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PJBS

ISSN 1028-8880

**Pakistan
Journal of Biological Sciences**

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Ectomycorrhizal Diversity Associated with *Cedrus deodara* and *Pinus wallichiana* in the Kashmir Himalaya, India

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Abstract: The present study was undertaken to document the ectomycorrhizal diversity associated with the *Cedrus deodara* and *Pinus wallichiana* in the Kashmir Himalaya, India. The extensive field surveys carried out in the Kashmir Himalaya at five study sites resulted in the collection and identification of 76 potential ectomycorrhizal fungal species associated with the *Cedrus deodara* and *Pinus wallichiana*. Maximum 32 number of species were found associated with *Pinus wallichiana*, 19 with *Cedrus deodara* and 25 species were found growing in association with both the conifers. The present study reveals that *Cedrus deodara* and *Pinus wallichiana* in the Kashmir Himalaya, India harbour diverse ectomycorrhizal fungal species.

Key words: Macrofungi, ectomycorrhizal, *Cedrus deodara*, *Pinus wallichiana*, Himalaya

INTRODUCTION

The roots of more than 90% of vascular plants in terrestrial ecosystems form symbiotic root-fungal associations known as mycorrhiza (Azul *et al.*, 2008). Only taxa belonging to families Brassicaceae, Caryophyllaceae, Cyperaceae and Juncaceae are non-mycorrhizal (Peat and Fitter, 1993). Among several different types of mycorrhizal associations the ectomycorrhizal fungi (ECM) often are considered an ecological guild distinguished by their stable biotrophic association with the roots of woody plants and production of macroscopic sporocarps (Luoma *et al.*, 1991). Despite the great taxonomic and phylogenetic diversity of the species involved in ECM association this type of symbiosis is remarkable for the conservation of its structural and anatomical features. Malloch *et al.* (1980) proposed that about 5000 species of higher fungi form ectomycorrhizal associations globally. Molina *et al.* (1992) pointed out that about 5400 species of fungi form ectomycorrhizal associations with most dominant woody plant families, like Betulaceae, Fagaceae, Pinaceae and Myrtaceae. However, studies on tropical forests and Australian *Eucalyptus* and their mycorrhizal associations have revealed new and previously undescribed ECM fungi (Claridge, 2002; Haug *et al.*, 2005). Weiss *et al.* (2004) pointed out the importance of the Sebacinaceae as mycorrhiza formers and Koljalg *et al.* (2000) demonstrated, for the first time, the symbiotic nature of several resupinate *Theleporoid* fungi, previously thought to be saprotrophic. On the basis of

morphotyping only, Agerer (2006) calculated that about 5800 fungal species belonging to 184 genera form ectomycorrhizal associations. Worldwide there are some 7000-10000 fungal species that form ectomycorrhizal association (Taylor and Alexander, 2005). Recently, Rinaldi *et al.* (2008) reported that ectomycorrhizal fungi are represented by 343 genera including 11, 950 species, of which 252 genera belong to Basidiomycota, 84 to Ascomycota and 5 to Zygomycota. The absorbing fine roots of woody plants belonging to families Betulaceae, Pinaceae, Fagaceae, Salicaceae and Dipterocarpaceae interact with these ectomycorrhizal fungal species to form a mutualistic association of considerable significance (Buscot *et al.*, 2000).

The state of Jammu and Kashmir is divided into three geographic regions: Ladakh, Kashmir Valley and Jammu. The Kashmir Valley lies between 33°20' and 34°54' N latitude and 73°55' and 75°35' E longitudes covering an area of 15, 948 km². The climate of the valley is predominantly temperate and a unique feature of the climate is occurrence of four distinct seasons in a year, namely spring (March-May), summer (June-August), autumn (September-November) and winter (December-February). The average maximum and minimum temperatures are 31 and 18°C in July and 4 and 2°C in January, except in Ladakh where maximum temperature is 30°C and minimum temperature is -50°C. Annual rainfall in the state varies from 100-155 mm, except in Ladakh where the precipitation is low and varies from 100-200 mm.

The forests of the Kashmir Himalaya due to wide variability in climate, altitude, slope, nature of forests, etc. show a rich diversity in micro-flora. The forest areas of Kashmir Himalaya in general are classified into three main groups: Kashmir temperate forests, Kashmir subalpine forests and Kashmir alpine forests (subtropical dry evergreen forest type covers a few small pockets in the northwest part of Kashmir (Dar *et al.*, 2002). The major forest divisions are Kamraj, Langate, Sindh, Jhelum valley, Pir Panjal. The coniferous forests predominate in the Kashmir province. The potential ectomycorrhizal hosts in these forests belong to two families, the Pinaceae, particularly *Abies pindrow* (Royle) Spach, *Picea smithiana* (Wall.) Boiss, *Pinus wallichiana* Jackson, *Cedrus deodara* (Rox.) D. Don. and the Betulaceae. The sub-alpine zone harbours *Rhododendron* and *Juniperus*, *Betula* etc. followed by alpine zone which abounds in many threatened endemic plant species.

The coniferous forests of Kashmir Himalaya serve an excellent habit for macro-fungi emanating in different seasons due to wide variability in climate, altitude, slope, type of forests etc. but the study on Kashmir Himalaya regarding diversity of macro-fungi and their ectomycorrhizas have been started in the recent years and is still in an exploratory or pioneer stage and undoubtedly there are many more species to be recorded from this region (Watling and Abraham, 1992). Watling and

Gregory (1980) recorded 119 taxa of macro-fungi from Kashmir. The list has been extended to 145 species (Beig *et al.*, 2008), 150 (Dar *et al.*, 2009) from Kashmir and upto late 2009 hardly 250 macro-fungal species were reported from the whole Jammu and Kashmir (Dar *et al.*, 2009). Dar *et al.* (2010) added four new species viz., *Russula aurea*, *Russula atropurpurea*, *Suillus variegates* and *Boletus rhodoxanthus* to the list. The identification of macro-fungal species in Kashmir Himalaya assumes significance with respect to their future use either as edible mushrooms or as medicinal source or as mycorrhiza to support plant growth under stressed conditions. The present study was undertaken to document the ectomycorrhizal diversity of Kashmir forests associated with *Cedrus deodara* and *Pinus wallichiana* in the Kashmir Himalaya, India.

MATERIALS AND METHODS

Place of collection: Field surveys for documentation of sporocarps of ectomycorrhizal fungi were carried out in the Kashmir valley at five study sites, namely Mammer Dardewoder, Naranag, Gutlibagh, Yusmarg and Hurpora (Fig. 1). Geographic coordinates and altitude of study sites surveyed is given in Table 1. The selected sampling areas were visited at regular intervals during 2010 and 2011 and occurrence and distribution of ectomycorrhizal

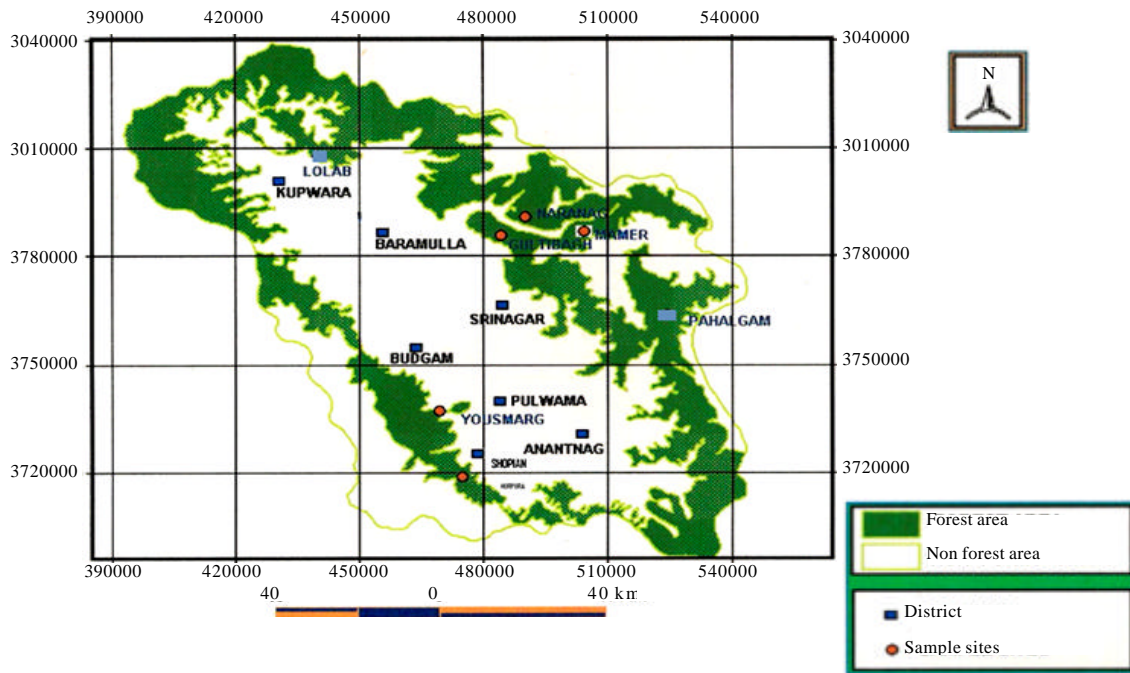


Fig. 1: Forest map of Kashmir Valley showing study sites

Table 1: Geographic location and altitude of study sites

Study site	District	Altitude	Latitude	Longitude
Mammer (MMR-D)	Ganderbal	2400	34.14	75.01
Naranag (NAR-G)	Ganderbal	2180	34.21	74.58
Gutlibagh (GUT-B)	Ganderbal	1800	34.11	74.49
Yusmarg (YUS-G)	Budgam	2380	33.50	74.40
Hurpora (HUR-P)	Shopian	2330	33.41	74.46

(ECM) fungi were recorded. Standard methods were followed for the collection of macrofungi (Kumar, 1989; Atri *et al.*, 2003). The identification was made on the basis of critical macro- and microscopic observations of the specimens and perusal of relevant literature (Lakhanpal and Kumar 1984; Abbott and Currah, 1997).

Collection and processing of ectomycorrhizal (ECM) fungi:

In the field, all the sporocarps of basidiomycetes occurring in the vicinity of tree species from the sampling sites were collected at periodical intervals. The fruit-bodies were observed at the first sight for their connection with the roots of nearby plants for confirming their mycorrhizal nature. Notes on the general type of habit, habitat, collection number, date of collection and proper hosts were recorded for all the fungi. Morphological features of the sporocarps/fruit bodies such as shape, texture, colour etc were recorded when the fungi were in fresh condition. To provide a clear visual record of the main characteristics of the fungal sporocarps/fruit bodies, photographs were taken in the field itself. As far as possible, detection of the hyphal connection between sporocarps/fruit bodies and mycorrhizal roots was made. ECM fungal fruit bodies at their different stages and mycorrhizal roots were collected and kept in study bags/cotton cloth bags and transported to the laboratory. Spore prints were prepared and both macroscopic and microscopic details on the fungi were recorded and identification of the fungi up to species level made. Fungal specimens were air-dried and preserved.

Morphological characters: The sporocarps/fruit bodies were collected and the morphological features were recorded in the field. The macroscopic characters like colour, size and shape of the Pileus, gills and or tubes, Stipe, attachment of gills or tubes, presence or absence of Stipe, annulus and Volva, presence or absence of rhizomorphs, etc., were recorded in the field.

Preservation of fruit bodies: Attempt was made to isolate the axenic cultures from fresh fruit bodies of different ECM fungi and then the specimens were air dried using an electric hot air oven. The dried specimens were preserved in polythene covers containing naphthalene balls to prevent from pests and mites attack and brought to the

laboratory for further analysis for proper identification. The sporocarps were maintained in 4% formaldehyde solution and preserved in the herbarium.

RESULTS

The Kashmir forests, dominated by conifers with sparse broad-leaved plantation, serve an excellent habitat for many rare and unnoticed basidiomycetous and ascomycetous ectomycorrhizal fungi. The forest sites surveyed were dominated by deodar (*Cedrus deodara*) and kail pine (*Pinus wallichiana*). During survey of selected sites of Mammer Dardewoder, Naranag, Gutlibagh, Yusmarg and Hurpora forests, conducted in growing season of 2010-2011, 76 potential ectomycorrhizal fungal species belonging to 14 families and 24 genera were collected and identified on the basis of their physico-morphological characteristics. The list of these 76 ectomycorrhizal species along with their sporocarps type, fungal class and abundance across different study sites surveyed is given in Table 2. Conspectus of species belonging to different fungal groups reveals that the Russulaceae, Boletaceae, Amanitaceae and Cortinariaceae were dominant families with 17, 11, 11 and 10 species, respectively. Number of genera was highest in Boletaceae (4), Tricholomataceae (3) and Cortinariaceae (3). Genera that were represented with highest number of species included *Amanita* (11), *Russula* (10), *Lactarius* (7) and *Suillus* (6). Out of these 76 ECM species 74 belonged to Basidiomycetes and 2 to Ascomycetes, 68 were with epigeous sporocarps and 8 with hypogeous sporocarps (Table 2). Maximum number of species (32) were associated with *Pinus wallichiana*, 19 with *Cedrus deodara* and 25 species were found growing in association with both the conifers (Fig. 2).

Based on their occurrence across different sites, 7 species were abundant, 9 frequent, 26 common, 27 rare and 7 species were very rare (Fig. 3). *Helvella crispa*, *Helvella elastic* and *Gomphus floccosus* were reported from only one study site, whereas *Inocybe geophylla*, *Inocybe rimosa*, *Inocybe fastigiata*, *Suillus luteus*, *Scleroderma citrinum* and *Geastrum minimum* were recorded from all the study sites.

List of ectomycorrhizal fungi

Amanitaceae: During the present study 11 species were reported from genus *Amanita*. *Amanita vaginata* (Fries) Vittadini was found growing in association with *Cedrus deodara* and was reported from Mammer Dardewoder, Yusmarg, Hurpora and Naranag forests. *Amanita phalloides* (Vail. ex Fr.) Link was reported from

Table 2: List of ectomycorrhizal species, along with their sporocarps type, fungal class, host and abundance across different study sites investigated during 2010-2011 assessments

Family	ECM Species	Host	Sporocarp type	Abundance	
Basidiomycetes					
Amanitaceae	<i>Amanita vaginata</i> (Fries) Vittadini	<i>Cedrus deodara</i>	Epigeous	Frequent	
	<i>Amanita phalloides</i> (Vail. ex Fr.) Link	<i>Cedrus deodara</i> and <i>Pinus wallichiana</i>	Epigeous	Common	
	<i>Amanita muscaria</i> (L.:Fr.) Hooker	<i>Cedrus deodara</i> and <i>Pinus wallichiana</i>	Epigeous	Rare	
	<i>Amanita flavoconia</i> G.F. Atk.	<i>Cedrus deodara</i>	Epigeous	Common	
	<i>Amanita pantherina</i> Krombh	<i>Cedrus deodara</i> and <i>Pinus wallichiana</i>	Epigeous	Rare	
	<i>Amanita virosa</i> (Fr.) Bertillon	<i>Cedrus deodara</i>	Epigeous	Rare	
	<i>Amanita citrine</i> S.F. Gray	<i>Pinus wallichiana</i>	Epigeous	Common	
	<i>Amanita excelsa</i> Kummer	<i>Pinus wallichiana</i>	Epigeous	Common	
	<i>Amanita francheti</i> Fayod	<i>Pinus wallichiana</i>	Epigeous	Rare	
	<i>Amanita rubescens</i> S.F. Gray	<i>Pinus wallichiana</i>	Epigeous	Common	
	<i>Amanita vittadini</i> Vitt.	<i>Pinus wallichiana</i>	Epigeous	Common	
	Boletaceae	<i>Stiellus luteus</i> (Fries) S.F. Gray	<i>Cedrus deodara</i> and <i>Pinus wallichiana</i>	Epigeous	Abundant
		<i>Stiellus brevipes</i> (Peck) Kuntze	<i>Cedrus deodara</i>	Epigeous	Common
		<i>Stiellus granulatus</i> (Fries) Kuntze	<i>Cedrus deodara</i> and <i>Pinus wallichiana</i>	Epigeous	Common
		<i>Stiellus elegans</i> (Klotzsch) Singer	<i>Cedrus deodara</i>	Epigeous	Common
<i>Stiellus sibiricus</i> Singer		<i>Cedrus deodara</i> and <i>Pinus wallichiana</i>	Epigeous	Abundant	
<i>Stiellus plorans</i> Singer		<i>Pinus wallichiana</i>	Epigeous	Common	
<i>Boletus edulis</i> Bull.		<i>Cedrus deodara</i> and <i>Pinus wallichiana</i>	Epigeous	Common	
<i>Boletus versicolor</i> Rostk		<i>Cedrus deodara</i>	Epigeous	Rare	
<i>Leccinum</i> sp.		<i>Pinus wallichiana</i>	Epigeous	Rare	
<i>Xerocomus bakshii</i> Singer and Singh		<i>Pinus wallichiana</i>	Epigeous	Very rare	
<i>Xerocomus</i> sp.		<i>Pinus wallichiana</i>	Epigeous	Frequent	
Russulaceae		<i>Russula delicata</i> Fr.	<i>Cedrus deodara</i> and <i>Pinus wallichiana</i>	Epigeous	Abundant
		<i>Russula decolorans</i> Fr.	<i>Cedrus deodara</i>	Epigeous	Frequent
		<i>Russula fragilis</i> (Pers.) Fr.	<i>Cedrus deodara</i> and <i>Pinus wallichiana</i>	Epigeous	Rare
		<i>Russula emetica</i> (Schaeff.:Fr.) Pers.	<i>Cedrus deodara</i> and <i>Pinus wallichiana</i>	Epigeous	Common
	<i>Russula lutea</i> (Huds. ex Fr.) S.F. Gray	<i>Cedrus deodara</i> and <i>Pinus wallichiana</i>	Epigeous	Common	
	<i>Russula brevipes</i> Peck	<i>Cedrus deodara</i>	Epigeous	Rare	
	<i>Russula maculata</i> Quel.	<i>Cedrus deodara</i>	Epigeous	Rare	
	<i>Russula rubicund</i> Quel.	<i>Pinus wallichiana</i>	Epigeous	Very rare	
	<i>Russula sanguinea</i> Fr.	<i>Pinus wallichiana</i>	Epigeous	Rare	
	<i>Russula deusifolia</i> Gillet	<i>Pinus wallichiana</i>	Epigeous	Common	
	<i>Lactarius scrobiculatus</i> (Fr.) Fr.	<i>Cedrus deodara</i> and <i>Pinus wallichiana</i>	Epigeous	Rare	
	<i>Lactarius delicosus</i> S.F. Gray	<i>Cedrus deodara</i>	Epigeous	Common	
	<i>Lactarius controversus</i> Fr.	<i>Pinus wallichiana</i>	Epigeous	Frequent	
	<i>Lactarius deterrimus</i> Groger	<i>Pinus wallichiana</i>	Epigeous	Common	
	<i>Lactarius subpurpureus</i> Peck	<i>Pinus wallichiana</i>	Epigeous	Rare	
<i>Lactarius</i> sp.	<i>Cedrus deodara</i> and <i>Pinus wallichiana</i>	Epigeous	Rare		
<i>Lactarius</i> sp.	<i>Cedrus deodara</i> and <i>Pinus wallichiana</i>	Epigeous	Rare		
Cortinariaceae	<i>Inocybe geophylla</i> (Pers.) Kummer	<i>Cedrus deodara</i> and <i>Pinus wallichiana</i>	Epigeous	Abundant	
	<i>Inocybe rimosa</i> (Bull.) Quel.	<i>Cedrus deodara</i>	Epigeous	Abundant	
	<i>Inocybe fastigiata</i> Quel.	<i>Cedrus deodara</i>	Epigeous	Abundant	
	<i>Inocybe maculata</i> Boud.	<i>Pinus wallichiana</i>	Epigeous	Common	
	<i>Cortinarius decipiens</i> Fr.	<i>Pinus wallichiana</i>	Epigeous	Rare	
	<i>Cortinarius parafulmineus</i> R. Henry	<i>Pinus wallichiana</i>	Epigeous	Frequent	
	<i>Cortinarius</i> sp.	<i>Cedrus deodara</i> and <i>Pinus wallichiana</i>	Epigeous	Common	
	<i>Cortinarius</i> sp.	<i>Cedrus deodara</i> and <i>Pinus wallichiana</i>	Epigeous	Frequent	
	<i>Hebeloma pusillum</i> Lange	<i>Pinus wallichiana</i>	Epigeous	Common	
	<i>Hebeloma crustuliniforme</i> Quel.	<i>Pinus wallichiana</i>	Epigeous	Common	
Cantharellaceae	<i>Cantharellus cibarius</i> Fr.	<i>Cedrus deodara</i> and <i>Pinus wallichiana</i>	Epigeous	Rare	
	<i>Clavariaceae</i>				
Clavariaceae	<i>Ramaria flava</i> (Fr.) Quel.	<i>Cedrus deodara</i>	Epigeous	Common	
	<i>Ramaria botrytis</i> (Pers.) Ricken	<i>Cedrus deodara</i> and <i>Pinus wallichiana</i>	Epigeous	Rare	
	<i>Ramaria rubripermaneus</i>	<i>Cedrus deodara</i>	Epigeous	Frequent	
	<i>Ramaria anrea</i> (Fr.) Quel.	<i>Pinus wallichiana</i>	Epigeous	Rare	
	<i>Clavariadelphus ligula</i> (Quel.) Donk	<i>Cedrus deodara</i> and <i>Pinus wallichiana</i>	Epigeous	Rare	
Gomphaceae	<i>Gomphus floccosus</i> (Schw.) Singer	<i>Cedrus deodara</i>	Epigeous	Very rare	
	<i>Gomphus clavatus</i> S.F. Gray	<i>Pinus wallichiana</i>	Epigeous	Rare	
Lycoperdaceae	<i>Lycoperdon perlatum</i> Pers.	<i>Cedrus deodara</i> and <i>Pinus wallichiana</i>	Hypogeous	Rare	
	<i>Lycoperdon pyriforme</i> Schaeff	<i>Pinus wallichiana</i>	Hypogeous	Frequent	
	<i>Geastrum minimum</i> Schw.	<i>Cedrus deodara</i>	Hypogeous	Abundant	
<i>Geastrum</i> sp.	<i>Pinus wallichiana</i>	Hypogeous	Frequent		
Rhizopogonaceae	<i>Rhizopogon</i> sp.	<i>Pinus wallichiana</i>	Hypogeous	Common	
Hygrophoraceae	<i>Hygrophorus chysodon</i> Fr.	<i>Pinus wallichiana</i>	Epigeous	Common	
	<i>Hygrophorus pustulatus</i> Fr.	<i>Pinus wallichiana</i>	Epigeous	Rare	
Paxillaceae	<i>Paxillus involutus</i> Fr.	<i>Pinus wallichiana</i>	Epigeous	Common	
	<i>Paxillus rubicundulus</i> P.D.Orton	<i>Pinus wallichiana</i>	Epigeous	Common	

Table 2: Continue

Family	ECM Species	Host	Sporocarp type	Abundance
Sclerodermaceae	<i>Scleroderma citrinum</i> Pers.	<i>Cedrus deodara</i> and <i>Pinus wallichiana</i>	Hypogeous	Rare
	<i>Scleroderma verrucosum</i> Pers.	<i>Pinus wallichiana</i>	Hypogeous	Common
Tricholomataceae	<i>Clitocybe infundibuliformis</i> Quel.	<i>Pinus wallichiana</i>	Epigeous	Rare
	<i>Tricholoma terreum</i> Kummer	<i>Cedrus deodara</i>	Epigeous	Very rare
	<i>Tricholoma anrantium</i> (Fr.) Ricken	<i>Cedrus deodara</i> and <i>Pinus wallichiana</i>	Epigeous	Rare
	<i>Tricholoma sejunctum</i> Quel.	<i>Pinus wallichiana</i>	Epigeous	Very rare
	<i>Laccaria laccata</i> (Peck) Peck	<i>Cedrus deodara</i> and <i>Pinus wallichiana</i>	Epigeous	Rare
	<i>Laccaria</i> sp.	<i>Cedrus deodara</i> and <i>Pinus wallichiana</i>	Epigeous	Rare
Ascomycetes				
Helvellaceae	<i>Helvella crispa</i> (Scop.) Fr.	<i>Cedrus deodara</i>	Epigeous	Very rare
	<i>Helvella elastica</i> Bull.	<i>Cedrus deodara</i>	Epigeous	Very rare

Abundant: Species reported from all the five sites, Frequent: Species reported from four out of five sites, Common: Species reported from three out of five sites, Rare: Species reported from two out of five sites and Very rare: Species reported from one out of five sites

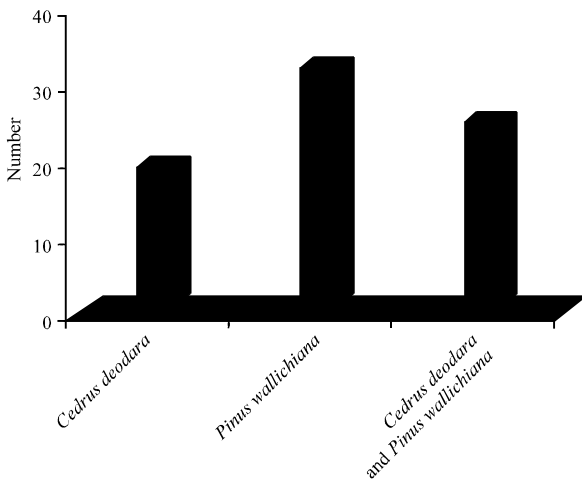


Fig. 2: Association pattern of species based on sporocarp types associated with the two conifers in the Kashmir Himalaya, India

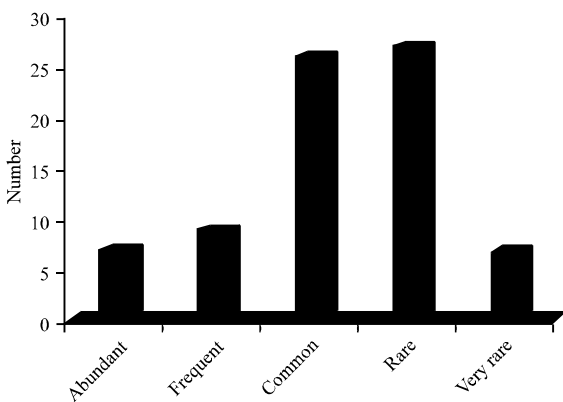


Fig. 3: Abundance of species based on occurrence of sporocarps across different study sites

Naranag and Yusmarg and was found growing in association with *Cedrus deodara* and *Pinus wallichiana*. *Amanita muscaria* (L.:Fr.) Hooker was reported from Mammer, Hurpora and Yusmarg and was

found growing in association with *Cedrus deodara* and *Pinus wallichiana*. *Amanita flavoconia* G.F. Atk. was found at Mammer and Yusmarg with *Cedrus deodara*. *Amanita pantherina* Krombh was found at Naranag and Yusmarg with *Cedrus deodara* and *Pinus wallichiana*. *Amanita virosa* (Fr.) Bertillon was found at Mammer, Naranag and Gutlibagh with *Cedrus deodara*. *Amanita citrine* S.F. Gray was found at Mammer and Gutlibagh with *Pinus wallichiana*. *Amanita excelsa* Kummer was found at Yusmarg with *Pinus wallichiana*. *Amanita francheti* Fayod was found at Hurpora and Yusmarg with *Pinus wallichiana*. *Amanita rubescens* S.F. Gray was found at Mammer, Yusmarg and Hurpora with *Pinus wallichiana*. *Amanita vittadini* Vitt. was found at Gutlibagh and Yusmarg with *Pinus wallichiana*.

Boletaceae: Six species from the genus *Suillus* have been reported during the study. *Suillus luteus* (Fries) S.F. Gray was collected from all the sampling sites and was found growing in association with both the conifers. *Suillus brevipes* (Peck) Kuntze was reported from Mammer, Hurpora and Yusmarg and was found growing in association with *Cedrus deodara*. *Suillus granulatus* (Fries) Kuntze was reported from Mammer, Hurpora and Yusmarg in association with *Cedrus deodara* and *Pinus wallichiana*. *Suillus elegans* (Klotzsch) Singer was collected from Naranag and Yusmarg with *Cedrus deodara*. *Suillus sibiricus* Singer was found at Naranag, Gutlibagh and Yusmarg with *Cedrus deodara* and *Pinus wallichiana*. *Suillus plorans* Singer was found at Mammer and Hurpora with *Pinus wallichiana*.

Two species from the genus *Boletus* (*Boletus edulis* Bull. and *Boletus versicolor* Rostk) have also been reported during the study. *Boletus edulis* Bull. was found at Mammer, Naranag and Yusmarg with *Cedrus deodara* and *Pinus wallichiana*. *Boletus versicolor* is new report from Kashmir and it was found at Mammer and Naranag with *Cedrus deodara*.

One species from genus *Leccinum* and two from *Xerocomus* have also been reported. *Xerocomus bakshii* was found at Mammer, Naranag

and *Hurpura* with *Pinus wallichiana*. *Xerocomus* sp., was found at Naranag and Yusmarg with *Pinus wallichiana*.

Cantharellaceae: *Cantharellus cibarius* Fr. was reported from Mammer, Naranag, Yusmarg and Hurpura and was found growing in association with *Cedrus deodara* and *Pinus wallichiana*.

Clavariaceae: *Ramaria flava* (Fr.) Quel. was found at Mammer, Naranag and Yusmarg with *Cedrus deodara*. *Ramaria botrytis* (Pers.) Ricken was collected from Mammer, Naranag, Hurpura and Yusmarg with *Cedrus deodara* and *Pinus wallichiana*. *Ramaria rubripermanens* is a new report from Kashmir and was found at Mammer and Yusmarg with *Cedrus deodara*. *Ramaria aurea* (Fr.) Quel. was found at Yusmarg with *Pinus wallichiana*.

Clavariadelphus ligula (Quel.) Donk was found at Hurpura and Yusmarg with *Cedrus deodara* and *Pinus wallichiana*.

Cortinariaceae: During the present study 10 species belonging to three genera of the family Cortinariaceae were reported. *Inocybe geophylla* (Pers.) Kummer was collected from all study sites and was found growing in association with *Cedrus deodara* and *Pinus wallichiana*. *Inocybe rimosa* (Bull.) Quel. was collected from Mammer, Yusmarg and Hurpura associated with *Cedrus deodara*. *Inocybe fastigiata* Quel. was collected from Mammer, Yusmarg and Hurpura with *Cedrus deodara*. *Inocybe maculata* Boud. was found at Naranag and Yusmarg with *Pinus wallichiana*.

Cortinarius decipiens Fr. was reported from Mammer, Yusmarg and Hurpura and was found in association with *Pinus wallichiana*. *Cortinarius parafulmineus* R. Henry was found at Yusmarg and Hurpura with *Pinus wallichiana*. *Cortinarius* sp. was collected from Naranag, Yusmarg and Hurpura with *Cedrus deodara* and *Pinus wallichiana*. *Cortinarius* sp., was found at Mammer and Gutlibagh with *Cedrus deodara* and *Pinus wallichiana*.

Hebeloma pusillum lange was collected from Mammer and Yusmarg growing in association with *Pinus wallichiana*. *Hebeloma crustuliniforme* Quel. was found at Mammer, Yusmarg and Hurpura in association with *Pinus wallichiana*.

Gomphaceae: *Gomphus floccus* (Schw.) Singer was collected from Mammer and was found growing in association with *Cedrus deodara*. *Gomphus clavatus* S.F. Gray was found at Naranag with *Pinus wallichiana*.

Hygrophoraceae: Two species from genus *Hygrophorus* (*Hygrophorus chysodon* Fr. and

Hygrophorus pustulatus Fr.) have been reported from Naranag and Yusmarg during the study. Both these species were found growing in association with *Pinus wallichiana*.

Lycoperdaceae: *Lycoperdon perlatum* Pers. was collected from all study sites and was found growing in association with *Cedrus deodara* and *Pinus wallichiana*. *Lycoperdon pyriforme* was collected from *Pinus wallichiana* forests at Mammer. Its mycorrhizal nature is not certain.

Geastrum minimum Schw. was collected from all study sites and was found growing in association with *Cedrus deodara*. *Geastrum* sp., was found at Yusmarg and Naranag with *Pinus wallichiana*.

Russulaceae: During the study 17 species belonging to genera *Russula* and *Lactarius* were reported. *Russula delica* Fr. was found at Mammer, Yusmarg, Hurpura and Naranag with *Cedrus deodara* and *Pinus wallichiana*. *Russula decolorans* Fr. was found at Gutlibagh and Yusmarg with *Cedrus deodara*. *Russula fragilis* (Pers.) Fr. *Russula emetica* (Schaeff.: Fr.) Pers. *Russula lutea* (Huds. ex Fr.) S.F. Gray were found growing in association with *Cedrus deodara* and *Pinus wallichiana* and *Russula brevipes* Peck *Russula maculata* Quel. with *Cedrus deodara* and *Russula rubicund* Quel. *Russula sanguine* Fr. *Russula densifolia* Gillet were found associated with *Pinus wallichiana*. *Lactarius delicoisus* S. F. Gray was found at Mammer and Yusmarg with *Cedrus deodara*. *Lactarius controversus* Fr. *Lactarius deterrimus* Groger *Lactarius subpurpureus* Peck were found associated with *Pinus wallichiana* and *Lactarius scrobiculatus* (Fr.) Fr. and two unidentified *Lactarius* species were found in association with *Cedrus deodara* and *Pinus wallichiana*.

Rhizopogonaceae: *Rhizopogon* has been collected from Mammer and Gutlibagh and was found associated with *Pinus wallichiana*.

Paxillaceae: *Paxillus involutus* Fr. was reported from Naranag, Yusmarg and Hurpura study sites with *Pinus wallichiana*. *Paxillus rubicundulus* P.D. Orton was found at Mammer and Yusmarg with *Pinus wallichiana*.

Sclerodermaceae: *Scleroderma citrinum* Pers. Was collected from all the study sites and was found in association with *Cedrus deodara* and *Pinus wallichiana*. *Scleroderma verrucosum* Pers. was found at Gutlibagh and Naranag with *Pinus wallichiana*.

Tricholomataceae: Six species belonging to three genera were reported from this large family.

Clitocybe infundibuliformis Quel. was reported from *Pinus wallichiana* at Mammer. Its mycorrhizal nature is not certain.

Tricholoma terreum Kummer was found at Mammer, Yusmarg and Hurpora with *Cedrus deodara*. *Tricholoma aurantium* (Fr.) Ricken was found at Naranag, Yusmarg and Hurpora with *Cedrus deodara* and *Pinus wallichiana*. *Tricholoma sejunctum* Quel. was found at Mammer and Naranag with *Pinus wallichiana*.

Laccaria laccata (Peck) Peck, *Laccaria* sp., were found associated with *Cedrus deodara* and *Pinus wallichiana*.

Helvellaceae: *Helvella crispa* (Scop.) Fr. and *Helvella elastica* Bull. the two ascomycete ectomycorrhizal species were reported from Mammer with *Cedrus deodara*.

DISCUSSION

Sporocarp surveys carried out during the present study resulted in identification of 76 potential ECM species belonging to genera such as *Amanita*, *Boletus*, *Suillus*, *Inocybe*, *Lactarius*, *Russula*, *Ramaria*, *Inocybe*, *Cortinarius*, *Cantharellus*, *Clavariadelphus*, *Laccaria*, *Scleroderma*, *Suillus*, *Tricholoma*, *Gomphus*, *Geastrum* and *Lycoperdon* in association with *Cedrus deodara* and *Pinus wallichiana*. Earlier workers (Watling and Abraham, 1992; Dar *et al.*, 2007, 2009; Beig *et al.*, 2008) have also reported occurrence of several such species associated with various conifers in different parts of

Kashmir Himalaya. Sharma and Singh (1990) reported association of species of *Amanita*, *Russula*, *Clitocybe infundibuliformis*, *Lactarius delicoisus*, *L. zonoricese*, *Leucopaxillus giganteus*, *Strobilomyces jloccopus*, *Boletus edulis*, *B. erythropus*, *Thelophora terrestris*, *Cantharellus cibarius* and *Laccaria laccata* with *Cedrus deodara* from Himachal Pradesh. Abraham and Kaul, 1985 reported 175 taxa from the Kashmir Himalaya of which 53 were found to form ectomycorrhizal associations with different coniferous species. Later Watling and Abraham (1992) described 77 ECM fungal taxa from Kashmir Himalayan forests. Based on the surveys carried out in Kashmir, these authors reported *Amanita excelsa*, *Amanita flavoconia*, *A. francheti* and *Boletus edulis* as new records from India. Beig *et al.* (2008) while describing mycorrhizal biodiversity of Kashmir forests reported 24 ectomycorrhizal species from coniferous forests. Dar *et al.* (2009) pointed out that conifer forests in the Kashmir Valley harbour some 260 species of macrofungi and reported *Russula delica* and *Russula paludosa* as new ectomycorrhizal records from Kashmir. Pande *et al.* (2004) reported that out of a total of 98 ectomycorrhizal species from western Himalaya, 55 were associated with *Pinus wallichiana* and *Cedrus deodara*. Kumari *et al.* (2010) reported *Cantharellus pseudoformosus*, a new species associated with *Cedrus deodara* from Himachal Pradesh, India. A compilation of the data is presented in (Table 3) based on studies of Watling and Abraham (1992), Beig *et al.* (2008), Dar *et al.* (2009), Pande *et al.* (2004) and Rinaldi *et al.* (2008) and present study.

Table 3: Total number of ectomycorrhizal species of different genera reported in association with *Cedrus deodara* and *Pinus wallichiana* (present study) and other hosts in different Himalayan regions and whole world

ECM genus	No. of species/host			
	Kashmir Himalaya		Western Himalaya	Whole world
	<i>Cedrus deodara</i> and <i>Pinus wallichiana</i>	Members of Pinaceae	<i>Pinus wallichiana</i> and <i>Cedrus deodara</i>	All hosts
<i>Amanita</i>	11	11	12	500
<i>Boletus</i>	2	2	4	300
<i>Leccinum</i>	1	-	2	75
<i>Suillus</i>	6	5	7	50
<i>Xerocomus</i>	2	-	-	-
<i>Russula</i>	10	16	10	750
<i>Lactarius</i>	7	8	9	400
<i>Cortinarius</i>	4	7	4	2000
<i>Inocybe</i>	4	8	2	500
<i>Hebeloma</i>	2	2	2	150
<i>Cantharellus</i>	1	1	1	65
<i>Hygrophorus</i>	2	2	3	100
<i>Laccaria</i>	2	1	2	25
<i>Tricholoma</i>	3	4	2	200
<i>Clitocybe</i>	1	-	3	-
<i>Paxillus</i>	2	2	-	15
<i>Ramaria</i>	4	4	-	60
<i>Clavariadelphus</i>	1	2	-	18
<i>Gomphus</i>	2	3	2	10
<i>Scleroderma</i>	2	1	-	25
<i>Rhizopogon</i>	1	-	-	150
<i>Lycoperdon</i>	2	1	-	-
<i>Geastrum</i>	2	1	-	-
<i>Helvella</i>	2	2	-	40

Kashmir is famous for its beauty and attracts tourists from all corners of the world. Mostly these tourist places are located in the dense forests. This creates immense pressure on these forests. Overgrazing, cutting down of trees and forest fires both natural and man-made, has led to soil exposure and subsequent erosion exacerbated by rain and snows are major reasons for landslides. These are the factors which have created immense pressure on forests and these valuable forests are under threat. It is important that these dense forests which support valuable diversity should be conserved and the diverse organisms categorized. It is the mycorrhizal association which supports forest trees which are responsible for beauty of tourist places and are commercial sources of timber and firewood. Ectomycorrhizal fungi cannot survive in the soil for long periods without a host, so hyphae are typically attached to living roots. So for any forest protection programme, the study of ecology of mycorrhizal fungi is very important and more effort is required to examine the ecosystem of these diverse communities. Several important techniques to maintain a diverse community of ectomycorrhizal fungi across the landscape are available to forest managers. These include: retaining refuge plants, mature trees and old-growth forests; retaining the forest floor during harvest and mechanical site preparation; avoiding high-intensity broadcast burns; minimizing the effects of species shifts, particularly following grass seeding; maintaining the edge-to-area ratio of harvested areas within certain limits; planting a mixture of tree species soon after harvest; retaining coarse woody debris; and managing for the fruiting bodies formed by ectomycorrhizal fungi, including edible mushrooms and truffles, fungi species used by wildlife and rare and endemic species.

CONCLUSION

The present study revealed that coniferous forests of Kashmir Himalaya, India support diverse and varied ectomycorrhizal fungal species. These diverse forests need to be explored and surveyed minutely for macro-fungi emanating in different seasons. The present study emphasizes the need for the extensive and minute survey of these forests which could definitely lead to discovery of many new and unnoticed ectomycorrhizal species from this diverse region.

ACKNOWLEDGMENTS

The authors are highly grateful to Prof. T.N. Lakhnupal for helping them in identification of some ECM sporocarps. The authors also acknowledge Department of Biotechnology, Government of India for

financial support provided under grant number (BT/PRO8072/AGR/21/215/2006), without which the conduct of the study would have been impossible.

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