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Litter decomposing fungi in sal (*Shorea robusta*) forests of central India

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Abstract. *Soni KK, Pyasi A, Verma RK. 2011. Litter decomposing fungi in sal (*Shorea robusta*) forests of central India. Nusantara Bioscience 3: 136-144.* The present study aim on isolation and identification of fungi associated with decomposition of litter of sal forest in central India. Season-wise successional changes in litter mycoflora were determined for four main seasons of the year namely, March-May, June-August, September-November and December-February. Fungi like *Aspergillus flavus, A. niger* and *Rhizopus stolonifer* were associated with litter decomposition throughout the year, while *Aspergillus fumigatus, Cladosporium cladosporioides, C. oxysporum, Curvularia indica,* and *C. lunata* were recorded in three seasons. Some fungi including ectomycorrhiza forming occur only in the rainy season (June-August) these are *Astraeus hygrometricus, Boletus fallax, Calvatia elata, Colletotrichum dematium, Corticium rolfsii, Mycena roseus, Periconia minutissima, Russula emetica, Scleroderma bovista, S. geaster, S. verrucosum, Scopulariopsis alba* and four sterile fungi. Fungi like *Alternaria citri, Gleocladium virens, Helicosporium phragmitis,* and *Pithomyces chartarum* were rarely recorded only in one season.

Keywords: decomposition, fungi, forests, litter, sal, seasonal variation.

Abstrak. *Soni KK, Pyasi A, RK Verma. 2011. Fungi pembusuk serasah pada hutan-hutan meranti merah muda (*Shorea robusta*) di India tengah. Nusantara Bioscience 3: 136-144.* Penelitian ini bertujuan untuk mengisolasi dan mengidentifikasi fungi yang terlibat dalam dekomposisi serasah dari hutan meranti merah muda di India tengah. Sejalan dengan perubahan suksesional fungi pendegradasi serasah, maka penelitian dilakukan pada empat musim utama dalam setahun, yaitu Maret-Mei, Juni-Agustus, September-November, dan Desember-Februari. Fungi seperti *Aspergillus flavus, A. niger* dan *Rhizopus stolonifer* terlibat dalam dekomposisi serasah sepanjang tahun, sementara *Aspergillus fumigatus, Cladosporium cladosporioides, C. oxysporum, Curvularia indica,* dan *C. lunata* terlibat dalam tiga musim. Beberapa fungi termasuk fungi pembentuk ectomycorrhiza hanya ditemukan pada musim hujan (Juni-Agustus) yaitu *Astraeus hygrometricus, Boletus fallax, Calvatia elata, Colletotrichum dematium, Corticium rolfsii, Mycena roseus, Periconia minutissima, Russula emetica, Scleroderma bovista, S. geaster, S. verrucosum, Scopulariopsis alba* dan empat fungi steril. Fungi seperti *Alternaria citri, Gleocladium virens, Helicosporium phragmitis* dan *Pithomyces cortarum* jarang ditemukan dan hanya ditemukan dalam satu musim.

Kata kunci: dekomposisi, serasah, fungi, hutan-hutan meranti merah muda, variasi musiman.

INTRODUCTION

The soil is regarded as a heterogeneous collection of minerals and organic materials. A major portion of organic matter in soil comes from plant material in the form of litter. There is considerable amount of litterfall annually in tropical dry deciduous forests. According to Burges (1958), the total litterfall in tropical forest may reach to 1.53 thousand kg/ha/yr. The leaf litter contains considerable amount of nutrients necessary for plant growth. In tropical forests most of the nutrient stock is in the form of biomass and relatively little in soil. Nutrients available in the plant litter falling in dry season are rapidly mineralized in the following monsoon and taken up by roots in the wet season, therefore the importance of forest floor as an integral part of the ecosystem has been recognized for a long time. In that way, decomposing litter helps , and the soil productivity is enhanced. The decomposition of plant litter at the soil surface is brought about by a variety of organisms including bacteria, fungi, actinomycetes, protozoa, nematodes, and insects. As a result of microbial attack and activity, the litter is subjected to chemical changes like oxidation, hydrolysis, reduction, and condensation (Walksman 1952). Besides decomposition, these are also involved in some other important biological process of an ecosystem (Harley 1971).

The importance of studying sal litter decomposition by above mentioned microbial agencies has been initiated long back (Lutz and Chandler 1946; Webster 1956; Hudson 1962). Absence of process of decomposition due to drought, fire, frost, insects and nutrient deficiency in soil created large scale sal mortality in central India (Khan 1953; Lal 1956; Pandey 1966; Prasad et al. 1983). It has also been emphasized that abnormally high temperature during the month of May causes sudden recession of water level. This factor adversely affects normal physiological function around the feeder root of sal forest. The phenomenon of litter layering during the month of March to May and gradual decomposition from June to December and mineralization from October to February with the well distribution of rains and suitable temperature creates balanced process of nutrient release and their uptake by sal

trees. This phenomenon is disturbed by unequal distribution of rains. The successional fungi which carry large amount of enzymes, enable to convert complex organic molecule to CO_2, H_2O and mineral components would be drastically depleted from the terrestrial habitat of sal forest. This kind of disturbance dealt with the succession and further nutrient uptake the decomposition process is a complete chain if it is part-wise or factor-wise dealing with gradual mineralization and further mycorrhizal development in and around feeder root system in mother sal trees or in juvenile seedling regeneration that was seriously disturbed. Recent observation on the ecology of litter decomposing fungi indicated need for detailed study in order to understand the role of fungi in litter decomposition (Dwivedi and Shukla 1977; Mehrotra and Aneja 1979; Sinha and Dayal 1983; Soni and Jamaluddin 1990; Jamaluddin et al. 1984; Maria and Shridhar 2002; Hossain and Othman 2005).

In the present study, an attempt was made to isolate, identify fungi and study the fungal succession in the process of decomposing litter under natural sal forest ecosystem in three states of central India. Occurrence and importance of fungi under various stages of litter decomposition are also given.

MATERIALS AND METHODS

Study area

The area chosen for collection of sal litter lies in three different states of India namely Madhya Pradesh, Chhattisgarh, and Orissa. The selected sites includes: Amarkantak-Achanakmar biosphere reserve, covers both Madhya Pradesh and Chhattisgarh; Amarkantak (N22^{0}40' E81^{0}45') and Motinala (N22°21'0" E80°54') comes in Madhya Pradesh, Gariyaband (N20°38'24" E82°3'36") and Achanakmar (N22°25', E81°51') are in Chhattisgarh while Jharsuguda (N20°40' to 22°1'and E82°39' to 85°15') falls in Orissa (Figure 1). In these sites, sal forest belongs to second and third category. Associated species present in these forests include *Buchanania lanzan, Anogeissus latifolia, Cleistanthus collinus,* and *Flemingia paniculata*. This study was carried out from March 2009 to February 2010.

Study of litter decomposing fungi

For the study on litter decomposition by fungi the collected fungi were processed, cultured on media, purified, and identified as per methods, briefly described below.

Direct observation

Leaf litter sample squares were cut into 5x5 mm^2 small pieces with a sterile parallel razor at random from the base, middle and apex. These pieces were cleaned, stained (Shipton and Browns 1962), observed under stereo-zoom microscope and fungal colonization was recorded.

Preparation of fungal culture

Damp chamber method. Squares of leaf litter were placed in a sterile Petri plates of 9.0 cm diameter to form a moist chamber. Fungal flora was recorded daily to document ecological succession. Isolation of fungi was also done on potato dextrose agar (PDA) medium (Keyworth 1951).

Dilution method. Forty squares of litter sample pieces cut as described above were placed in 60 mL of distilled water, rinsed repeatedly for five times then placed in a sterilized 500 mL conical flask containing 60 mL distilled water. Flask was wrist shaken and dilution up to 10^{-3} was prepared. One mL inoculums from each dilution were plated on PDA medium and incubated for seven days at 27^{0}C in a BOD incubator. Each petridish was considered as a unit sample. The frequency class was expressed as suggested by Saksena (1955).

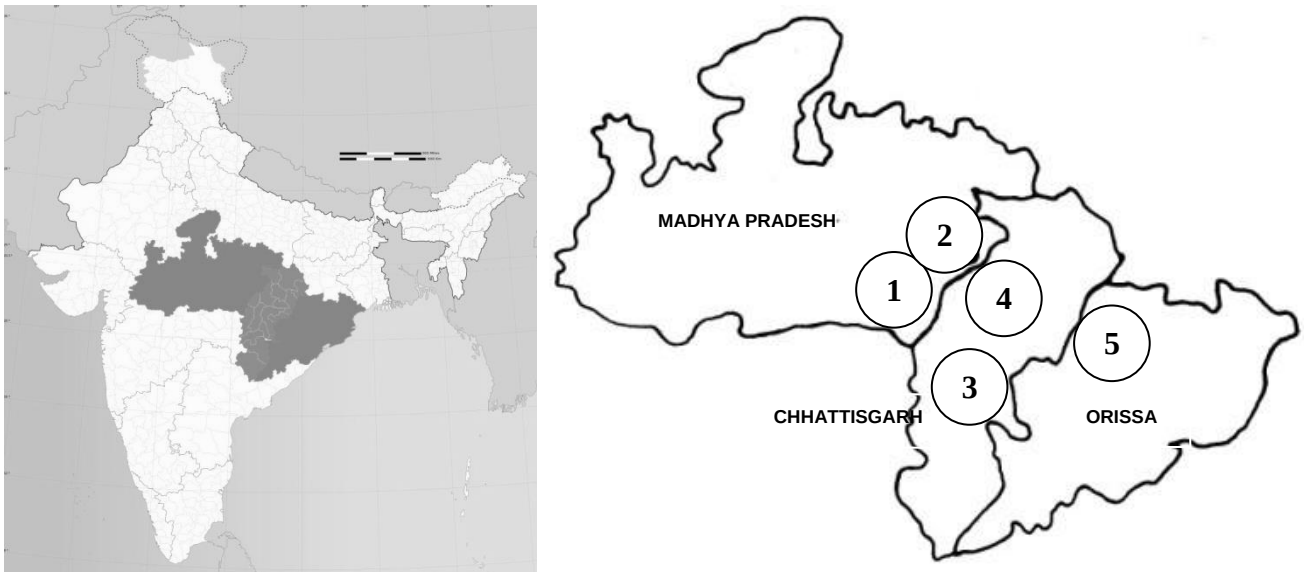

Figure 1. Map showing study sites in three states (Madhya Pradesh, Chhattisgarh and Orissa) of India. 1. Amarkantak and 2. Motinala, comes in Madhya Pradesh, 3. Gariyaband and 4. Achanakmar are in Chhattisgarh, while 5. Jharsuguda falls in Orissa.

Washed disc method. Leaf litter discs (5x5 mm^2) after their treatment by dilution plate method were serially washed 10 times by successive changes of sterile water (Harley and Waid 1955), dried on sterile filter paper and plated on sterile PDA medium. Fungal colonies were identified and counted, and presence of each fungus was expressed in terms of percentage occurrence based on a total of 75 discs examined.

Direct plating method. Quantitative estimation of mycoflora associated with the collected litter samples was done as suggested by Warcup (1950) for studying soil mycoflora. Well ground pinch of litter samples were taken in Petri plates and 10-15 mL of molten PDA medium was poured. The plates were allowed to solidify and incubated at 27^0C for 5-10 days.

Purification of fungal cultures

Purification of fungal cultures was done preferably by streak plate and dilution plate method briefly described as follows.

Streak plate method. Sterilized fungal inoculating needle was touched on desired sporulating fungal colony and streaked in fresh plates of PDA medium in zigzag manner. After 48 hrs of incubation colonies were studied.

Dilution plate method. Moisten tip of fungal inoculating needle was touched over the colonies and then inoculated into 5 mL distilled water, shaken vigorously and diluted up to 10^{-3}. One mL of each dilution was aseptically transferred into sterilized petriplate in triplicates then media was poured over the inoculum. Plates were incubated for 48-72 hrs at 27^0C in a BOD incubator. Then hyphal tips were transferred onto PDA medium slants by using a sterile inoculating needle.

Agar block method. A block of agar was taken on the tip of sterilized needle and gently touched to the sporulating mass of desired fungus in a Petri plate. The block was gently slid over the plate containing Czepeks agar medium. The surface of the plates observed immediately under low power of stereo-zoom microscope to assure the place of a well-separated spore. A piece of sterilized filter paper has adhered at the tip of inoculating needle and brought near to it. The well-separated spore clung to the surface of filter paper which was then transferred to a fresh Petri plate to get a pure monosporic culture (Ashara 1975).

Sporulation. Some fungi belonging to ascomycetes and Deuteromycetes showing poor or no sporulation on common media were grown on specialized media and incubated at suitable temperature (25^0C) which stimulated the sporulation in fungi.

Calculation of occurrence and frequency of fungi

Occurrences and frequencies of fungi occurring in litter were calculated and categorized by the procedures described by Saksena (1955) as per formulae are given below:

$$\% \text{ Occurrence} = \frac{\text{Number of colonies of individual species in all the quadrats studied}}{\text{Total number of colonies of all the species}} \times 100$$

$$\% \text{ Frequency} = \frac{\text{Number of plates containing particular fungus}}{\text{Total number of plates}} \times 100$$

Categorization of frequency classes

Class	% Frequency	Category
I	1-20	Rare
II	21-40	Occasional
III	41-60	Frequent
IV	61-80	Common
V	81-100	Dominant

Maintenance of fungal cultures

Living cultures of important fungi were maintained on PDA medium slants under low temperature in a refrigerator.

Microscopic study

For microscopic study, slides were prepared in lactophenol + cotton blue staining reagent and details of fungal colonization in litter were observed and recorded under stereo-zoom microscope (Leica Germany, model Wild M3Z). Micro slides were observed under advanced research microscope, Leica Germany, model Leitz DMRB/E, using 5x, 10x, 20x 40x objectives and 10x and 15x eyepieces and photomicrographs were taken. Photographs of fruit bodies of macro-fungi were taken by 12 megapixel digital camera (Sony, model Cybershot H-50).

Identification of fungi

Fungi were identified on the basis of their growth characteristics, morphological characteristics and ontogeny with the help of manuals, monographs and taxonomic papers of various authors (Gilman 1957; Grove 1967; Subramanian 1971; Ainsworth et al. 1972; Barnett and Hunter 1972; Ellis 1971, 1976; Sutton 1980; von Arx 1981; Verma et al. 2008).

RESULTS AND DISCUSSION

Results

A total of 63 fungal species have been recorded from decomposing sal litter present on forest floor of central India. Season-wise occurrences of these fungi are given below.

March-May

With the start of summer season most of the fallen leaves are accumulated on the ground (Figure 2.A-B). The fallen leaves gradually dry up and are distributed throughout the stand by wind. Physically litter composed of dry, flat, partially folded, light brown leaves. It also composed of pieces of woody twigs and barks. In early litter formation freshly fallen dry leaves mixture is usually found near the tree bases. The layering occurred simultaneously as the leaf

fall progressed. The sequence of colonization of leaves indicated that mostly the oldest leaves are first to be colonized. Decomposition process begins before the plant part senescence. The organism involved is related to the type of plant part in litter and the environment. As soon as any plant part senescence saprophytic fungi began to colonize and multiply. The direct and indirect observation of litter revealed fungal population colonizing the litter at different stages of decomposition. The spread of fungal colonization was studied until the plant parts became completely fragile. The elimination and categorization of fungi occurring on different litter parts were made. A wide variety of fungi appeared at different stages of decay. The fungal flora changed as decomposition progressed. During this quarter the freshly fallen litter samples revealed less number of fungal species. Total 17 fungal species have been directly observed and isolated from the freshly fallen sal leaf litter. The most frequent colonizing fungi were *Asterostomella shoreae*, *Cladosporium oxysporum*, *Curvularia indica* and *Curvularia lunata* (Table 1, Figure 3).

Figure 2.A-B. Leaf litterfall in sal forest of central India

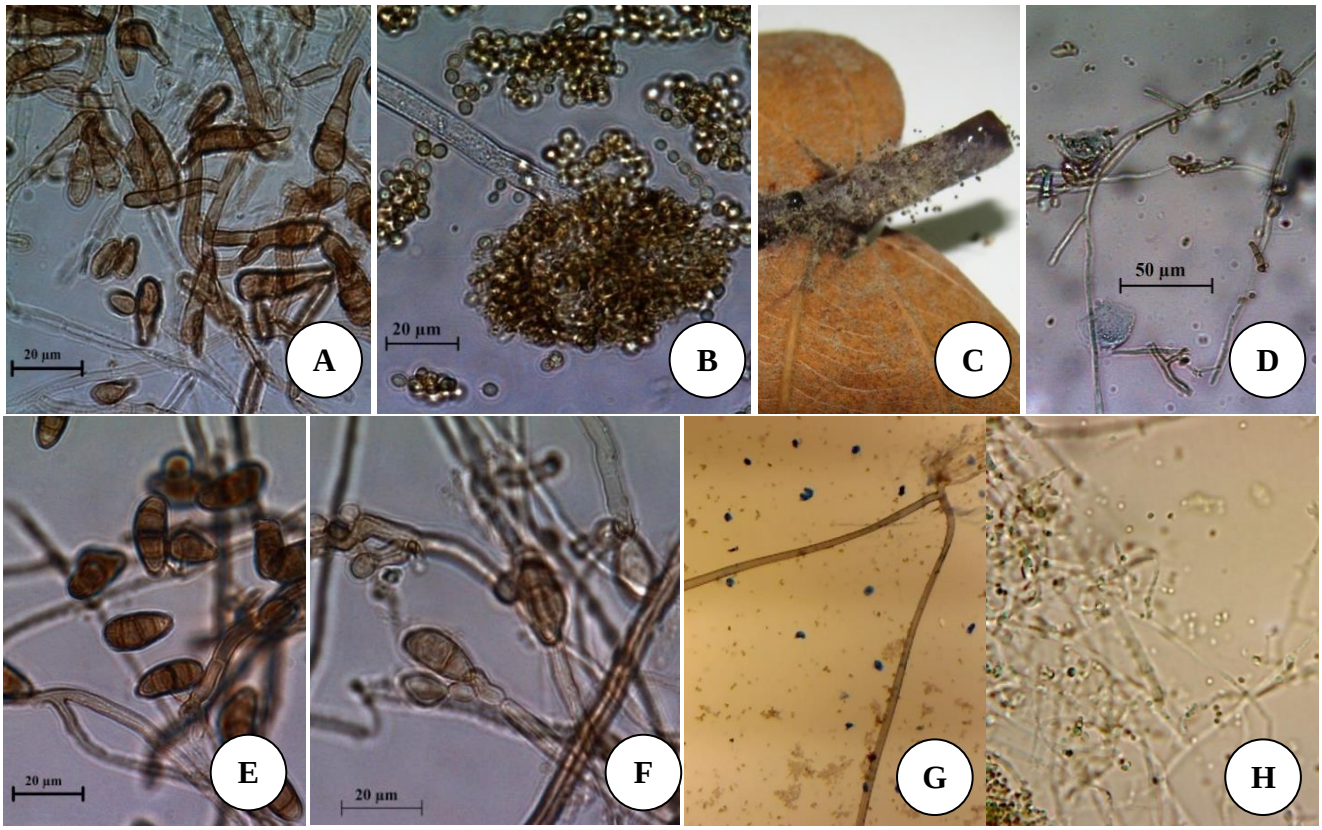

Figure 3.A-H. Litter decomposing fungi of sal forest. A. *Alternaria citrina*, B. *Aspergillus flavus*, C. *Aspergillus niger*, D. *Cladosporium oxysporum*, E. *Curvularia indica*, F. *Curvularia lunata*, G. *Rhizopus stolonifer*, H. *Trichoderma viride*

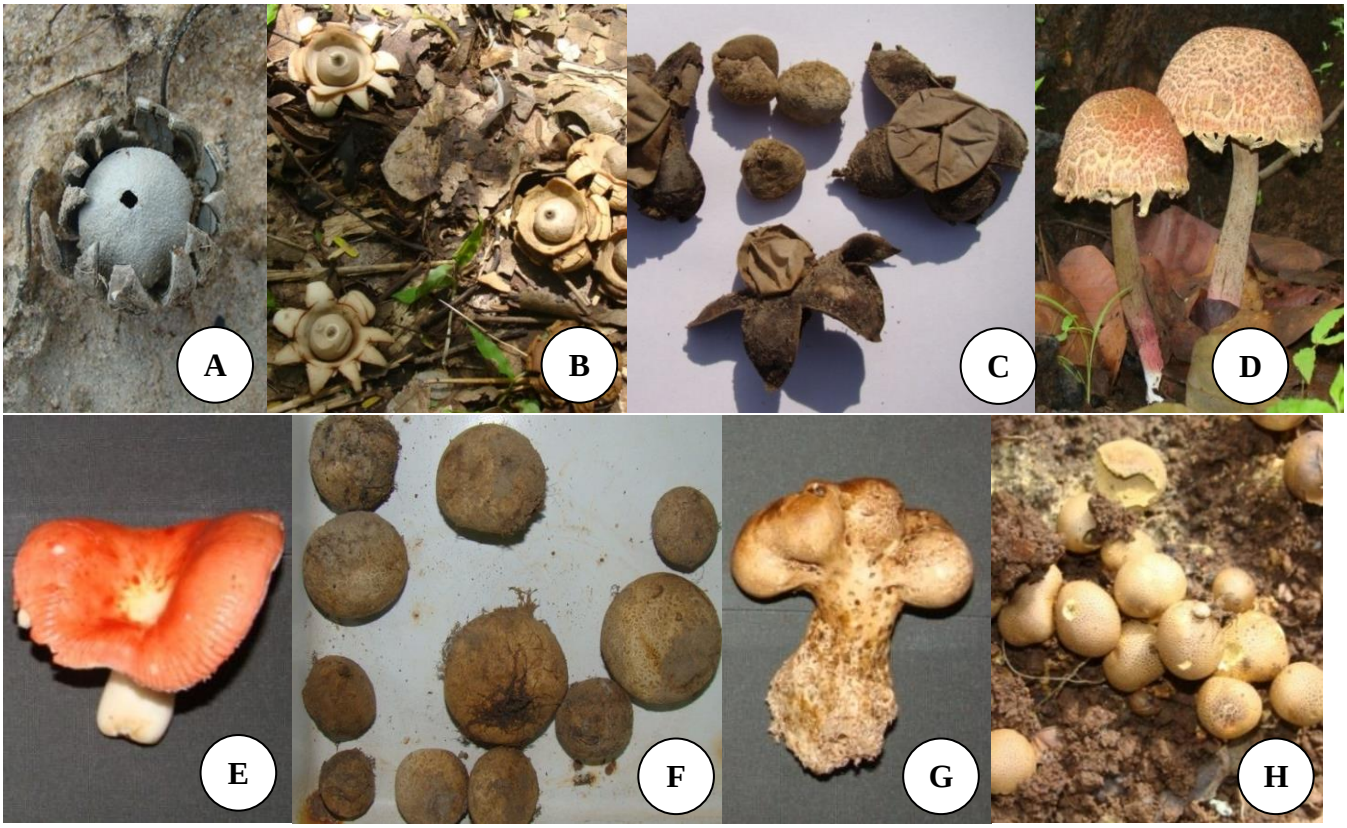

Figure 4. A-H. Mycorrhizal and litter decomposing fungi of sal forest. A. *Astraeus hygrometricus*, B. *Geastrum fimbriatum*, C. *Geastrum triplex*, D. *Boletus fallax*, E. *Russula emetica*, F. *Scleroderma bovista*, G. *Scleroderma geaster*, and H. *Scleroderma verrucosum*

June-August

During June most of the leaf and non-leaf litter mixed and spread throughout the forest floor and the stratification progressed. The litter gradually changed on the onset of monsoon and weathering, started simultaneously due to wind current, hot weather followed by rains. The layer formation was observed near tree bases, stone boundaries, and in depressed ground and formed oligostratal layer. In the second week of June strong shower soaked the litter and within 15 days the color of litter started changing to darker. The litter set up in an appropriate frame on the forest floor. The color, texture, and other chemical changes occurred consequently due to heavy rains. The litter becomes succulent which were readily colonized by fungi. The decomposing litter sheets took different shapes depending upon the canopy density and slope of forest floor. Regular rain increased the activity of fungal flora and this period is very important for litter decomposition as most of the soil-borne fungi were very active. After holding sufficient moisture colonization by several centimeters long saprophytic fungi were developed and appeared as a whitish, light brownish and blackish web of mycelium in between the gaps of decomposing pads of litter. Fruit bodies of several gasteromycetous fungi have also emerged on forest floor in a colonial form which was generally attached to the feeder root network of sal. High moisture *i.e*. 85-95% relative humidity and 27-35^{0}C temperature favor the excellent growth of soil, mycorrhizal and several other saprophytic fungi. Common ectomycorrhizal fungi noticed were *Boletus fallax Calvatia elata*, *Geastrum triplex*, *Russula emetica*, *Scleroderma bovista*, *S. geaster* and *Scleroderma verrucosum* (Figure 4). *Marasmius* and *Mycena*, were also emerged on forest floor.

Overall 32 species belonging to 23 genera were recognized as a colonizer of litter decomposer during June-August. Out of these eight fungal species namely *Aspergillus fumigatus, G. triplex*, *Lophodermium shoreae*, *Marasmius gordipes*, *Mycena roseus*, *R. emetica*, *Trichoderma harzianum*, and sterile fungus-1 shown its highest frequency and categorized under dominant frequency (V) and exhibited highest percentage of occurrence. Simultaneously five fungi namely *Aspergillus niger*, *C. elata*, *S. verrucosum*, and sterile fungus-2 were included in (IV) frequency and colonized with abundant percentage occurrence. In this category, the nature of fungal succession agents is both mycorrhizal and non-mycorrhizal. These fungi are season specific, and their occurrence and colonization are directly related to substrate and moisture content of top litter layer. In category third (III), eight fungi were recorded with the frequent colonization level. These are *Aspergillus astus*, *Cladosporium herbarum*, *C. oxysporum*, *Colletotrichum dematium*, *Corticium rolfsii*, *C. lunata*, *Phoma exigua*, sterile 3-4, *Trichoderma viride*, and *Wiesneriomyces javanicus*, which belong to Deuteromycetes. Populations of these fungi suddenly increased and rapidly colonized the upper and middle layer of litter. In category second (II) seven fungi were recorded and categorized as occasional.

Table 1. Season-wise frequency and occurrence of different fungi involving in litter decomposition of sal forests in central India

Name of fungi	Mar-May		June - Aug		Sep- Nov		Dec - Feb	
	Freq	Occur	Freq	Occur	Freq	Occur	Freq	Occur
Achlya debaryana Hump.	I	10.5	II	11.4	-	-	-	-
Alternaria alternata Fr. Keissl.	III	8.6	-	-	-	-	II	6.4
Alternaria citri Penz.	I	1.8	-	-	-	-		
Aspergillus flavus Link.	III	13.5	III	8.2	V	24.2	V	19.8
Aspergillus fumigatus Fres.	-	-	V	25.3	V	20.5	IV	18.0
Aspergillus niger Tiegh.	III	11.8	IV	18.2	V	22.2	V	23.2
Aspergillus terreus Thom.	-	-	-	-	-	-	V	20.5
Aspergillus ustus Bainier	-	-	III	13.0	-	-	II	6.4
Asterostomella shoreae Soni, Hosag,Pyasi & RK Verma	V	20.5	-	-	-	-	-	-
Astraeus hygrometricus Pers.	-	-	V	28.0	-	-	-	-
Boletus fallax Corner	-	-	IV	17.6	-	-		-
Botryodiplodea theobromae Pat.	-	-	-	-	-	-	II	6.4
Calvatia elata (Massee) Morgan	-	-	IV	18.2	-	-		
Chaetomium globosum Kunze ex Fr.	-	-	-	-	II	3.9	II	3.7
Cladosporium cladosporioides Link	II	4.6	II	4.6	-	-	II	2.8
Cladosporium herbarum Pers	-	-	III	13.0	-	-	III	13.0
Cladosporium oxysporum Berk	V	28.2	III	8.8	-	-	II	5.0
Colletotrichum dematium Pers.	-	-	III	11.8	-	-		
Colletotrichum gloeosporioides (Penz.) Sacc.	-	-	II	8.6	-	-	II	7.8
Coprinus aquatilis Peck	-	-	-	-	-	-	II	4.1
Corticium rolfsii Curzi.	-	-	-	-	III	11.4	-	-
Curvularia indica Subram.	IV	18.0	-	-	II	5.3	I	1.5
Curvularia lunata Wakker	IV	18.6	-	-	III	12.9	III	12.6
Curvularia prasadii Boedijn.	-	-	-	-	II	3.8	-	-
Drechslera spicifera (Bainier) Arx	I	1.2	-	-	-	-	-	-
Fusarium concolor Reinking.	I	1.0	-	-	II	3.3	-	-
Fusarium equiseti (Corda) Sacc.	-	-	-	-	II	2.6	-	-
Fusarium moniliforme J. Sheld.	-	-	-	-	II	2.8	-	-
Fusarium semitectum Berk.	-	-	-	-	II	2.4	II	2.3
Fusarium solani Sac.	I	1.2	II	3.9	-	-	II	3.8
Geastrum triplex Jungh.	-	-	IV	7.6	-	-	II	8.5
Geastrum fimbriatum Fr.	-	-	IV	7.6	-	-	II	8.5
Gliocladium virens Corda	-	-	-	-	-	-	III	11.6
Lophodermium shoreae Jamal, Dadwal & Soni	-	-	V	20.5	-	-	III	10.7
Marasmius gordipes Sacc. & Paol.	-	-	V	28.0	-	-	II	4.5
Mucor circinelloides Tiegh.	-	-	-	-	III	12.4	III	10.6
Mycena roseus Pers.	-	-	V	20.2	-	-		
Paecilomyces variotii Bainier.	-	-	-	-	-	-	I	1.8
Penicillium notatum Westling.	II	7.4	-	-	-	-	I	0.8
Periconia minutissima Corda	-	-	II	5.3	-	-	-	-
Pestalotiopsis versicolor (Speg.) Steyaert	-	-	-	-	II	4.6	II	3.5
Phoma exigua Desm.	V	28.1	-	-	III	2.0	II	4.6
Phoma macrostoma Mont.	-	-	-	-	II	6.7	-	-
Phoma medicaginis Malbr. & Roum.	-	-	-	-	II	2.5	-	-
Phoma multirostrata (P.N. Mathur, S.K. Menon & Thirum.) Dorenb. & Boerema	-	-	-	-	II	3.6	-	-
Phoma nebulosa (Pers.) Berk.	-	-	-	-	II	7.6	I	1.6
Pithomyces cortarum Berk.	-	-	-	-	-	-	I	1.2
Rhizopus stolonifer Ehrenb.	III	10.6	II	10.0	II	8.6	III	10.3
Russula emetica (Schaeff.) Pers.	-	-	V	27.8	-	-	-	-
Scleroderma bovista Fr.	-	-	IV	16.7	-	-	-	-
Scleroderma geaster Fr.	-	-	IV	16.7	-	-	-	-
Scleroderma verrucosum (Bull.) Pers.	-	-	IV	16.7	-	-	-	-
Scopulariopsis alba Szilvinyi.	-	-	II	8.6	-	-	-	-
Sterile fungus 1	-	-	V	27.5	-	-	-	-
Sterile fungus 2	-	-	IV	18.6	-	-	-	-
Sterile fungus 3	-	-	III	10.2	III	11.1	-	-
Sterile fungus 4	-	-	III	11.5	III	10.5	-	-
Trichoderma harzianum Rifai	-	-	V	28.2	-	-	III	11.5
Trichoderma koningii Oudem.	III	13.8	-	-	-	-	II	7.8
Trichoderma viride Pers.	-	-	III	10.8	-	-	-	-
Verticillium lecanii Zimm.	-	-	-	-	II	3.5	I	2.5
Wiesneriomyces javanicus Koord.	-	-	-	-	III	10.3	-	-
Helicosporium phragmitis Höhn.	-	-	-	-	-	-	III	11.2

Note: Freq = frequency; Occur = occurrence. The Roman numbers show the frequency classes and the Arabic numbers represent percentage frequency and occurrence of fungi.

They sometimes occur and sometimes does not depending upon the sampling time, locality, and substrate. During August some specific fungi were also recorded from the dead insect body namely *Scopulariopsis alba,* and *Verticillium lecanii* from Achanakmar. Their population increased sufficiently under moist incubation chamber.

September-November

During this quarter physical character of most of the litter losses, their lamina and its color were also turned to dark brown. It became fragile and deposited near the base of trees and restricted by under storey crop (weed and saplings of tree species). Upper surface of litter produced well matured tiny dots of *L. shoreae* which is a dominant fungus of sal forest. Its range of distribution is also categorized as common to all the selected sites. In all seventeen fungal species were identified in the litter of sal from September to November. The frequency of Aspergilli increased to dominant and categorized in fifth (V) category. These are *Aspergillus flavus, A. niger,* and *A. terreus*. The frequency of phycomycetous fungi was increased hence categorized in category (III). These are *Mucor* and *Rhizopus* and they were observed in all the samples, *Penicillium notatum, Phoma nebulosa, Pithomyces cortarum,* and *V. lecanii* were grouped in the rare category (II) as they appeared in few samples.

December-February

In early December both the layer of sal litter considerably changed in the physical characteristics. Most of the leaf lamina was broken into smaller pieces and turned into skeletal stage. On the basis of direct observation, it was observed that this skeletal material was covered with black mycelial filamentous fungi which ran parallel as well as intermingled with the dead substrate under cool and dry condition. The sites also maintained their moisture by late winter rains and due to sub moist and cool condition the activity of coelomyceteous fungi followed by ascomyceteous fungi were recorded. The dematiaceous fungi were also recorded which colonized the final stage of sal litter decomposition. A total 32 fungal species were observed in decomposed sal litter. Zygomyceteous fungi, for example, *Rhizopus stolonifer* was present as a rare category. The members of Deuteromycetes dominated over other classes in this quarter. The frequency of Aspergilli decreased; however, *A. niger* maintained its top order of colonization. The other two fungi, *C. herbarum* and *L. shoreae* were also exhibited dominance during the December ending. Ten members of coelomycete including species of *Botryodiplodia, Coleophoma, Colletotrichum* and *Phoma* were colonized the fragmented material of litter, pycnidia and pycnidial stomata profusely developed over the dead moist succulent part of sal litter and produced rich sporulation under cool and moist situation.

Discussion

Mycoflora plays an important role in the cycling of mineral nutrients by decomposing plant tissue. Their two-fold action, *i.e.* breaking down of complex organic compounds and trapping of the released elements in the fungal bodies prevents the elements from leaching and balances the ecosystem (Witkamp1969). The decomposing sal litter possessed a great variety of fungi belonging to different taxonomic groups which have been recorded throughout the year under natural forest ecosystem. In this study the population of fungi colonizing the litter layers was studied qualitatively and quantitatively.

In sal forest leaf fall starts from the last week of February and continued till April. Initially, the members of Deuteromycetes were the main colonizer. *Alternaria alternata, A. shoreae, C. oxysporum, C. indica, C. lunata,* and *P. exigua* were dominant colonizer on freshly fallen litter. As per their growth and pattern, it appeared that these fungi were already present in senescent leaves prior to leaf fall. Dwivedi and Shukla (1977) studied fungal decomposition in relation to CO_2 evolution in a tropical sal forest of Varanasi, Uttar Pradesh, India and reported that the Phycomycetes are the initial colonizers, which were replaced by cellulose decomposing ascomycetes and Deuteromycetes. They observed that fresh litter supported lesser number of fungi, half decomposed litter was colonized by a wide range of fungal species and the exhausted litter was invaded by only a few numbers of fungi. They also noted regular occurrence of *Alternaria alternata, C. herbarum,* and *C. lunata,* which was in the agreement with general observation as reported in tropics (Hudson 1968).

During June onwards *T. harzianum, Trichoderma koningii, R. emetica, M. roseus, M. gordipes, Scleroderma verrucossum, T. viride* were noticed in the fresh litter layer as well as in previous years granulated blackish humus layer. These basidiomyceteous mycorrhizal fungi extended their mycelial network in fragmented litter parts and surface grew fine feeder root system of sal. Due to sufficient moist ground, the root network grew up superficially and well networked with the symbiont mycelial rhizomorphs. September was found the best month for the fungal development and decomposition process. Three species of *Aspergillus,* i.e. *A. niger, A. flavus,* and *A. terreus* were recorded dominant. It is evident from the results that the litter after senescence is dominated by the members of Deuteromycetes thus the beginning of the scheme doesn't recall the general scheme as outlined by Garret (1963). The pattern of fungal succession in the litter of sal was alike in all the samples collected during all the four quarters and was similar to the finding of Hudson (1968). The member of coelomycetes was also an important component of litter decomposition of sal. Macauley and Thrower (1966) established a definite succession of fungi on the leaves of *Eucalyptus regnans* during their decomposition. According to them, coelomycetes tended to decrease with increasing decomposition. The pattern of ecological succession was followed as described by earlier workers (Ivarson and Sowden 1959; Hering 1967; Hudson 1968; Singh 1969; Jensen 1974; Dickinson 1976; Shukla 1976; Sinha and Dayal 1983; Soni and Jamaluddin 1990).

The majority of basidiomycetes appeared during August-September. The mycelium of these fungi activated decomposition process with onset of monsoon. It was due

to the fact that each layer of litter became moist, succulent and porous to provide conducive environment for proper mycelial development. During September a number of such fungi appeared on the decaying litter some of which showed their fructifications in colony form while other only in mycelia form such as *Coprinus aquatilis, C. rolfsii, M. gordipes, M. roseus,* and several yellowish brownish and whitish mycelia forms exhibited typical character of clamp connection in their developing mycelial stage. The activity of micro-fauna was also increased especially they found dead due to growth of entomogeneous fungi *Verticillium lecanii, Aspergillus* sp., etc. The quantitative analysis of mycoflora showed higher frequency of member of Deuteromycetes such as *C. oxysporum* and *P. exigua*. The host-specific fungi causing black mildew on senescent leaves were also present in freshly fallen leaf litter. Shukla (1976) also recorded competitive tolerance by the dominant fungal groups and tested culture filtrate of *Aspergillus flavus, A. niger, A. sclerotiorum. A. terreus,* and *T. harzianum*. Soni and Jamaluddin (1990) studied the fungal decomposition on Eucalyptus in dry deciduous forest for three successive years. They also found that members of Ascomycetes, Phycomycetes, and Basidiomycetes were the weak colonizer whereas the Deuteromycetes were the strong colonizer showing better adaptability and higher percentage distribution. According to them, wide range of humidity and temperature regimes were suitable for litter decomposition. Pande (1999) compared the decomposition rate of four tree species viz, *Shorea robusta, Tectona grandis, Eucalyptus,* and *Pinus roxberghii*. According to him, leaf litter decomposition followed the order sal 1.67, teak 1.65, pine 1.35, and eucalyptus 1.34 (the values represent decomposition constants 'K' which were calculated by the formula $x/x^o= 1\text{-}e^{kt}$ where x^o= initial weight and x= weight remaining after the time t, Olson 1963). In general, values for higher decomposition rate were observed during rainy season and the lowest during winter. He also pointed out that rainfall, number of rainy days, soil moisture, and temperature showed positive correlation with decomposition rate.

Mirchink and Demkina (1977) studied the ecology of litter fungi. They obtained dominant presence of dark-colored fungi as a proportion of total fungal species. In our study dark colored fungi recorded during later stage of sal litter decomposition. *Cladosporium* species is one of the important litter colonizers that belongs to saprophytic group.

The litter of Scott's pine (*Pinus sylvestris*) has supported a highly characteristic mycoflora and many of the saprophytic fungi common on pine and angiosperms litters. Results have indicated that many common soil fungi especially *Trichoderma* spp., member of Mucorales and *Penicillium* spp. colonize the surface of decomposing needles (Hudson 1968). Kendrick and Burges (1962) also reported very high frequencies of these fungi on washed needles but suggested that attempts to wash the needles may have not been completely successful and that these fungi existed on the needle surface mainly as passive spore loads. One species of *Penicillium* and three species of *Trichoderma* are also recorded in the present study. Egnnjobi (1974) studied the litterfall and mineralization in teak stand. He measured the litter fall at monthly interval for three years in a young stand of *T. grandis* dry forest zone of western Nigeria. On an average 70% of the litterfall between December and March and comprised 90% leaves. From the measurement of litter on the ground, it is concluded that complete mineralization of teak litter occurred within six months. In our study, we have observed that the complete mineralization of sal litter also took almost the same, time which in conformity with study of (Pande 1999). Some attempts were also made to stimulate growth of litter decomposition by fungi, for example, Lehmann and Hudson (1977) studied the fungal succession on normal and urea treated pine needles and reported that urea treatment stimulated development of *C. herbarum* but suppressed *Lophiostroma pinastri*. No such study has been conducted in tropical broad-leaved forests.

CONCLUSION

Sal litter on forest floor contains fungi throughout the year, and most of them showed seasonal variations. The study showed that decomposition of litter continuously takes place throughout the year; however, the process intensified during the rainy season. The fresh litter generally colonizes by member of imperfect fungi including genera *Alternaria, Cladosporium, Curvularia* and *Phoma* that colonize freshly fallen litter. The majority of basidiomycetes including ectomycorrhizal fungi appeared during August-September, and this is the best period for development of fungi and decomposition of litter. Dematiaceous fungi mostly colonize litter in later stages of decomposition.

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