	33.3	33.4	18.6	48.5	24.9	30	6.2	10	16.7	70	66.7
Penicillia (including sexual types)	3.2	—	—	38	—	48.3	40	6.2	10	—	—	—
Other fungi (Deutero-mycotina)	16	66.7	33.3	27.9	40	13.4	20	62.7	70	66.6	16.6	—
Mycelia sterilia	3.2	—	22.2	—	11.5	6.7	—	6.2	—	—	6.7	—
					Soil—B							
Mucorales	4.8	16.7	11.1	17.6	3.3	2.6	—	—	—	5.5	11.1	—
Ascomycetes	—	—	—	2.9	46.6	2.6	5	12.5	—	—	5.6	—
Aspergilli (including sexual types)	64.2	16.7	22.2	53	33.4	15.8	25	25	12.5	22.2	66.6	88.3
Penicillia (including sexual types)	2.4	—	—	14.7	—	5.2	35	37.5	25	11.1	—	16.7
Other fungi (Deutero-mycotina)	19.1	66.6	44.5	11.8	6.7	71.2	35	25	50	50.2	—	—
Mycelia sterilia	9.5	—	22.2	—	10	2.6	—	—	12.5	11	16.7	—

— : Absent

* : Data based on the dilution plate method.

Table 3—*Percentage frequency of fungi and special groups of fungi occurring

Name of fungus	June		July		Aug.		Sept.	
	S_1	S_2	S_1	S_2	S_1	S_2	S_1	S_2
Acremonium strictum	—	—	22.3	—	—	—	—	—
Acrophialophora neiniana	—	—	—	—	—	—	—	—
Alternaria alternata	—	—	—	—	—	—	3.1	—
A. tenuissima	—	—	—	—	—	—	—	—
Aspergillus brunneouniseriatus	—	4.8	—	—	—	—	—	—
A. candidus	—	4.8	11.1	—	—	11.1	—	38.3
A. flavipes	55.2	—	—	—	—	—	3.1	—
A. flavus	—	—	—	—	22.3	—	—	—
A. fumigatus	—	7.1	—	—	—	—	—	—
A. nidulans	—	—	—	—	—	—	—	5.9
A. niger	19.2	23.7	—	16.7	—	11.1	9.3	8.8
A. restrictus	—	—	—	—	—	—	3.1	—
A. sydowi	3.2	—	—	—	—	—	3.1	—
A. tamarii	—	19	—	—	—	—	—	—
A. terreus	—	4.8	11.1	—	11.1	—	—	—
A. ustus	—	—	11.1	—	—	—	—	—
Aspergillus sp.	—	—	—	—	—	—	—	—
Avreobasidium pullulens	—	—	—	—	—	—	—	—
Botryotriochum state of *Chaetomium*	—	2.4	—	—	—	—	—	—
Chaetomium erraticum	—	—	—	—	—	—	—	—
Cladosporium cladosporioides	—	—	11.1	—	—	11.1	15.5	5.9
C. herbarum	—	—	—	16.7	—	—	—	5.9
Cunninghamella echinulata	—	—	—	—	—	—	—	—
Curvularia brachyspora	—	—	—	—	—	—	—	—
C. aragrostidis	6.4	—	—	—	—	—	—	—
C. lunata	—	—	—	—	11.1	—	3.1	—
C. maculans	—	—	—	—	—	—	3.1	—
C. pallescans	—	—	—	—	—	—	—	—
Drechslera state of *Cochliobolus nodulosus*	—	—	—	—	—	—	—	—
D. state of *Cochliobolus specifer*	—	—	—	—	11.1	—	—	—
D. haweiiense	—	—	—	—	—	—	—	—
Epicoccum purpurascans	—	—	—	—	—	—	—	—
Fusarium sambucinum	—	—	—	16.6	—	—	—	—

in the two soils during the twelve months of study (S_1=soil 1,S_2=soil 2)

Oct.		Nov.		Dec.		Jan.		Feb.		Mar.		Apr.		May	
S_1	S_2	S_1	S_2	S_1	S_2	S_1	S_2	S_1	S_2	S_1	S_2	S_1	S_2	S_1	S_2
—	—	—	55.6	—	—	—	—	—	—	—	—	—	—	—	—
2.8	—	—	—	—	—	6.2	—	—	—	—	—	—	—	—	—
2.8	—	—	—	—	—	12.5	—	10	—	—	—	—	—	—	—
—	—	—	—	—	10	6.2	—	—	12.5	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	10	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
37	10	—	—	—	—	—	—	—	—	—	—	40	—	—	—
—	—	—	5.2	—	—	—	—	—	—	—	11.1	—	36.7	—	—
—	—	—	—	—	—	—	12.5	—	—	—	—	10	13.3	33.4	—
11.5	23.4	3.4	—	10	10	—	—	10	—	—	11.1	10	20	—	83.3
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	33.3	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	21.5	10.6	20	15	6.2	12.5	—	12.5	16.7	—	10	—	—	—
8.6	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
2.8	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	10	—	33.3	—
—	—	—	5.2	—	—	25.3	—	—	25	—	—	—	—	—	—
—	—	5	—	—	—	—	—	40	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	10	—	—	—
—	—	—	—	—	—	—	—	—	—	16.6	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
2.8	—	—	—	—	—	—	—	—	—	16.7	—	—	—	—	—
—	—	—	—	—	10	—	12.5	10	12.5	—	—	—	—	—	—
—	—	—	2.6	10	—	—	—	—	—	—	—	—	—	—	—
—	—	—	7.8	—	—	—	—	—	—	—	—	—	—	—	—
2.8	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	10	—	16.6	—	—	—	—	—
—	—	—	—	—	—	10	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

—*Contd.*

Table 3—

Name of fungus	June		July		Aug.		Sept.	
	S_1	S_2	S_1	S_2	S_1	S_2	S_1	S_2
F. semitectum	—	2.4	—	—	—	—	—	—
Geniculosporium state of *Xylaria*	—	—	11.1	—	—	—	—	—
Hendersonia punithalingamii sp. nov.	—	—	—	16.6	—	—	—	—
H. grisea	9.6	—	—	—	—	—	—	—
Humicola fuscoatra	—	—	—	—	—	—	—	—
Memnoniella echinata	—	—	—	—	—	—	—	—
Mucor hiemalis	—	—	—	—	—	—	12.4	—
M. racemosus	—	—	—	—	—	—	3.1	8.8
Myrothecium leucotrichum	—	—	11.1	—	—	—	—	—
Nigrospora state of *Khusnikaoryzae*	—	—	—	—	—	—	—	—
Paccilomyces terricola	—	—	—	—	—	—	—	—
Penicillium brafeldianum	3.2	—	—	—	—	—	38	—
P. rubrum	—	2.4	—	—	—	—	—	14.7
P. stackii	—	—	—	—	—	—	—	—
Pestalotiopsis mangiferae	—	—	11.1	—	—	—	—	—
Phoma sp.	—	9.5	—	—	—	22.3	—	—
Rhizopus nigricans	—	4.8	—	16.7	11.1	11.1	—	5.9
Saccharomyces sp.	—	—	—	—	—	—	—	—
Syncephalastrum racemosum	—	—	—	—	—	—	—	2.9
Thiclavia terricola	—	—	—	—	—	—	—	2.9
Trichoderma viride	—	4.8	—	16.7	11	11.1	3.1	—
Sterile mycelium with chlamydospores	—	—	—	—	—	11.1	—	—
Sterile mycelium with sclerotia	—	9.5	—	—	—	—	—	—
Sterile mycelium	2.3	—	—	—	22.2	11.1	—	—
SPECIAL GROUPS OF FUNGI								
Mucorales	—	4.9	—	8	16.7	11.1	15	17.6
Ascomycetes	—	—	—	—	—	—	—	2.9
Aspergilli (including sexual types)	77.6	64.2	33	16.7	33.4	22.2	18.6	53
Penicillia (including sexual types)	3.2	2.4	—	—	—	—	36	14.7
Other Fungi Imperfecti	16	19.1	66.7	66.6	33	44	27.9	11.8
Mycelia sterilia	3.2	9.5	—	—	22	22.2	—	—

* Data based on the dilution plate method.

(*Contd.*)

Oct.		Nov.		Dec.		Jan.		Feb.		Mar.		Apr.		May	
S_1	S_2	S_1	S_2	S_1	S_2	S_1	S_2	S_1	S_2	S_1	S_2	S_1	S_2	S_1	S_2
—	—	—	—	—	—	—	—	—	—	—	16.7	—	—	—	—
5.8	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	16.6	—	—
—	—	—	—	10	—	—	—	—	—	—	—	—	—	—	—
5.8	—	8.4	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	2.6	—	—	—	—	—	—	—	—	—	—	—	—
—	—	5	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	12	—	—	—	—	—	—	—	—	—
—	—	—	5.2	20	15	6	12.5	—	—	—	—	—	—	—	16.7
—	—	30	—	10	15	—	12.5	—	12.5	—	—	—	—	—	—
—	—	18.3	—	10	5	—	12.5	10	12.5	—	11.1	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
5.8	—	—	—	—	—	—	—	—	—	—	11.1	—	—	—	—
—	3.3	1.7	—	—	—	12.5	—	10	—	16.7	5.5	—	6.7	—	—
—	46.6	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	10	—	6.2	—	—	—	—	—	—	—	—	—
—	—	—	2.6	—	5	—	12.5	—	—	—	—	—	—	—	—
—	6.7	—	—	—	—	—	12.5	—	—	16.7	22.4	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	3.3	—	—	—	—	6.2	—	—	—	—	5.5	—	—	—	—
11.5	6.7	6.7	2.6	—	—	—	—	—	12.5	—	5.5	—	6.7	—	—
—	3.3	6.7	2.6	10	—	10.7	—	10	—	16.7	5.5	10	6.7	—	—
—	46.6	—	2.6	—	5	—	25	—	—	—	—	10	—	33.3	—
48.5	33.4	25	15.8	30	25	6.2	21	10	12.5	16.7	22	80	70	66.7	83.3
—	—	48.3	5.2	40	35	6.2	37.5	10	25	—	11.1	—	—	—	16.7
40	6.7	13	71.2	20	35	62.7	25	70	50	66.6	50.2	—	16.6	—	—
11.5	10	6.7	2.6	—	—	6.2	—	—	12.5	—	11	—	6.7	—	—

nant but also common to the soils under study. It is clear that Penicillia dominated in winter while Aspergilli were more in summer followed by monsoon. In monsoon and winter months the fungal composition changed with the appearance of Mucorales, Hypnomycetes besides the Aspergilli, Penicillia and Fungi Imperfecti (Table 3). The qualitative changes in the monsoon and winter season are due to the availability of adequate moisture, temperature less than summer months, plant cover and other nutrients. The differences in the distribution of fungi, preponderance of certain fungi and also presence or absence of certain fungi in two soils are also due to the availability of nutrients, their active growth and adaptation. The present investigation also indicated that the soil fungi are cosmopolitan geographically but do not differ much in their qualitative composition from earlier reports of tropical and subtropical regions (Piroeynski, 1968).

In our earlier studies it has been observed that members of Mucorales, Aspergilli, Penicillia, few ascomycetes and Fungi Imperfecti formed the major bulk of mycoflora associated with cultivated and dry deciduous soils (Manoharachary, 1977; Ramarao, 1970). However, the fungi associated with scrub jungle soils seems to be represented by diversified mycoflora representing a good qualitative fungal species. *Aspergillus brunneo-uniseriatus*, *Botryotrichum* state of *Chaetomium*, *Chaetomium nigricolor*, *Curvulatia brachyspora*, *C. ergostridis*, *Epicoccum purpurescens*, *Hendersonia punithalingamii* and *Robillarda sessilis* are the indicator species of the scrub jungle forest soils. Further these species were not reported earlier from cultivated, dry waste land soils, dry deciduous soils and temperate forest soils. It is pertinent to mention here that a new species of *Hendersonia* Sacc. (IMI 232556) has been isolated from soil-B. The *Botryotrichum* state of *Chaetomium* Kunze, *Chaetomium homopilatum* Omvik and the *Geniculosporium* state of *Xylaria* Hill ex Grev. are the new records for India, while *Allomyces cystogenus* var. *cystogenus* Emerson, *Chaetomium erraticum* Ames and *C. fusisporale* Rai and Mukerjee are new records for south India. *Chaetomium nigricolor* Ames and *Curvularia brachyspora* Boedijn are recorded for the first time from soil. The forest soil-mycoflora appears to be favoured by slightly acidic pH range coupled with adequate moisture, low temperatures and adequate nutrients besides the plant cover and altitude.

Conclusions

1. Soil-A had harboured good fungal population than soil-B. This is due to the amount of litter added to the soil a physico-chemical set up and climatological effect.
2. Fungal populations are being more in winter followed by monsoon than summer. That means temperature as a direct factor and soil moisture as an indirect factor played significant role.
3. Qualitatively scrub jungle forest soils are richer than cultivated soils. In the present investigation both the scrub jungle soils revealed the presence of some new fungi to Indian sub-continent. These results definitely reflect the role of soil physico-chemical factors besides the influence of vegetation and climate.
4. The dominance of some fungal species in a particular soil is due to their active growth and multiplication/adaptation to a particular soil type and/or due to the availability of necessary nutrients, moisture and temperature to them.

References

AHRENS & SATTCI, F. (1985). Analysis of microbial, physical and Chemical properties of Turkish soils and their correlations. *Mikrobiol*, **140** : 353-362.

ALEXANDER, M. (1971). *Introduction to soil microbiology*. John Wiley and Sons Inc. New York & London.

BARRON, G. L. (1968). *The genera of Hyphomycetes from soil*. The Williams & Wilkins Company, Baltimore.

BOOTH, C. (1971). *Methods in microbiology*. vol **4**, Academic press, New York.

BOOTH, C. (1971a). *The genus Fusarium*. C. M. I., Kew.

DOMCH, K. H. & GAMS, W. (1972). *Fungi in agricultural soils*. Logman, London.

ELLIS, M. B. (1971 . *Dematiaceous Hyphomycetes*. C. M. I., Kew.

ELLIS, M. B. (1976). *More dematiaceous Hyphomycetes*. C. M. I., Kew.

GARRETT, S. D. (1970). *Root infecting fungi*, Cambridge Univ. Press, Cambridge.

GRIFFIN, D. M. (1972). *Ecology of soil fungi*. Chapman & Hall Ltd. London.

GUBA, E. M. F. (1961). *Monograph of Monochaetia and Pestalotia*. Harward Univ. Press, Cambridge, Massachusetts.

JENSEN, V. (1974). Decomposition of angiosperm tree leaf litter. *In* : Dicknson, C. H. & Pugh, G. J. F. (eds)—*Biology of Plant litter deccmposi-*

tion. **1,** London.

JOHNSON, L. F. & CURL, E. A. (1972). *Methods for research on the ecology of soil borne plant pathogens.* Burgess. Publ. Co. Minnesota.

KIN-ICHIRO SAKAGUCHI & SUIGEO ABE (1957). *Atlas of microorganisms : the Penicillia.* Kanchara Shuppan Co. Ltd, Tokyo.

MANOHARACHARY, C. (1977). Microbial ecology of scrub Jungle and dry waste land soils from Hyderbad District, Andhra Pradesh (India). *Proc. Indian natn. Sci. Acad.*, **43 B** : 6-18.

ONIONS, A. H. S. & BARRON, G. L. (1967). *Monophialidic species of Paecilomyces.* C. M. I., Kew.,

PARK, D. (1968). The ecology of terrestrial fungi. *In :* Ainsworth & Sussaman (ed)—*The fungi.* Vol. **3** : 5-39.

PIROZYNSKI, K. A. (1968). Geographical distribution of fungi. *In : The fungi.* Ansiworth, & Sussaman, A S (eds)—487-504, Academic press, New York.

PUGH, G. J. F. (1974). Terrestrial fungi. *In :* Dickinson, C. H. & Pugh G. J. F. (eds)—*Biology of plant litter decomposition; Vol.* **2:** 333-336, Academic Press, London & New York.

RAMACHANDRA REDDY, T. K. (1962). Role of plant cover in distribution of fungi in Nilgiri forest soils. *Proc. Indian. Acad. Sci.*, **56B** : 185-194.

RAMARAO, P. (1970). Studies on soil fungi III; Seasonal variation and distribution of microfungi in some soils of Andhra Pradesh (India). *Mycopath. Mycol. Appl.*, **40** : 277-298.

RAPER, K. B. & FENNELL, D. I. (1965). *The genus Aspergillus.* The Williams & Wilkins Co., Baltimore.

RAPER, K. B. & THOM, C. (1949). *A manual of the penicillia.* Williams & Wilkins Co, Baltimore.

RIFAI, M. A. (1969). *A revision of the genus Trichoderma.* C. M. I., Kew England.

SAKSENA, R. K. (1967). The soil fungi—a biological appraisal. *Indian Phytopath.*, **20** : 13-25.

SETH, H. K. (1970). *A monograph of the genus Chaetomium.* Beihets *Zur Nova. Hadwigia*, **37** : 1-130.

SUBRAMANIAN. C. V. (1971). *Hyphomycetes.* ICAR Publication, New Delhi.

SUBRAMANIAN, C. V. (1973). Facets of life and strategy of moulds and mushrooms in soil. *J. Indian bot. Soc.*, **52** : 17-28.

TULLOCH, M. (1972). *The genus Myrothecium.* Tode ex Fr. Cl M. I., Kew.

WAKSMAN, S. A. (1944). Three decades with soil fungi. *Soil Sci.*, **58** : 89-114.

WARCUP, J. H. (1967). Fungi in soil in Burges, A. & Raw, F. (eds)—*Soil biology*, Academic Press, London.

WATERHOUSE, G. M. (1968). *The genus Pythium* Pringsheim, C. M. L., Kew.

WICKLOW, D. T. & CARROL, G. C. (1981). *The fungal communities, its organization and role in the ecosytem.* Marcel Dekkar Inc. N. Y. and Basel.

WIDDEN, P. P. (1981). Patterns of Phenology among fungal populations, *In :* Wicklow, D. T. & Carrol, G. C. (eds)— *The fungal community, its organisation and role in the ecosystem*, pp. 106-118.

WIDDEN, P. (1986). Functional relationships between Quebec forest soil microfungi and their environmen. *Can. J. Bot.*, **64** : 1424-1432.

WITKAMP, M. (1960). Seasonal fluctuations of the fungus in mull and mur of an oak forest. *Meded. Inst. toegep. biol. Onderz. Nat.*, **46** : 8.