Trade of *Cordyceps sinensis* from high altitudes of the Indian Himalaya: Conservation and biotechnological priorities

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***Cordyceps sinensis*, a parasitic fungus in the alpine regions, is highly valued in the traditional medicinal system of China, Nepal and India. The cost of one kg of wild collected fungus in the market varies from 30,000 to 60,000 Nepali Rupees in Nepal, and about Rs 1 lakh in India. This study explores the collection, trade route, market price at various stages of trade, and linkages in the region. Market price, trade and channels of *Cordyceps* collection are not transparent in the Indian subcontinent. Collection from wild habitats is a new income-generation opportunity in the remote locations of the Central Himalayan region. Among the stakeholders, conservation and sustainable harvest is the issue of debate. There is need for scientific exploration and research on biological screening of the Indian strains of this fungus, status in natural habitats, and artificial cultivation to harvest timely the prospects.**

Highlighting this species as a Chinese herb and its substances as anti-aging, pro-sexual, anti-cancer and immune boosting, now *Cordyceps* and its products are present in the market of the Western countries as over-the-counter medicine/tonic; however, the primary source is Tibet. For the past few years, there has been large-scale harvesting of the wild material from Nepal and India. This study highlights the importance of the fungus as medicine, a case study of collection and trade in the Central Himalayan region, and research needs in the Indian context.

CORDYCEPS is a fungus of subphylum Ascomycotina, class Pyrenomycetes, order Clavicipitales, and family Clavicipitaceae. A new classification of *Cordyceps* species has also been suggested on the basis of chemo-taxonomy of partial nucleotide sequnces of 18 S rDNA obtained from four different species[1]. Among the various species of the genus, *C. sinensis* (Berk.) Saac. is highly valued in the traditional medicinal system of China. Native occurrence of the fungus is confined to the high Himalayan mountains in Tibet, Nepal and India, at an altitude ranging from 3000 to 5000 m amsl, and in some provinces of China. The most common occurrence of the fungus is between 3500 and 4500 m elevation in cold and arid environment. In interior mountains, *C. sinensis* is commonly known as 'yarsa gumba' a Tibetan name [winter (yarsa) and summer (gumba)]. In the literature 'gunba' or 'gonba' have also been used instead of 'gumba'. In the Indian mountains, this is popular as 'keera jhar' (insect herb). The Chinese name for the fungus is 'Dong Chong Xia Cao' (meaning 'winter worm, summer plant'). This fungus is parasitic in nature, the host being the larvae of a small moth, Chongcao bat (*Hepialus armoricanus*, family Hepialidae). The mycelium of the fungus grows in the soil and colonizes the buried larvae (caterpillar) of this moth. The caterpillar becomes mummified by the growth of the mycelium. When alpine grasses start sprouting during summer, the mycelium of the fungus forms a fruiting body which, interestingly, always emerges from the head of the larva (Figure 1). This resembles grass sprouting but the difference is in the colour which is dark blue to black.

Cordyceps was discovered about 1500 years ago in Tibet by herdsmen who observed that their livestock became energetic after eating a certain mushroom. About 1000 years later, the Emperor's physicians in the Ming Dynasty learned about this Tibetan wonder and used this knowledge with their own wisdom to develop powerful and potent medicine[2]. Initial records of *Cordyceps* as medicine is as old as the Qing Dynasty in China and appeared in *Ben-Cao-Cong-Xin* (*New Compilation of Materia Medica*)[3] around 1757. The chemical composition of *Cordyceps* was explored in 1951, when cordycepin was identified[4] initially in *C. militaris*. In 1957, the constituents of

Figure 1. Fruiting body of *C. sinensis* with host larvae of moth.

Table 1. Chemical constituents of natural *Cordyceps*[2,7,8,10]

Cordycepic acid, glutamic acid, amino acids (phenylalanine, proline, histidine, valine, oxyvaline, arginine); Polyamines (1,3-diamino propane, cadaverine, spermidine, spermine, homospermidine, and purtescine); Cyclic dipeptides (cyclo-(gly-pro), cyclo-(leu-pro), cyclo-(val-pro), cyclo-(ala-leu), cyclo-(ala-val) and cyclo-(thr-leu); Saccharides and sugar derivatives (d-mannitol, oligosaccharides, and polysaccharides); Sterols (ergosterol, delta-3 ergosterol, ergosterol peroxide, 3-sistosterol, daucosterol and campasterol); Nucleotides and nucleosides (adenine, uracil, uridine, guanine, guanosine, thymidine, and deoxyuridine and cordycepin); 28 saturated and unsaturated fatty acids, their derivatives and other organic acids (oleic, linoleic, palmitic and stearic acids); Vitamins (B1, B2, B12, E and K); Inorganic elements (K, Na, Ca, Mg, Fe, Cu, Mn, Zn, Pi, Se, Al, Si, Ni, Sr, Ti, Cr, Ga, V, and Zr).

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C. sinensis were studied and a crystalline substance cordycepic acid was isolated[5]. Later on, it was identified as d-mannitol[6] and Chinese studies appeared predominantly on constituents of *C. sinensis*, but mostly the presence of known substances[7,8] (amino acids, steal acid, mycose, ergosterol, uracil, adenine, adoenosine, palmitic acid; Table 1). Now the medicine has also a place in modern clinical practices. Comprehensive reviews[3,9,10] on *C. sinensis* oriented towards modern medical science elaborate on the effect of the fungus in various treatments (Table 2), includeing immunologic, antineoplastic, antiarrythmic, hypoglycemic and erythropoietic effects[11].

This study was conducted in the Gori Ganga river valley, Central Himalayan region. It is adjacent to the international boundary of the neighbouring Himalayan country, Nepal. Few alpine habitats, where collection of *C. sinensis* is a continuing practice since the past few years (Figure 2), were investigated for two years. Because most of the trade is secretive in nature, trust was developed with the brokers and their agents, and dealers in the local market to obtain information. Primary field collectors and the following chain was identified for the trade route up to the possible level of identification. The identified persons were interviewed to recheck trade route, material collected and price involved at various stages. Primary field collectors in the alpine region were interviewed for the collection and money paid to them during different years.

Beside medicinal knowledge, other associated indigenous wisdom also exists. In nature, *Cordyceps* occurs in difficult terrain and is rare. Traditional knowledge to explore this fungus at high elevations of Tibet and China is to watch wild yaks; usually the mushroom is found where the yak grazes. During the time of open borders between India and Tibet (before the Indo-China conflict of 1962), traders of the Himalayan region in India visited Tibet frequently. Prevailing traditional knowledge among the traders was the use of this fungus to make their pack animals (carrying loads) energetic during travel in high altitudes (low-oxygen areas).

In traditional medicinal practices, wild harvested plants are considered to have higher therapeutic benefits; thus they command higher prices. *Cordyceps* has been highly prized for its medicinal properties for centuries, and the same tradition still continues. Traditionally, the fungus is traded in China for its weight in silver or gold[12]. An early mention (1919) about the trade of this fungus in China was described by Coales[13]. *Cordyceps* still hold high value in the markets of China; for example, in 1994, one kg of the fungus was sold[14] at US $700.

Market price, trade and channels of *Cordyceps* collection are not transparent in the Indian subcontinent (mostly informal and subsurface activity). However, commercial trading does exist. In local areas of fungus availability, the price may vary between NR (Nepali Rupees) 30,000 and

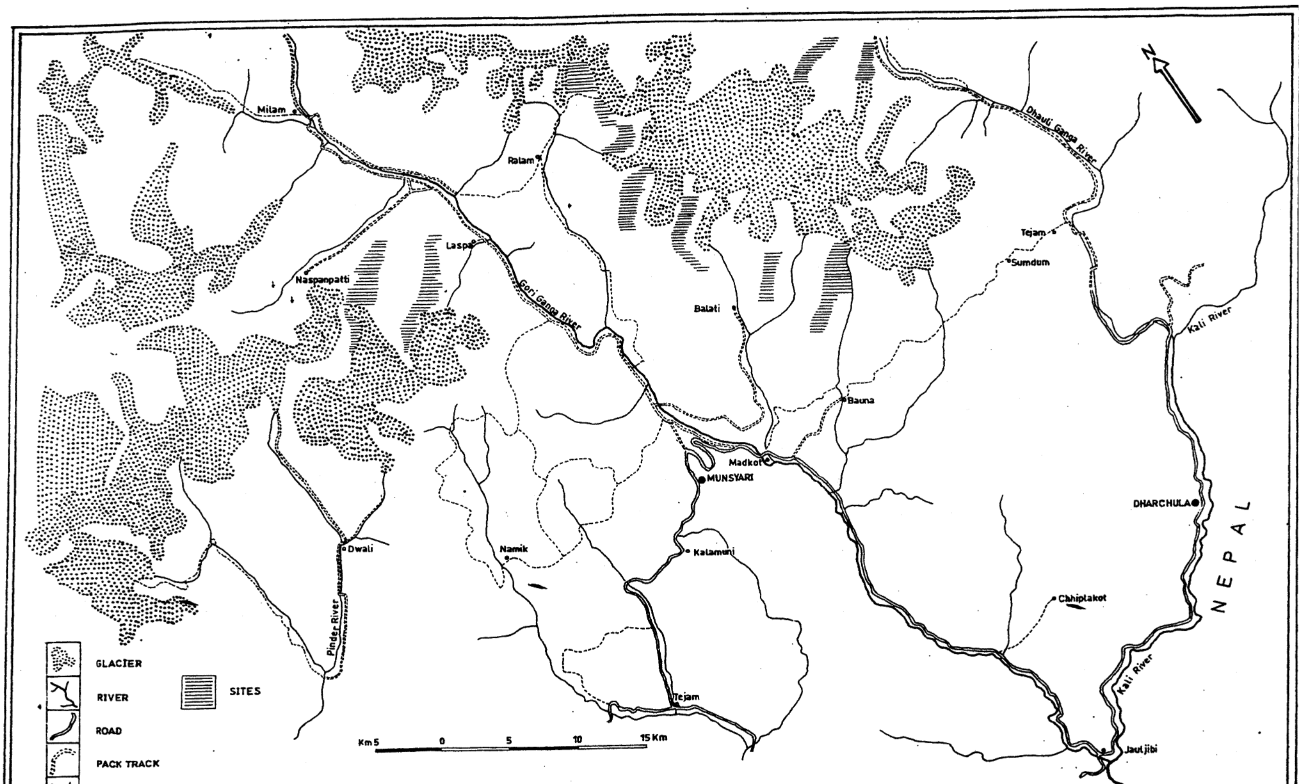

Figure 2. Alpine habitats of *C. sinensis* in the Gori Ganga river valley and local and regional markets of trade.

Table 2. Use of *Cordyceps* and its products (mainly Cs-4) in various medical treatments (refs 3, 9, 10 and references therein)

Animal study/clinical trial/treatment	Effectiveness
Improvement of physical performance	
Ratio between ATP and inorganic phosphate	Increased ($P < 0.001$)
Hypoxic environment	Prolonged survival and more efficient use of oxygen ($P < 0.001$)
Senescence	
Intolerance to cold, fatigue, dizziness	Improved ($P < 0.001$)
Tinnitus	Improved ($P < 0.001$)
Hyposexuality	Improved ($P < 0.05$)
Amnesia	Improved ($P < 0.003$)
Scavenging activity of superoxide dismutase, SOD (reduction in oxygen-free radical)	Significant increase in red blood cell SOD activity ($P < 0.001$) even in different disease conditions
Reproductive functions	
Sperm count	Higher ($P < 0.05$), increased, may promote spermatogenesis
Malformed spermatozoa	Reduced
Survival rate of spermatozoa	Increased
Endocrine system	Attenuated adrenal and spleen atrophy – an increased capability to adopt a cold environment
Cardiovascular system and circulatory functions	
Super-ventricular or ventricular arrhythmia	Complete/partial recovery of ECG, effective for tachyarrhythmia and bradyarrhythmia
Ischaemic heart disease	Clinical improvement in chest distress and palpitation
Blood fibrinogen and viscosity	Reduced ($P < 0.01$)
Contracted aorta	Artery relaxation seen
Dilation of arteries and increased blood supply	Can dilate the coronary and cerebrovascular arteries
Heart rate	Effective in reducing heart rate
Hyperlipidaemia	Can control
Atherosclerosis	Acts against the formation
Total cholesterol and triglycerides	Reduced ($P < 0.001$)
Both LDL and vLDL cholesterol	Decreased ($P < 0.001$)
HDL cholesterol	Increased ($P < 0.001$)
Blood glucose	Reduced ($P < 0.01$)
Respiratory system	
Intratrachael secretion	Increased ($P < 0.001$) facilitating expectoration
Cough latent period	Prolonged ($P < 0.001$)
Cough frequency	Decreased ($P < 0.001$)
Chronic bronchitis, bronchial asthma	Significant clinical improvement
Kidney and renal functions	
Blood nitrogen urea	Reduced ($P > 0.005$)
Serum ceratinine	Reduced ($P > 0.005$)
Haemoglobin	Increased ($P > 0.005$)
Kidney toxicity	Nephro-protective effect
Cellular sodium pump	More activated
Chronic interstitial oedema haemorrhage fibrosis and tubular denaturation-necrosis	Reduced
Morphological damages induced by cyclosporin	Prevented
Hepatic system (chronic hepatitis and related disease conditions)	
Hepatitis-B, thymol turbidity test	Returned to normal in one-third of the patients
Increased SGPT	Over half of the patients recovered to normal range
Serum albumin	Increased
Cancer (antiproliferative activity)	
Spontaneous metastases of B16 melanoma	Decreased liver weight ($P < 0.01$)
Drug resistant Lewis lung carcinoma (LLC)	Decreased liver weight ($P < 0.05$), significantly fewer metastatic foci than control
Primary weight of tumours	Reduced by 20% in LLC and 47% in B16 M compared to control
In vitro anti-tumour activity	LLC cells decreased by 96%, B16M cells decreased by 62%
Patients with advanced cancer receiving conventional cancer therapies	Restoring of immune cell functions
Various types of tumour	WBC maintained at < 3000 mm^{-3}, tumour size significantly reduced in half of the patients

60,000 for a kg in Nepal[15], while in the markets of Tibet and India, the cost per kg varies and is above (Indian Rupees) Rs one lakh (more than US $2000). It is believed that in the international market the fungus may fetch a price between one and two million rupees per kg (US $20,000–40,000). However, a high price index is associated with the fungus; the paid amount varies among the trade channels which start from wild material gatherers in the field. Brokers and their agents collect the material from various locations and sell it at a higher price.

Among the various alpine habitats located in the Gori Ganga river valley, Nagina Dhura and Cherthy Dhura are the most preferred sites for fungus gatherers. However, during 2002 five other sites have also been explored for this fungus and material has been collected from here. Local market and collection point for this fungus in the valley is Munsyari. Dharchula town is a major storehouse for trade. The trade route of the fungus from this region is elaborated in Figure 3. Primary gatherers (mostly villagers of the valley) stay in the alpine regions for several days and collect the fungus. During the growing period of the fungus, the main broker from the regional market sends his employees to various localities for collection of material. Other than this channel, various mechanisms have been developed. Few more independent agents also work, but the final destination for most of the collected material in that area is usually a regional broker. Gathering information about the collection, route and market is difficult because it is secretive in nature.

A new trend has been observed in the inner mountain ranges of the Central Himalaya, where collection and selling of *Cordyceps* has emerged as a new source of income in the rural areas. In the river valley of Gori Ganga alone, the number of fungus gatherers at alpine habitats has increased about fourfold since the year 2000. During 2002, nearly 900 persons went to seven different alpine habitats in search of the fungus (average ~ 128 persons per habitat) and collected about 186 kg of the fungus. Each gatherer collected about 200 g of fungus worth of about Rs 8600 (according to the purchase price in the year 2002), if the material was sold immediately in the alpine habitats. Carrying the collected fungus material a few kilometres down to the local market, the selling price increases to about Rs 7000 per kg. Since the year 2000, purchase price at the field site and in the local market has increased tremendously and so also the income of a gatherer (Figure 4). Between the year 2000 and 2002, the income of a wild material gatherer had increased by 3.7 times and above four fold if the material was sold at the field or to agents in the local market respectively. Factors such as high price associated with the fungus in the form of liquid cash and vulnerability of collected material for theft and loot, make the transaction secretive in the local market, while due to cross-boundary trade between two countries, the rest of the trade is under the surface. Infor-

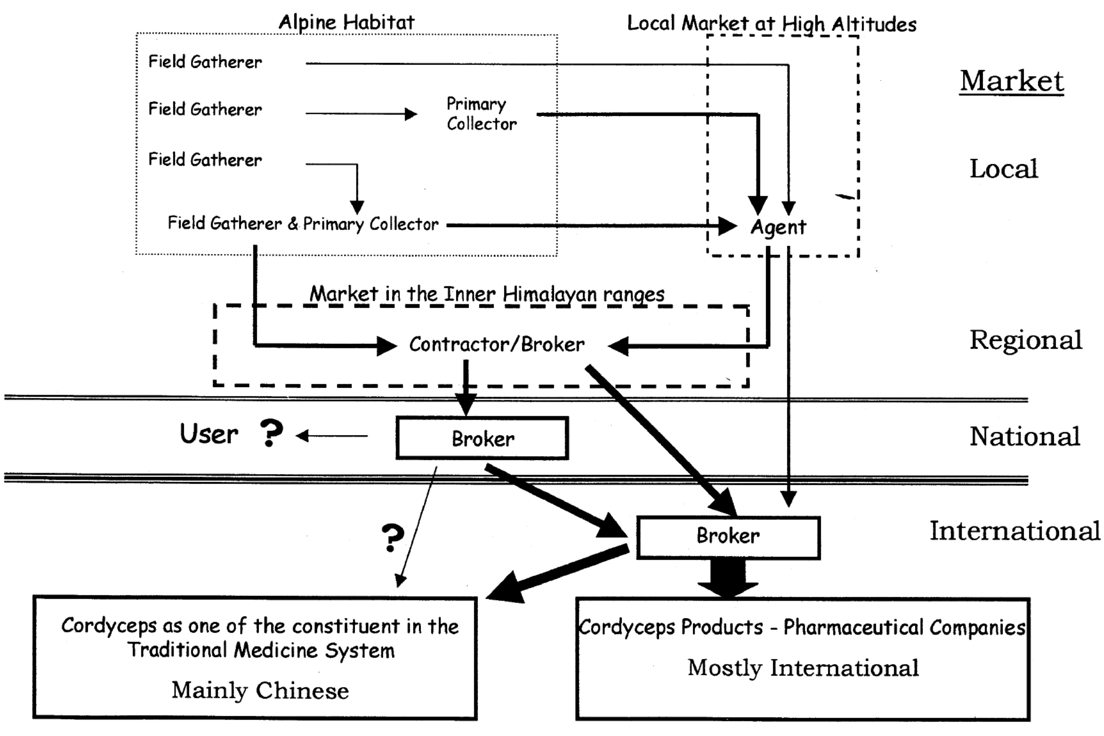

Figure 3. Trade route of *C. sinensis* which starts from high-altitude regions of Himalaya and ends at the International market. Gradient of continuity and line thickness for a component indicates openness and closeness of that system, e.g., …… open.

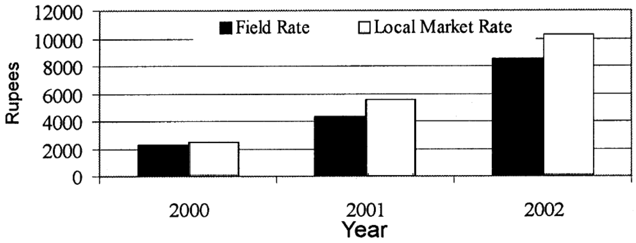

Figure 4. Average income of a field gatherer in the Central Himalayan region during different years.

mation extracted from different sources indicates that the cost of one kg of fungus at the final destination (brokers in national and international markets) was much higher than the price paid to field gatherers in the year 2002, and ranged between Rs 68,000 and 80,000 in Tibet, while in Nepal a slight increase was noted Rs 80,000–90,000. However, in the Indian market, the material was sold at the rate of Rs 125,000 to 130,000 per kg.

According to conservationists, wild material gatherers extract natural resources without considering sustainability and use destructive methods. This process leads to poor or no resource availability in a timescale, because the main aim is maximum harvest for more income generation. Endemic nature of the fungus along with mass collection attributes (as evident by the Central Himalayan case) from the wild puts it in the category of threatened plants. Nepal banned the collection, use, sale, distribution, transportation and export of *C. sinensis*[16] in 1992. However, being such a high-priced raw material and endemic in nature, no regulations and legislation control the collection, trade and export of *C. sinensis* in India, and the fungus is not in the Negative List of Export. Conservation approach suggests that alpine habitats and their neighbouring ecosystems can be protected. Under the protected Area Network (PAN) of India, few alpine zones have been brought under Biosphere Reserves (Nanda Devi Biosphere Reserve in Uttaranchal, Kanchandzanga Biosphere Reserve in Sikkim, and Dehan-Debang Biosphere Reserve in Arunachal Pradesh), National Parks (Gangotri National Park and Govind National Park in Uttaranchal, Great Himalayan National Park and Pin Valley National Park in Himachal Pradesh) and Wildlife sanctuaries in the high altitude regions of the Himalaya (Askot Wild Life Sanctuary and Kedarnath Wild Life Sanctuary in Uttaranchal). The efficacy of the system to monitor such vast areas in a difficult terrain is always questionable, particularly in view of the limited resources available with park authorities. Protection of alpine habitats is also a major concern in the Himalyan Kingdom of Bhutan, where major financial support was received from the Denmark last year to support activities[17] in the Bumdeling Wildlife Sanctuary to meet conservation objectives. One of them is to protect the core zone through establishment of a permanent guard post which has been identified as habitat for *C. sinensis* as well as high-altitude animals.

According to the rural-development approach, seasonal collection of the fungus is a rare avenue of income-generation in the interior regions of mountains, where other livelihood options are minimal. Keeping in view the contribution to the economy of the villagers and use of the fungus by traditional medicinal healers, recently, the ban on its collection has been lifted by the Nepal government. This has been welcomed by the people living in the backward regions of country[15]. In India due to lack of awareness (about the cost of the fungus in commercial trading) among the villagers, proper benefits are not reaching the primary gatherers who do intensive labour. Sustainability approach suggests that villagers may be educated about proper use of resources and the price tag of the material collected by them. Another method which may be adopted is cyclic regulation of different habitats for fungus collection. This approach may achieve conservation as well as sustainable harvesting of *C. sinensis*; but confrontation between different village communities over a common resource (sometimes an alpine habitat is shared by various villages for grazing and other purposes) will be a hurdle. This approach may be adopted in protected areas under the supervision of authorities.

There is need for scientific exploration in India to (i) explore the presence of the fungus in different places of the Himalayan region; (ii) document the occurrence and status, of the wild population, and (iii) formulate a strategy for conservation as well as sustainable harvesting of the fungus. The Chinese strain is culturable in artificial medium and the products are commercially available in USA and Canada[2,18,19]. Few of the medicinal properties of cultured mycelium and products from mycelial fermentation have been examined in experimental and clinical trials; those showed promising results[20–28]. In Korea, a non-academic association of mushroom biologists and mushroom growers is providing knowledge to farmers on *Cordyceps* fruit-body induction on synthetic media[29]. In the Indian context, biotechnological interventions are required to (i) screen various natural populations for their constituents, and (ii) develop a protocol for growing Indian strains in artificial medium. These steps will lead to an expansion of the pharmaceutical industry and simplified cultivation practices may provide income-generating opportunities to the villagers (as in Korean case). To meet the market demand through alternative supply will reduce pressure on the natural population of the fungus.

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Species diversity of ectomycorrhizal fungi associated with temperate forest of Western Himalaya: a preliminary assessment

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An attempt has been made to give an assessment of the species diversity of epigeous ectomycorrhizal fungi of the temperate forests of Western Himalaya, based on studies carried out in the region. The main hosts were oaks (primarily *Quercus leucotrichophora* and *Q. floribunda*), pines (*Pinus roxburghii* and *P. wallichiana*) and deodar (*Cedrus deodara*). The species richness of ectomycorrhizal fungi was 43 in oak forests and 55 in conifer forests, which is close to midpoint values on the range derived from the literature for similar forest types. The major genera in terms of species were *Amanita* (15 sp.), *Russula* (13 sp.), *Boletus* (12 sp.), *Lactarius* (9 sp.), *Hygrophorus* (4 sp.) and *Cortinarius* (4 sp.). Some of these genera showed clear-cut host specificity – *Amanita* was primarily associated with conifers and *Russula* and *Boletus* with oaks. All these forests with the dominance of ectomycorrhizal hosts, had low tree species diversity.

ECTOMYCORRHIZAL fungi can account for 25% or more of the root mass of forests, thus representing a major below-ground structural component of the forest ecosystem. However, it remains the least known component from the standpoint of species diversity. Most of the past research on mycorrhizae was centred on plant–fungus interactions; their role on community ecosystem development, though important, remains poorly understood[1]. Interest in the diversity of macro fungi has grown in recent years, but it largely concerns species number at the global level[2]. We need to know about diversity of these fungi at a community or local level to develop management plans[3] and to understand the pattern of diversity in relation to environmental changes. According to an estimate[2], less than a dozen published studies have measured species richness of epigeous macro fungi at the community scale

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