



Survey of Wild Edible Mushrooms in Darma Valley, Kumaun Himalaya, Uttarakhand

Priya Bisht and Chandra Singh Negi*

Ecology & Biodiversity Laboratory, Department of Zoology
M B Government Postgraduate College, Haldwani-263 139, India
*E-mail: csnsacred1@gmail.com

Abstract: Wild edible mushrooms (WEM) form an important component of the dietary needs of the traditional people. A preliminary survey was conducted in the Darma valley, inhabited by the Rung sub-tribe, practicing a transhumant mode of sustenance. Exploitation of WEM is carried out in their summer homes, during the interim period from June-August. Altogether 19 species were identified as edible from the broad landscape, encompassing 6 villages. However, the inhabitants harvested only 9 species- for their consumption. The present study presents data about the quantity of the WEM harvested; the traditional knowledge base as to the medicinal uses of some of the species; and the mycorrhizal association of the species with the above-ground vegetation. Of significance are the 12 species, which exhibit mycorrhizal association with *Abies spectabilis*, while another 3 species exhibiting mycorrhizal association with *Betula utilis*. Apart from *Ganoderma* sp. and *Morchella esculenta*, none of the other species harvested is marketed. The paper highlights the conservation aspect of wild mushrooms, as well as probable methodologies for sustainable harvesting of the WEM.

Keywords: Anthropogenic pressure, Mycorrhizal association, Wild edible mushroom

Over the last few decades, the abundance and diversity of mushrooms marketed as food and medicine worldwide have steadily grown. The 2327 species of wild edible and medicinal fungi are collected, consumed, and traded worldwide (Boa 2004). As relates to their antiquity, the consumption of wild edible mushrooms (WEM) has been traced to around 13,000 years back, going by the archaeological records from Chile (Rojas and Mansur 1995), while the written records of their consumption go back to 2000 years in China (Boa 2004). The collection and scientific study of mushrooms in India began in the 19th century and has continued to the present day (Kaul 2002). The mushroom is the fruiting body, or better still, the reproductive structure of a macrofungus that generates spores. These spores can be observed without the aid of magnification, and the mushroom itself is visible and can be manually harvested. Mushrooms offer local people a source of seasonal food, medicine, and an alternative source of income, while maintaining forest health (Sysouphanthong et al., 2010, Mortimer et al., 2012). The abundance of wild mushrooms is also a bioindicator of the ecosystem health (Dai et al., 2009, Sysouphanthong et al., 2010, Egli 2011, Du et al., 2011a, b). In Yunnan Province, China, up to 700 species of wild mushrooms are known to be edible and are utilized by local indigenous people as both a source of food and income (Mortimer et al., 2012). Similarly, an estimated 300 species of fungi are used as food in Mexico (Garibay-Orijel et al., 2006). Presently, an estimated value worth more than two billion US\$ is ascribed to only a few edible and marketed species of mushrooms (Wang and Hall 2004). In 2010, a total of 10572 tonnes of *Boletus edulis*

alone was exported from China, worth US \$71.83 million (Mortimer et al., 2012). This international trade is in fact vital for the livelihoods of collectors (Hamayun et al., 2006), with more than half of the cash income in some rural areas of Tibet and China's Yunnan Province, derived exclusively from mushroom exports to Japan and Europe (Chen 2004).

Several principal bio-active compounds- polysaccharides, glycoproteins, ergosterols, triterpenes, and antibiotics are isolated from mushrooms, which are known for their myriad pharmacological activities, such as (i) anti-fungal, (ii) anti-inflammatory, (iii) antitumour, (iv) antiviral, (v) antibacterial, (vi) hepato-protective, (vii) anti-diabetic, (viii) hypolipidemic, (ix) anti-thrombotic/antifibrotic, (x) hypotensive activities, (xi) anti-fatiguing, (xii) anti-oxidative, and (xiii) chemoprotective (Stamets 2002, Paul and Snyder 2009). In addition to antibiotics used in medicine (Sur and Ghosh 2004), mushrooms also yield fermentation products used in the food industry (Koizumi 2001), enzymes used industrially for the biotechnology of wood (Mai et al., 2004), as well as find applications in eco-friendly bioremediation of contaminated sites (Stamets 2005, Brar et al., 2006). Such studies should be explored for other species of mushrooms, too, as a biocontrol agent for getting rid of insect pests. Traditionally, however, mushrooms form a most common Non-timber Forest Products (NTFPs), harvested, primarily as food. While some of the species are eaten raw, or roasted, many, however, are cooked as a most preferred culinary dish. In traditional societies, the mushrooms harvested from the wild undergo processing and are preserved to be consumed at times of food scarcity. From an

ecological perspective, mushrooms and their mycorrhizal processes greatly impact nutrient cycling by playing an essential role in the transport, storage, and release of nutrients such as carbon (C), phosphorus (P), and nitrogen (N) (Varma et al., 2017, Bortier et al., 2018). Some of the mushroom species have very specific host plant species, while the others may be more general species (Pande et al., 2004). While commercial prospects of wild edible mushrooms, as well as their sustainable harvesting methods, have been dealt with (Boa 2004, Wang and Hall 2004, Mortimer et al., 2012), such studies are presently lacking altogether in this part of the country. Again, while one would subscribe to the exploitation of the WEM for the economic benefits of the inhabitants, more so, when it is known that picking large macrofungal species, such as *Lactarius* and *Russula*, for example, without disturbing the habitat has no negative impact on the future harvests (Egli et al., 2006). Similarly, unsustainable means, such as scouring the floor of the forest, or any perceptible change in the above-ground vegetation profile will severely impact upon the very viability of the WEM (Luoma et al., 2006). This is more so, in the case of the perennial species, e.g., *Fomitopsis spp.*, for the simple reason that they develop over many years, therefore would be much more susceptible to overharvesting (Berch et al., 2007). The present paper relates to the exploration of the diversity of the wild edible species (WEM), the principal species being harvested and the quantity being harvested there of, a preliminary listing of WEM exhibiting mycorrhizal association with the tree species, and lastly, the traditional knowledge base vis-à-vis wild edible mushrooms within the broad landscape, i.e., the Darma valley.

MATERIAL AND METHODS

The field survey was conducted within the Darma Valley, a constituent part of the greater landscape, referred to as Askote Conservation Landscape, located in Eastern Kumaun Himalaya, between 80°15' to 81°52' E longitude and 29°52' to 30°32' N latitude, with the Darma valley occupying just the central part of this landscape and lying across and along the River Dhauli, which is one of the major tributaries of the River Kali that again forms the international boundary between India and adjoining Nepal (Fig. 1). The villages studied lie within an altitudinal range between 3000 and 3400 meters amsl. The study sites were primarily dominated by *Abies spectabilis*, and in a few cases by *Betula utilis*, lying on an average between 3000-3400 meters amsl, i.e., between sub-alpine and alpine zone. The ambient temperature recorded during the conduction of the study period- June to August, ranged between 10 and 20°C, while the average humidity ranged between 72 and 86 percent. Within the

broad landscape, the majority of the study sites are treated as sacred. These sites, however, do exhibit signs of tree lopping, primarily for fuelwood collection, and secondarily, tree felling for the erection of ritualistic Aalam Sammo (syn. Flag pole).

The study primarily comprised of identification of the wild edible mushroom species, their association with particular plant species, quantity being harvested per family, and ethnobotanical knowledge associated with any particular mushroom species. Toward quantifying the harvested lot, the individual households were visited, and the raw weight of the collected lot was measured. The field survey was conducted along with the harvesters. This apart, information was gathered through a semi-structured questionnaire, personal interviews, and consultation with local inhabitants, particularly with the elderly folks. The collected specimens of WEM were identified by seeking the help of the experts, as well as through an extensive literature survey.

RESULTS AND DISCUSSION

Altogether 19 species of mushrooms were identified as edible from the landscape. However, in the six villages surveyed for harvesting of WEM, this number dwindled to just 9 species- *Clavatia craniiformis*, *Ramaria sanguinea*, *R. fennica*, *R. flava*, *R. botrytis*, *Clavaria zollingeri*, *Gomphus clavatus*, *Pleurotus ostreatus*, and *Kuehneromyces mutabilis* (Fig. 2). The total yield of all mushroom species harvested across the six villages was 3051 kg (Table 1). However, the harvested lot, varied across the six villages, both in terms of

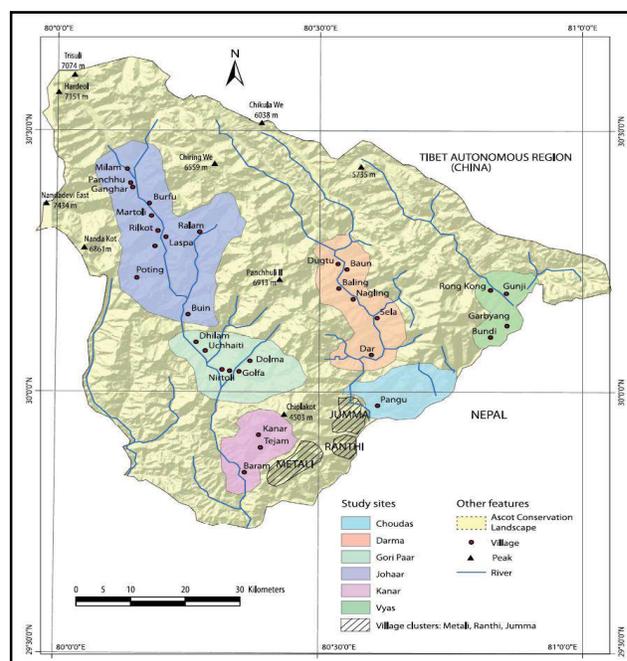


Fig. 1. Site location

the quantity of each species harvested and the number of WEMs being harvested. As concerns the volume, two species- *Gomphus clavatus* and *Ramaria spp.*, constituted the bulk of the harvested lot. These two species were abundant in *Abies*-dominated forests, lying adjacent to Baling, Philam and Bon villages (Fig. 3, Table 1).

There was significant variability in the seasonal harvesting of wild edible mushrooms across the Darma Valley. *Gomphus clavatus* is the most extensively harvested species, totaling 1449 kg, with a particularly high yield in Baling (1006 kg). *Ramaria spp.* also shows notable harvesting, with a total of 703 kg, highlighting its importance in the region. Other species, such as *Pleurotus ostreatus* and *Boletus edulis*, were collected in smaller quantities, indicating variable availability, or preference. Village-specific trends include a significant harvest of *Pleurotus ostreatus* in Nangling and *Boletus edulis* in Dugtu. The low total yield in Dantu (14 kg) suggests limited mushroom availability, or harvesting activity (Table 1, Fig. 2). Several mushrooms exhibited mycorrhizal associations with tree species (Table 2). The findings substantiate the results of Semwal (2003), Pande et al. (2004), Semwal et al. (2005, 2006) and Upadhyay et al. (2008). Significantly, the vernacular names given to one particular species either related to its invariable association with the particular plant/tree species or were derived according to its precise shape/morphology. Thus, *Bhuj mokshya* (*Kuehneromyces mutabilis*), and *Akhrot mokshya* (*Laetoporus sulphureus*) are associated with Bhojpatra (*Betula utilis*) and *Akhrot* (*Juglans regia*), respectively, while *Kuri mokshya* (*Boletus edulis*), *Puccham mokshya* (*Ramaria spp.*), *Damo mokshya* (*Clavatia craniiformis*), *Cherpiya* (*Auricularia auricula-judae*) are named as per their resemblance to bowl, rice, drum, and ear lobe, respectively.

Even though a substantial number of WEMs were identified from the landscape (Fig. 4), most were either

unknown to the local inhabitants or were not harvested because of their relatively lower population size. Interestingly, even though the studied villages were located quite near to each other, some of the species being harvested in one village, remained unexploited in the other village. This could be traced to a look-alike of one edible species, which might have resulted in some unfortunate event. However, the precise cause remained unfounded. Such events, however, result in phenomena as exhibited in the landscape, where a



Fig. 2. (from top left to right): The edible mushrooms currently harvested within the broad landscape- 1. *Clavatia craniiformis* (Schwein.) Fr. ex De Toni 1888, 2. *Ramaria sanguinea* (Pers.) Quel. 1888, 3. *R. fennica* (P. Karst.) Ricken 1920, 4. *Clavaria zollingeri* Lev. 1846, 5. *Gomphus clavatus* (Pers.) Gray 1821, 6. *Ramaria flava* (Schaeff.) Quel. 1888, 7. *Pleurotus ostreatus* (Jacq. ex Fr.) P. Kumm. 1871, 8. *Kuehneromyces mutabilis* (Schaeff.) Singer & A.H. Sm. 1946, 9. *Ramaria botrytis* (Pers.) Ricken 1918

Table 1. Seasonal collection of wild edible mushrooms (raw weight in Kg) from different villages of Darma Valley (Based on the survey with harvesting households, n= 144)

Species	Quantity (raw, in Kg)						Total
	Baling	Nangling	Boun	Philam	Dugtu	Dantu	
<i>Gomphus clavatus</i>	1006	119	75	149	100	0	1449
<i>Ramaria spp.*</i>	380	70	48	72	127	6	703
<i>Clavatia craniiformis</i>	0	0	81	33	0	8	122
<i>Pleurotus ostreatus</i>	0	363	0	0	0	0	363
<i>Boletus edulis</i>	2	0	39	6	289	0	336
<i>Kuehneromyces mutabilis</i>	4	0	0	0	74	0	78
Total	1392	552	243	260	590	14	3051

* Altogether 4 different species of *Ramaria* are exploited, which include *R. sanguinea*, *R. fennica*, *R. flava*, and *R. botrytis*

relatively higher age group is involved in the harvesting of WEM (Table 3). Whether the current harvesting of WEM is detrimental or not, could only be ascertained by periodic assessment of the yield of each WEM, over a period, say 5-6 years. However, presently, the lesser number of harvesters per household (between 1-2, Table 3), aided by a lesser number of individual forays made into the forest for collection, could well be judged as sustainable harvesting practice.

Within the forest located above the village Baling, there was greater abundance, as well as the diversity of WEMs in the relatively well-preserved forest segment, as compared to the forest segment experiencing more anthropogenic disturbance, primarily in terms of tree lopping and felling. It was found that the extent of forest canopy cover (own observation) affects the ambient temperature and humidity, as well as the moisture content in the underlying soil- all the factors that are necessary for the fruiting of the mushrooms. The canopy cover and the number of canopy branch layers, in fact significantly relate to the number/abundance of the fruiting bodies. Abrego et al. (2015) also highlighted that macrofungi are particularly sensitive to habitat loss and fragmentation. It is believed that increased opening resultant of tree felling and lopping could lead to higher variations in microclimate patterns, especially as concerns greater availability or percolation of light, resulting in turn in a substantial increase in the ambient temperature at the ground level (Dale et al., 2001, Greenberg and Forrest 2003). The above finding has two important applications- first, how the changes in the canopy cover relate to the yield of the particular WEM, and secondly, and more importantly, how best one could manage the forest cover to raise the productivity of the WEM of interest. This comprehensive data reveals considerable variation in mushroom species availability and harvesting levels, highlighting the impact of human activities on mushroom populations in the region. However, determining the sustainability of current harvesting

practices remains challenging in the present landscape, necessitating more detailed studies are warranted to ascertain- (i) quantity harvested per household per visit, (ii) quality of the harvested lot- immature versus mature samples



Fig. 3. (from top left to right): The edible species reported to be edible in one village, but not reported as such from the adjoining village. 1. *Tremella fuciformis* Berk 1856, 2. *Paxillus involutus* (Batsch) Fr., 1838, 3. *Laetiporus sulphureus* (Bull.) Murrill 1920, 4. *Laccaria amethystine* (Huds.) Cooke, 5. *Collybia confluens* (Pers.) R. H. Petersen, 6. *Fomes fomentarius* (L.) Fr. 1849, 7. *Amanita rubescens* (Pers. ex Fr.) Gray, 8. *Auricularia auricula-judae* (Bull.) J. Schröt., 9. *Boletus edulis* Bull. 1782, and 10. *Cantharellus cibarius* Fr. 11. *Morchella esculenta* Fr. and 12. *Ganoderma lucidum* Karst 1881. The last two species are exclusively harvested for the markets, and fetch good prices, nonetheless much below than what these two species command in the markets outside

Table 2. Mycorrhizal association of the mushroom species

Host species	The broad category of macrofungus
<i>Abies spectabilis</i>	<i>Lactarius sp.</i> , <i>Gomphus clavatus</i> , <i>Ramaria spp.</i> , <i>Auricularia auricula-judae</i> , <i>Fomes fomentarius</i> , <i>Hericium sp.</i> , <i>Strobilomyces sp.</i> , <i>Clitocybe sp.</i> , <i>Inocybe sp.</i> , <i>Galarina sp.</i> , <i>Russula sp.</i> , <i>Cortinarius sp.</i>
<i>Betula utilis</i>	<i>Kuehneromyces mutabilis</i> , <i>Boletus edulis</i> , <i>Pleurotus ostreatus</i>

Table 3. Characteristics of harvesting households surveyed in the different villages of Darma valley

Characteristics	Baling	Nangling	Boun	Philam	Dugtu/ Saun	Dantu	Total
Total households surveyed	30	26	23	20	30	15	144
Informants	95	41	70	35	111	28	380
Average age (years)	32	33	37	35	40	35	35
No. collectors per household	2	1	2	2	2	1	1.66

(mature samples though are not usually preferred by the locals), (iii) mode of traditional harvesting practices (whether few mature samples are left out for regeneration purposes, or not), and (iv) whether the harvester semi-process the harvested lot in the forest itself.

The sustainability or unsustainability of the harvesting practices could be ascertained through observations that relate to changes in the species diversity associated with the WEM of interest. Overharvesting is often a major concern, whether for economic gain or subsistence needs (Hens and Boon 2003a,b, Boa 2004). The high diversity of wild mushrooms is a vital requirement for a healthy forest ecosystem (Boa 2004), and a healthy forest is necessary to maintain a high diversity and productivity of wild mushrooms, Moore and Chiu 2001, Boa 2004). Studies that replicate the above findings, but conducted with WEMs of interest in the present landscape, will undoubtedly help in taking up the remedial measures. Till such studies are undertaken, it would be safe to institute a rotational harvesting method or policy, wherever, the locals cite a decline in yield (Lu 1998). Otherwise too, a regulatory or monitoring mechanism is instituted that stipulates a certain mature stage of each harvested WEM (Chen 2004).

CONCLUSION

Currently, the WEM harvested within the landscape could be categorized as sustainable, considering the quantity of the harvested lot, and the anthropogenic pressure exerted, i.e., 1-2 individuals per household engaged in the harvesting, since the market forces, as concerns the edible species of WEM being harvested, are relatively speaking, non-existent. However, the current lower anthropogenic pressure on the WEM, could also be because the harvesting season of WEM coincides with the harvesting of the most lucrative Yartsa Gunbu (*Ophiocordyceps sinensis*), when almost all the villagers occupy the alpine meadows, the habitat sites of Yartsa Gunbu is another example of WEM. Even though, the present exploitation of WEM might seem sustainable, there is nonetheless, an urgent need to undertake studies related to the habitat ecology, phenology, and response/s of the WEMs to disturbances, such as over-harvesting, tree felling, as also the salient changes in the community dynamics, which could act as an ecological indicator, defining the change- both positive (in favour of the increased yield of WEM), or negative (signifying the negative impact of the increased abundance of the associated species) on yield of WEM of concern. Such studies would undoubtedly yield information, which then could be applied to the sustainable harvesting of the WEM, as well as in raising their productivity/yield. For the present landscape, with underdeveloped markets, this remains a

sound option, which would not just result in stabilizing productivity, but would certainly open up opportunities for viable marketization of their harvested lot.

REFERENCES

- Abrego N, Bässler C, Christensen M and Heilmann-Clausen J 2015. Implications of reserve size and forest connectivity for the conservation of wood-inhabiting fungi in Europe. *Biological Conservation* **191**: 469-477
- Arnolds E 1995. Conservation and management of natural populations of edible fungi. *Canadian Journal of Botany* **73**: 987-998
- Berch SM, Ka KH, Park H and Winder R 2007. Development and potential of the cultivated and wild-harvested mushroom industries in the Republic of Korea and British Columbia. *BC Journal of Ecosystems and Management* **8**(3): 53-75.
- Boa E 2004. *Wild edible fungi: A Global Overview of Their Use and Importance to People*, FAO, Rome.
- Bortier MF, Andivia E, Genon JG, Grebenc T and Deckmyn G 2018. Towards understanding the role of ectomycorrhizal fungi in forest phosphorus cycling: A modelling approach. *Central European Forestry Journal* **64**(2): 79-95.
- Brar SK, Verma M, Surampalli RY, Misra K, Tyagi RD, Meunier N and Blais JF 2006. Bioremediation of hazardous wastes: A review. *Practice Periodical of Hazardous, Toxic and Radioactive Waste Management* **10**: 59-72.
- Chapman B, Xiao G and Myers S 2004. Early results from field trials using *Hypholoma fasciculare* to reduce *Armillaria ostoyae* root disease. *Canadian Journal of Botany* **82**: 962-969.
- Chen YL 2004. Song Rong (*Tricholoma matsutake*), a valuable forest mushroom from China: consumption, development and sustainability, pp. 78-93. In: Kuster K and Belcher B (eds). *Forest products, livelihoods and conservation: case studies of non-timber forest products systems*, Vol 1, Asia. Center for International Forestry Research, Bogor, Indonesia.
- Dai YC, Yang ZL, Cui BK, Yu CJ and Zhou LW 2009. Species diversity and utilization of medicinal mushrooms and fungi in China (Review). *International Journal of Medicinal Mushrooms* **11**: 287-302.
- Dale VH, Joyce LA, McNulty S, Neilson RP, Ayres MP, Flannigan MD, Hanson PJ, Irland LC, Lugo AE, Peterson CJ and Simberloff D 2001. Climate change and forest disturbances: climate change can affect forests by altering the frequency, intensity, duration, and timing of fire, drought, introduced species, insect and pathogen outbreaks, hurricanes, windstorms, ice storms, or landslides. *BioScience* **51**(9): 723-734
- Du P, Cui BK and Dai YC 2011a. High genetic diversity in wild culinary medicinal wood ear analysis. *International Journal of Medicinal Mushrooms* **13**: 289-298.
- Du P, Cui BK and Dai YC 2011b. Genetic diversity of wild *Auricularia polytricha* in Yunnan province of Southwestern China revealed by sequence-related amplified polymorphism (SRAP) analysis. *Journal of Medicinal Plants Research* **5**: 1374-1381.
- Egli S 2011. Mycorrhizal mushroom diversity and productivity-an indicator of forest health? *Annals of Forest Science* **68**(1): 81-88.
- Egli S, Peter M, Buser C, Stahel W and Ayer F 2006. Mushroom picking does not impair future harvests: Results of a long-term study in Switzerland. *Biological Conservation* **129**: 271-276.
- Garibay-Orijel R, Cifuentes J, Estrada Torres A and Caballero J 2006. People using macro-fungal diversity in Oaxaca, Mexico. *Fungal Diversity* **21**: 41-67.
- Greenberg CH and Forrest TG 2003. Seasonal abundance of ground-dwelling arthropods in forest and canopy gaps of the southern Appalachians. *Southeastern Naturalist* **2**(4): 591-608
- Hamayun M, Khan SA, Ahmad H, Shin DH and Lee IJ 2006. Morel collection and marketing: A case study from the Hindu-Kush

- Mountain region of Swat, Pakistan. *Lyonia* **11**(2): 7-13.
- Hens L and Boon EK 2003a. Causes of biodiversity loss: A human ecological analysis. *Futuro dos Recursos* **1**: 1-28.
- Hens L and Boon EK 2003b. The Johannesburg Conference. *Environment Development and Sustainability* **5**: 7-39.
- Kaul TN 2002. Conservation of Mycodiversity in India: An appraisal, pp. 131-147. In: Watling R, Frankland JC, Ainsworth AM, Isaac S and Robinson CH (eds). *Tropical Mycology*. CABI Publishing.
- Koizumi T 2001. Mystery of fermented-food: There are friendly molds too! *Japanese Journal of Medical Mycology* **42**: 1-5.
- Lu R 1998. *Enterprises in Mountain-specific Products in Western Sichuan, China*, International Centre for Integrated Mountain Development, Kathmandu, Nepal.
- Luoma DL, Eberhart JL, Abbott R, Moore A, Amaranthus MP and Pilz D 2006. Effects of mushroom harvest technique on subsequent American matsutake production. *Forest Ecology and Management* **236**: 65-75.
- Mai C, Kües U and Militz H 2004. Biotechnology in the wood industry. *Applied Microbiology and Biotechnology* **63**: 477-494.
- Moore D and Chiu SW 2001. Fungal products as food, pp 223-51. In: Pointing SB and Hyde K D (eds). *Bio-Exploitation of Filamentous Fungi*. Fungal Diversity Press, Hong Kong.
- Mortimer PE, Karunaratna SC, Li Q, Gui H, Yang X, Yang X, He J, Ye L, Guo J, Li H, Sysouphanthong P, Zhou D, Xu J and Hyde KD 2012. Prized edible Asian mushrooms: Ecology, conservation and sustainability. *Fungal Diversity* **56**: 31-47.
- Pande V, Palni UT and Singh SP 2004. Species diversity of ectomycorrhizal fungi associated with temperate forest of Western Himalaya: a preliminary assessment. *Current Science* **86**(12): 1619-1623.
- Paul BD and Snyder SH 2009. The unusual amino acid L-ergothioneine is a physiologic cytoprotectant. *Cell Death and Differentiation* **17**(7): 1134-1140.
- Perini C ed. 1998. Conservation of fungi in Europe, pp. 159. In: *Proceedings of the 4th meeting of the European Council for the Conservation of Fungi*, September 9-14, 1997, Università degli Studi de Siena, Vipiteno (Sterzing, Italy), Siena, Italy.
- Pradhan P, Dutta AK, Paloi S, Roy A and Acharya K 2016. Diversity and distribution of macrofungi in the Eastern Himalayan ecosystem. *Eurasian Journal of Biosciences* **10**: 1-12.
- Rojas C and Mansur E 1995. *Ecuador: Informaciones generales sobre productos forestales no madereros para-America Latina y el Caribe*, FAO Regional Office for Latin America and the Caribbean, Santiago, Chile. Serie Forestal, pp. 208-223.
- Semwal KC 2003. *Systematics and ecological studies on the Genus Amanita from Garhwal Himalaya*. Ph.D. thesis, H.N.B. Garhwal University, Srinagar Garhwal, Uttarakhand, India.
- Semwal KC, Bhatt RP and Upadhyay RC 2005. The Genus *Amanita* from Garhwal Himalaya region of India. *Mushroom Research* **14**(2): 50-55.
- Semwal KC, Bhatt RP and Upadhyay RC 2006. Occurrence and growth characters of *Amanita* spp. in Garhwal Himalaya. *Indian Phytopathology* **59**(3): 309-313.
- Semwal KC, Stephenson SL, Bhatt VK and Bhatt RP 2014. Edible mushrooms of the Northwestern Himalaya, India: a study of indigenous knowledge, distribution and diversity. *Mycosphere* **5**(3): 440-461
- Stamets P 2002. *Mycomedicinals: An Informational Treatise on Mushrooms*, MycoMedia Productions, Olympia, Washington DC.
- Stamets P 2005. *Mycelium running: How mushrooms can help save the world*, Ten Speed Press, Berkeley, California.
- Sur B and Ghosh GR 2004. Bioactive products of fungi. In: Kushwaha RKS (ed). *Fungi in Human and Animal Health*. Scientific Publishers, Jodhpur, India.
- Sysouphanthong P, Thongkantha S, Zhao RL, Soyotong K and Hyde KD 2010. Mushroom diversity in sustainable shade tea forest and the effect of fire damage. *Biodiversity and Conservation* **19**: 1401-1415.
- Upadhyay RC, Semwal KC, Tripathi A and Kumari D 2008. Three taxa of *Amanita hemibapha* from North-Western Himalaya (India). *Mushroom Research* **17**(1): 1-7.
- Varma A, Prasad R and Tuteja N 2017. *Mycorrhiza - nutrient uptake, biocontrol, ecorestoration*, 4th edition, Springer International Publishing, Cham.
- Wang Y and Hall IR 2004. Edible ectomycorrhizal mushrooms: Challenges and achievements. *Canadian Journal of Botany* **82**: 1063-1073.