Forest Systems
26(1), eR02, 7 pages (2017)
eISSN: 2171-9845
https://doi.org/10.5424/fs/2017261-10790
Instituto Nacional de Investigación y Tecnología Agraria y Alimentaria (INIA)

REVIEW ARTICLE

OPEN ACCESS

Wild mushrooms in Ethiopia: A review and synthesis for future perspective

Tatek Dejene, Juan-Andrés Oria-de-Rueda and Pablo Martín-Pinto

Sustainable Forest Management Research Institute. University of Valladolid (Palencia). Avda. Madrid 44, 34071. Palencia, Spain.

Abstract

Aim of study: To review and provide all-purpose information about wild mushrooms in Ethiopia and to create awareness for conservation and use of mycological resources.

Area of study: We focused mainly on Ethiopia, where information about wild mushrooms is scanty and their status is unknown under the rampant degradation of the habitats.

Main results: We reviewed all relevant references related to wild mushrooms and their ecological niches, cultural practices and species used for cultivation as well as the anthropogenic factors affecting the conservation of fungal diversity.

Research highlights: This review summarizes issues related to the diversity of wild mushrooms, the main ecological niches and their associated fungal species, and mushroom cultivation practices in Ethiopia. Moreover, threats and the need for future conservation of wild mushrooms in the country are also reported. This review paper can serve as base line information and indicator for further mycological studies in Ethiopia as well as in other developing countries with similar scenarios.

Keywords: Diversity; ecological niches; Ethiopia; mushroom cultivation; wild mushrooms.

Citation: Dejene, T., Oria-de-Rueda, J. A., Martín-Pinto, P. (2017). Wild mushrooms in Ethiopia: A review and synthesis for future perspective. Forest Systems, Volume 26, Issue 1, eR02. https://doi.org/10.5424/fs/2017261-10790.

Received: 21 Nov 2016 **Accepted:** 24 Feb 2017.

Funding: This work is supported by Erasmus Mundus-Dream project.

Competing interests: The authors have declared that no competing interests exist.

Correspondence should be addressed to Pablo Martín-Pinto: pmpinto@pvs.uva.es

Introduction

Wild mushrooms are either epigeous or hypogeous heterotrophic organisms that belong to the *Basidiomycota* and *Ascomycota* divisions (Chang & Lee, 2004; Crous *et al*., 2006). Many of the wild mushroom species are becoming important parts of the livelihoods of rural people in different parts of the world (Sarma *et al*., 2010; Cai *et al*., 2011), being collected as valuable Non Timber Forest Products (NTFPs) (Chang & Lee, 2004; Boa, 2004). They help people to reduce vulnerability to poverty and strengthen the livelihoods through a reliable source of income. Globally, about 140,000 important mushroom species have been reported (Boa, 2004). These can serve as sources of food (Boa, 2004), medicine (Ferreira *et al*., 2010), enzymes and various industrial compounds (Gryzenhout *et al*., 2010).

Pegler & Rayner (1969) and Pegler (1977) noted that the East Africa region is rich in macrofungal species. Many of these species are presumed to be either cosmopolitan or to be widespread across Africa (Pegler, 1977; Munyanziza, 1994). Like other East African countries, Ethiopian fungal flora remains unexplored (Sitotaw *et al*., 2015b), as most regions and habitats in the country have been seldom studied (Sitotaw *et al*., 2015a). Reports regarding wild mushroom diversity rarely exist (Sitotaw *et al*., 2015b; Megersa *et al*., 2017). This is due to a lack of research infrastructures as well as to a lack of fungal taxonomists and specialists in fungal ecology (Osarenkhoe *et al*., 2014). Finally, and likely as a result, fungi are not included in the biodiversity database of the country (IBC, 2005). This poor knowledge on Ethiopian fungal species is worrying as fungi are highly sensitive towards habitat disturbances, namely anthropogenic threats that are rife across the country (IBC, 2005; Goldmann *et al*., 2015).

Despite poor scientific knowledge on fungal diversity, wild mushroom hunting and utilization is a traditional common practice among the different tribes in the country (Tuno, 2001; Semwal *et al*., 2014). Mushrooms have been used for their nutritional, traditional and medicinal properties, and are also involved in local mythology (Tuno, 2001; Abate, 2014). Equally to other wild edibles, they have also been used as a coping food during food shortage periods (Lulekal *et al*., 2011, Alemu *et al*., 2012). In some local markets mushrooms are also available (Abate, 2014), where they are sold by the local people to earn some income to supplement the household economy.

In this review, we aimed to provide basic information about wild mushrooms in Ethiopia by assessing the available documents and to create awareness for conservation and a wider use of mycological resources in the country. This paper aims to serve as a basic document for further mycological studies in the country, and elsewhere in the region with similar scenarios.

Diversity of wild mushrooms

Functionally wild mushrooms are categorized as saprophytes, that obtain nutrients from dead organic materials; parasitic which depend on living plants and mycorrhizal, that form associations with host plants from which each partner gets benefits from each other (Ferris *et al*., 2000).

Mushrooms also tend to be linked to the vegetation of an area. Hence, understanding the ecology of host or keystone species helps to find the possible associated taxa in any habitat (Härkönen *et al*., 2003). In Ethiopia there are diverse habitats (Friis *et al*., 2010) characterized by a high richness of species, including the fungi (Sitotaw *et al*., 2015b). However, the published literature to which we had access lack to portrait the country's mycoflora profile but only focuses on a handful of species. Here we summarize and present a short overview of wild mushrooms and their related habitats in Ethiopia (Table 1). The discussion analyses the following categories: (1) mushrooms in indigenous forests, (2) mushrooms in grazing lands, (3) mushrooms in termite mounds and (4) mushrooms in exotic tree plantations.

Mushrooms in indigenous forests

Indigenous forests are a typical part of Ethiopian landscape (Friis *et al*., 2010), covering a range of environments. The occurrence of mushrooms in these forests is widespread during the rainy season (Abate, 2014). Some taxa like *Lentinus* spp. are also unique as they fruit during the dry season (Tuno, 2001).

The most important scholar references on fungal diversity come from the comprehensive works of Hjortstam & Ryvarden (1996) who reported fifteen *Corticiaceae* species (List of species not given), of which *Mycoacia brunneofusca* and *Vuilleminia obducens* were new to science. Decock *et al*. (2005) also reported a total of four taxa from the highland forests region, and of which *Fomitiporia tenuis* and *F. aethiopica* were newly reported to the world. Some other taxa have also been reported by Tuno (2001), Abate (2008), Alemu (2013), Muleta *et al*. (2013), Abate (2014) and Sitotaw *et al*. (2015a) from indigenous forests in different parts of the country.

Most recently, Megersa *et al*. (2017) reported 49 fungal taxa from Degaga natural forest in three years of collections (Complete list of the taxa not given). Also, our research team collected 64 macrofungal species in a single rainy season, suggesting the presence of moderate diversity of fungi in the dry Afromontane forests in the Southern region (Pers.obs). Interestingly, some of the taxa like *Agaricus* spp., *Agrocybe* spp., and *Calvatia* spp. in our collections could only be identified at the genus level, while some others couldn't be identified at all, indicating the likely presence of species new to science. Based on a survey report of NTFPs from the Benishnagul Gumz Region, Alemu *et al*. (2012) also reflected a wider diversity of macrofungal species in Western dryland forests. The species reported there were described using local names only and lack their precise Latin names.

All of the taxa reported in indigenous forests were saprophytic (Table 1). Unfortunately, most valuable ectomycorrhizal (ECM) species common in African forests like *Lactarius* spp. and *Amanita* spp. (Okhuoya *et al*., 2010), were not reported in any of the references assessed. This was not surprising as most of the tropical woody tree species are unable to form associations with ECM fungi (Brundrett, 2009), particularly those indigenous tree species of Ethiopia.

Mushrooms in grazing areas

Upland grazing areas are found on the highland plateaus about 2000-3000 m above sea level. The farming systems in these areas are characterized by livestock rearing in addition to crop production. Abate (1999), Alemu (2013), Abate (2014) and Sitotaw *et al*. (2015a) cited some taxa in these areas. The saprophytic species belong to the genus *Agaricus* spp. was the dominant so far reported in the upland grazing areas. Despite valuable, the diversity of fungal species in Ethiopian grazing lands might be a lot richer than what has been so far reported; something that further complementary studies could confirm.

Mushrooms associated with termites

The symbiotic association of *Termitomyces* fungal species with termites is a remarkable example of the

Table 1. Resum of taxa of wild mushrooms reported so far from Ethiopia and with reference to their associated habitats.

List of taxa	Habitat	Sources
Agaricus arvensis Schaeff.	NF, GA	Abate (2014), Alemu (2013)
Agaricus campestris L.	NF, GA	Abate (1999), Abate (2008), Alemu (2013), Sitotaw *et al*. (2015a)
Agaricus xanthodermulus Callac & Guinb.	GA	Sitotaw *et al*. (2015a)
Agaricus xanthodermus Genev.	GA	Sitotaw *et al*. (2015a)
Amanita spp. Pers.	No avail	Megersa *et al*. (2017)
Armillaria spp. (Fr.) Staude	NF	Abate (2008), Abate (2014)
Auricularia spp. Bull. exJuss.	NF	Abate (2008), Abate (2014)
Bjerkandera adusta (Willd.) P. Karst.	No avail	Megersa *et al*. (2017)
Catathelasma ventricosum (Peck) Singer	No avail	Megersa *et al*. (2017)
Chlorophyllum molybdites (G. Mey.) Massee	NF, PT	Abate (2008), Abate (2014), Megersa *et al*. (2017)
Climacodon septentrionalis (Fr.) P. Karst.	No avail	Megersa *et al*. (2017)
Clitocybe nuda (Bull.) H.E. Bigelow & A.H. Sm.	NF	Alemu (2013)
Coprinus spp. Pers.	NF	Abate (2014)
Corticiaceae spp. Herter	NF	Hjortstam & Ryvarden (1996)
Craterellus spp. Pers.	No avail	Megersa *et al*. (2017)
Dictyophora indusiata (Vent.) Desv.	NF	Tuno (2001)
Diplomitoporus rimosus (Murrill) Gilb. & Ryvarden	NF	Hjortstam & Ryvarden (1996)
Fomitiporia aethiopica Decock, Bitew & G. Castillo	NF	Decock *et al*.(2005)
Fomitiporia pseudopunctata (A. David, Dequatre & Fiasson) Fiasson	NF	Decock *et al*.(2005)
Fomitiporia robusta (P. Karst.) Fiasson & Niemelä	NF	Decock *et al*.(2005)
Fomitiporia tenuis Decock, Bitew & Castillo	NF	Decock *et al*.(2005)
Ganoderma applanatum (Pers.) Pat.	No avail	Megersa *et al*. (2017)
Geastrum triplex Jungh.	No avail	Megersa *et al*. (2017)
Gymnopilus spp. P.Karst.	NF	Abate (2008)
Gymnopus eucalyptorum (Pers.) Roussel	No avail	Megersa *et al*. (2017)
Gyromitra spp. Fr.	NF	Alemu (2013)
Hypholoma spp. (Fr.) P.Kumm.	NF	Abate (2008)
Laetiporus sulphureus (Bull.) Murrill	NF	Abate (2008), Muleta *et al*. (2013), Abate (2014)
Lentinellus cochleatus (Pers.) P. Karst.	No avail	Megersa *et al*. (2017)
Lentinus spp. Fr.	NF	Tuno (2001), Abate (2008)
Lenzites betulina (L.) Fr.	No avail	Megersa *et al*. (2017)
Lepista spp. (Fr.) W.G. Sm.	No avail	Megersa *et al*. (2017)
Macrolepiota procera (Scop.) Singer	No avail	Megersa *et al*. (2017)
Macrolepiota spp. Singer	NF, GA	Abate (2008), Abate (2014)
Morchella esculenta (L.) Pers.	No avail	Megersa *et al*. (2017)
Mycoacia brunneofusca Hjortstam & Ryvarden	NF	Hjortstam & Ryvarden (1996)
Omphalotus olearius (DC.) Singer	NF	Abate (2008)
Onnia tomentosa (Fries) P. Karsten	No avail	Megersa *et al*. (2017)
Phallales spp. E. Fisch	NF	Tuno (2001)
Phellinus populicola Niemelä	No avail	Megersa *et al*. (2017)
Pholiota adipose (Fr.) P. Kumm.	No avail	Megersa *et al*. (2017)
Pholiota spp. (Fr.) P. Kumm.	NF	Abate (2014)

Table 1. Continued

List of taxa	Habitat	Sources
Physisporinus rivulosus (Berk. & M.A. Curtis) Ryvarden	NF	Hjortstam & Ryvarden (1996)
Polyporus cinnabarinus (Jacq.) Fr.	No avail	Megersa *et al*. (2017)
Polyporus spp. P. Micheli ex Adans.	NF	Alemu (2013)
Polyporus squamosus (Huds.) Fr.	No avail	Megersa *et al*. (2017)
Pycnoporus spp. P. Karst.	NF	Alemu (2013)
Ramaria stricta (Pers.) Quél.	No avail	Megersa *et al*. (2017)
Russula spp. Pers.	No avail	Megersa *et al*. (2017)
Schizophyllum commune Fr.	NF	Tuno (2001), Abate (2008), Alemu (2013)
Stereum rugosum Pers.	No avail	Megersa *et al*. (2017)
Suillus luteus (L.) Roussel	PT	Abate (2008)
Termitomyces aurantiacus (R. Heim) R. Heim	TM	Sitotaw *et al*. (2015b)
Termitomyces clypeatus R. Heim	TM	Muleta *et al*. (2013), Sitotaw *et al*. (2015b)
Termitomyces eurrhizus (Berk.) R. Heim	No avail	Megersa *et al*. (2017)
Termitomyces eurrhizus (Berk.) R. Heim	TM	Sitotaw *et al*. (2015b)
Termitomyces letestui (Pat.) R. Heim	TM	Sitotaw *et al*. (2015b)
Termitomyces microcarpus (Berk. & Broome) R. Heim	TM	Muleta *et al*. (2013), Abate (2014), Sitotaw *et al*. (2015b)
Termitomyces robustus (Beeli) R. Heim	TM	Sitotaw *et al*. (2015b)
Termitomyces schimperi (Pat.) R. Heim	TM	Sitotaw *et al*. (2015b)
Thelephora terrestris Ehrh.	No avail	Megersa *et al*. (2017)
Trametes gibbosa (Pers.) Fr.	No avail	Megersa *et al*. (2017)
Trametes versicolor (L.) Lloyd	NF, PT	Alemu (2013), Megersa *et al*. (2017)
Trichaptum biforme (Fr.) Ryvarden	No avail	Megersa *et al*. (2017)
Vascellum spp. F. Marda	GA	Abate (2008)
Vuilleminia obducens Hjortstam & Ryvarden	NF	Hjortstam &Ryvarden (1996)

GA: grazing area, NF: natural forest, TM: termite mounds and PT: plantation forest, No avail: habitat not available in the document. Fungal taxa names and authors' names were obtained from Mycobank database (http://www. mycobank.org)

coexistence of fungi with insects (Frøslev *et al*., 2003; Yamada *et al*., 2005; Damian, 2012). The fungus produces small nodules, which are consumed by termites along with the degraded substrate piles, named combs. During rainy periods, the mycelium that grows degrading the termite combs produces mushrooms, which penetrate the termite nests and soil to reach the surface and thus spread their spores (Frøslev *et al*., 2003). In Ethiopia, most of the *Termitomyces* fungal species (Table 1) are reported from the lowland areas of the country, where termite mounds are more abundant (Muleta *et al*., 2013; Abate, 2014; Sitotaw *et al*., 2015b; Megersa *et al*., 2017).

Mushroom in exotic tree plantations

Plantation forests are dominated by exotic tree species, mainly of the *Eucalyptus, Cupressus, Pinus* and *Acacia* genera (Bekele, 2011). The mass introduction and expansion of these trees in the country implies as a consequence, the indirect introduction of associated exotic fungal species too. This is the case of several ECM mushrooms (Table 1) originated from Mediterranean and temperate climates associated with these non-native trees (Megersa *et al*., 2017). For example, *Suillus luteus* is common in *Pinus* tree species plantations (Abate, 2008). Such mushroom species have a potential to diversify the value of plantation forests through mycosilvicultural management approaches (Boa, 2004; Peredo *et al.,* 1983) and can be produced in high quantities.

Mushroom cultivation

Mushroom cultivation can contribute towards the goal of habitat conservation and food security. Around the world about 60 mushroom species have been cultivated commercially (Chang & Miles, 2004). The most common ones include *Agaricus bisporus, Lentinula edodes, Pleurotus ostreatus, Flammulina velutipes, Volvariella volvacea, Grifola frondosa,* and *Pholiota nameko* (Gizaw, 2010). In Ethiopia, the practice of mushroom cultivation is a recent activity, mostly restricted to urban areas (Yehuala, 2008; Abate, 2014). Agricultural and agro-industrial wastes have been used at a small scale to produce four most commonly cultivated mushrooms: *A. bisporus, L. edodes, P. ostreatus* (Yehuala, 2008; Gebrelibanos *et al*., 2016) and *P. florida* (Gebrelibanos *et al*., 2016). The levels of essential and non-essential metals in cultivated mushrooms such as *P. ostreatus* and *P. florida* were also studied in Haramaya, Oromia Region (Gebrelibanos *et al*., 2016). However, lack of awareness and cultivation skills still leave plenty of room for improvement and growth regarding mushroom cultivation (Yehuala, 2008; Muleta *et al.,* 2013).

Owing to their flavor and nutritional value, the consumption of cultivated mushrooms is now constantly increasing, particularly in the main cities. On the other hand, conservative eating habits are also hindering the transfer of cultivation technology at a local level, particularly in areas where mushroom consumption is not a common practice.

Threats and the need for conservation

Many threats affecting wild mushrooms are similar to those that globally affect the biodiversity in Ethiopia (IBC, 2005). The most important of all, deforestation, comes as a consequence of anthropogenic change to which global environmental and climate change also add (Lulekal *et al*., 2011). According to Teketay (2001), deforestation is immense and estimated between 150000 – 200000 ha of land per year. Factors contributing to habitat degradation, such as fires, are also affecting the fungal communities in forest systems (Vásquez-Gassibe *et al*., 2016), which is also a recurrent phenomenon in the natural forest systems in the country. This adversely influences the macrofungi and diminishes their diversity and production (Miller & Lodge, 1997). Such impact also limits the benefits that can be obtained from fungal resources. Thus, urgent conservation strategies and actions are needed, giving special considerations to those species currently used by the local people.

Conclusions and prospects

The reviewed references in this document highlight the existence of a valuable mycoflora in Ethiopia. Also, reveal some ecological niches in which important wild mushrooms exist. However, they miss to portrait the fungal diversity profiles in the country overall. Some of the taxa reported in some references are also not properly identified as they are only registered with their local names (Alemu *et al*., 2012). This also applies to other countries in the Region that supposed to have high potential linked to this natural resource as well, and reveals the need to accomplish thorough scientific studies in order to get a glimpse of the vast number of fungal species across the Region. Furthermore, the status of many wild mushroom species is also unclear, as habitat degradation is immense. We believe that further studies involving close examinations of different habitats are needed, since there might be yet unknown species with valuable potential but equally unknown uses.

According to our review, many are the possible options to widen the cultivation of mushrooms at small and large scales. At a small-scale level, homestead cultivation is possible using locally available substrates. Plantation forests in Ethiopia and also in others countries in the region could provide opportunities to introduce important mushroom species and can be used for large scale cultivation purposes. Globally highly appreciated taxa such as *Boletus pinophilus, B. edulis* and *Lactarius deliciosus* could be produced in plantation forests by means of seedling mycorrhization (Högberg & Piearce, 1986; Perry *et al*., 1987; Águeda *et al*., 2008; Mediavilla *et al*., 2016). Thus, adopting and scaling up of mycorrhization technologies may offer incentives for widening mushroom cultivation practices. This could also be a major future research area. Also, wood waste could be used (Sefidi & Etemad, 2015) to cultivate important medicinal species such as *Pleurotus ostreatus, Ganaoderma lucidum* and *Coriolus versicolor* in natural and plantation forest systems.

Acknowledgements

We thank Dr. Wubalem Tadesse, the general director of the Ethiopian Environment and Forestry Research Institute for directing us towards this important topic of research in Ethiopia. We also thank Dr. Luis Santos del Blanco (IDForest) for his helpful comments for improving this paper.

References

Abate D, 1999. Agaricus campestris in upland Ethiopia. Mycologist 13(1): 28. https://doi.org/10.1016/S0269-915X(99)80075-5

Abate D, 2008. Wild mushrooms in Ethiopia and our eating habit. National Mushroom Conference, Addis Ababa university, Faculty of Science, Addis Ababa, Ethiopia, May 14-15.

Abate D, 2014. Wild mushrooms and mushroom cultivation efforts in Ethiopia. WSMBMP Bulletin 11.

Águeda B, Parladé J, Fernández-Toirán LM, Cisneros Ó, María de Miguel A, Modrego MP, Martínez-Peña F, Pera J, 2008. Mycorrhizal synthesis between Boletus edulis species complex and rockroses (Cistus spp.). Mycorrhiza 18: 443–449. https://doi.org/10.1007/s00572-008-0192-3

Alemu F, 2013. Assessment of wild mushrooms and wood decaying fungi in Dilla University main campus, Ethiopia. IJAR 1(8): 458-467.

Alemu H, Debela N, Mamuye A, Jano M, 2012. Wild Edible Plants by Gumuz Tribes as nutritious and sustainable food stuffs in the Metekel and Kamashi Zones of Benishangul-Gumuz Regional State. An assessments report submitted to Tikuret Legumuz Hizb Limat Mahibr, Assosa Ethiopia.

Bekele M, 2011. Forest plantations and woodlots in Ethiopia. African Forest Forum Work Paper 1: 1-51.

Boa ER, 2004. Wild edible fungi: a global overview of their use and importance to people. Non-wood forest products -17, FAO. Rome.

Brundrett M, 2009. Mycorrhizal associations and other means of nutrition of vascular plants: understanding the global diversity of host plants by resolving conflicting information and developing reliable means of diagnosis. Plant Soil 320: 37–77. https://doi.org/10.1007/s11104-008-9877-9

Cai M, Pettenella D, Vidale E, 2011. Income generation from wild mushrooms in marginal rural areas. Forest Policy Econ 13(3): 221–226. https://doi.org/10.1016/j.forpol.2010.10.001

Chang ST, Miles PG, 2004. Mushrooms: cultivation, nutritional value, medicinal effect, and environmental impact (2nd ed.). CRC Press LLC. https://doi.org/10.1201/9780203492086

Chang YS, Lee SS, 2004. Utilization of macrofungi species in Malaysia. Fungal Divers 15: 15-22.

Crous PW, Rong IH, Wood A, Lee S, Glen H, Botha W, Slippers B, de Beer WZ, Wingfield MJ, Hawksworth DL, 2006. How many species of fungi are there at the tip of Africa? Stud Mycol55: 13–33. https://doi.org/10.3114/sim.55.1.13

Damian DT, 2012. Termitomyces species from Tanzania, their cultural properties and unequalled Basidiospores. JBLS 3(1): 140-159.

Decock C, Bitew A, Castillo G, 2005. Fomitiporia tenuis and Fomitiporia aethiopica (Basidiomycetes, Hymennomycetales), two undescribed species from Ethiopian Highlands: taxonomy and phylogeny. Mycologia 97(1):121-129. https://doi.org/10.3852/mycologia.97.1.121

Ferreira IC, Vaz JA, Vasconcelos MH, Martins A, 2010. Compounds from wild mushrooms with antitumor potential. Anticancer Agents Med Chem 10 (5): 424-436. https://doi.org/10.2174/1871520611009050424

Ferris R, Peace AJ, Newton AC, 2000. Macrofungal communities of lowland Scots pine (*Pinus sylvestris* L.) and Norway spruce (Piceaabies (L.) Karsten.) Plantations in England: relationships with site factors and stand structure. For Ecol Manage 131: 255–267.

Friis BI, Demissew S, Breugel P, 2010. Atlas of the potential vegetation of Ethiopia. The Royal Danish Academy of Sciences and Letters, Copenhagen. 306pp.

Frøslev TG, Aanen DK, Læssøe T, Rosendahl S, 2003. Phylogenetic relationships of Termitomyces and related taxa. Mycol Res 107 (11): 1277–1286. https://doi.org/10.1017/S0953756203008670

Gebrelibanos M, Megersa N, Tadesse AM, 2016. Levels of essential and non-essential metals in edible mushrooms cultivated in Haramaya, Ethiopia. Int J Food Cont 3(2). https://doi.org/10.1186/s40550-016-0025-7

Gizaw B, 2010. Cultivation and yield performance of Pholiotanameko on Different agro industrial wastes. Msc thesis. Addis Ababa University, Addis Ababa, Ethiopia.

Goldmann K, Schöning I, Buscot F, Wubet T, 2015. Forest management type influences diversity and community composition of soil fungi across temperate forest ecosystems. Front Microbiol 6: 1300. https://doi.org/10.3389/fmicb.2015.01300

Gryzenhout M, Roets F, de Villiers R, 2010. Fungal conservation in Africa. Mycologia Balcanica 7: 43–48.

Härkönen M, Niemela T, Mwasumbi L, 2003. Tanzanian Mushrooms. Edible, harmful and other fungi. Botanical Museum publisher. Helsinki, Finland. 200 pp.

Hjortstam K, Ryvarden L, 1996. New and interesting wood-inhabiting fungi (Basidiomycotina-Aphyllophorales) from Ethiopia. Mycotaxon 60:181-190.

Högberg P, Piearce GD, 1986. Mycorrhizas in Zambian trees in relation to host taxonomy, vegetation type and successional patterns. J Ecol 74(3): 775-785. https://doi.org/10.2307/2260397

IBC (Institute of Biodiversity Conservation), 2005. National biodiversity strategy and action plan. December, 2005. Addis Ababa, Ethiopia.

Lulekal E, Asfaw Z, Kelbessa E, Damme PV, 2011. Wild edible plants in Ethiopia: a review on their potential to combat food insecurity. Afrikafocus 24 (2): 71-121.

Mediavilla O, Olaizola J, Santos-del-Blanco L, Oria-de-Rueda JA, Martín-Pinto P, 2016. Mycorrhization between Cistus ladanifer L. and Boletus edulis Bull is enhanced by the mycorrhiza helper bacteria Pseudomonas fluorescens Migula. Mycorrhiza 26 (2): 161 – 168. https://doi.org/10.1007/s00572-015-0657-0

Megersa S, Gure A, Feleke S, Alemu M, 2017. Macrofungi species richness and diversity in Dagaga and Gambo plantation and natural forests of Arsi forest enterprise, Oromia, Ethiopia. IJIR 3(1): 1681 -1686. Miller RM, Lodge DJ, 1997. Fungal Response to Disturbance: Agriculture and Forestry, In: Söderström

B.E., (Ed.), The Mycota IV environmental and microbial relationships, Springer-Verlag, Berlin. 47-68 pp.

Muleta D, Woyessa D, Yanealem T, 2013. Mushroom consumption habits of Wacha Kebele resident, southwestern Ethiopia. Global Research Journal of Agricultural and Biological Sciences 4(1): 6-16.

Munyanziza E, 1994. Miombo trees and mycorrhizae: ecological strategies, a basis for afforestation. Doctoral thesis. Wageningen Agricultural University, The Netherlands.

Okhuoya JA, Akpaja EO, Osemwegie OO, Oghenekaro AO, Ihayere CA, 2010. Nigerian Mushrooms: underutilized Non-Wood Forest Resources. J Appl Sci Environ Manage 14(1): 43 – 54. https://doi.org/10.4314/jasem.v14i1.56488

Osarenkhoe O, John O, Theophilus D, 2014. Ethnomycological conspectus of West African mushrooms: An Awareness Document. Advances in Microbiology 4: 39-54. https://doi.org/10.4236/aim.2014.41008

Pegler DN, 1977. A preliminary Agaric flora of East Africa. Kew Bull Add Ser VI, London. 615 pp.

Pegler DN, Rayner RW, 1969. A contribution to the Agaric flora of Kenya. Kew Bulletin 23(3): 347- 412. https://doi.org/10.2307/4117177

Peredo H, Oliva M, Huber A, 1983. Environmental factors determining the distribution of Suillus luteus fructifications in Pinus radiata grazing-forest plantations. Plant and Soil 71: 367-370. https://doi.org/10.1007/BF02182677

Perry DA, Molina R, Amaranthus MP, 1987. Mycorrhizae, mycorrhizas, and reforestation: current knowledge and research needs. Can J For Res17: 929-940. https://doi.org/10.1139/x87-145

Sarma TC, Sarma I, Patiri BN, 2010. Wild edible mushrooms used by some ethnic tribes of Western Assam. The Bioscan 3:613 -625.

Sefidi K, Etemad V, 2015. Dead wood characteristics influencing macrofungi species abundance and diversity in Caspian natural beech (Fagus orientalis Lipsky) forests. Forest Syst 24(2):eSC03. https://doi.org/10.5424/fs/2015242-06039

Semwal KC, Lemma H, Dhyani A, Equar G, Amhare S, 2014. Mushroom: Nature›s Treasure in Ethiopia. MEJS 6(2): 138-147.

Sitotaw R, Li Y, Wei T-Z, Abate D, Yao Y-J, 2015a. Two new records of Agaricus species from Ethiopia. Mycotaxon 130(4): 1171-1183. https://doi.org/10.5248/130.1171

Sitotaw R, Mulat A, Abate D, 2015b. Morphological and molecular studies on Termitomyces species of Menge district, Assosa Zone, Northwest Ethiopia. Sci Technol Arts Res J 4: 49-57. https://doi.org/10.4314/star.v4i4.7

Teketay D, 2001. Deforestation, wood famine and environmental degradation in Ethiopia›s high land ecosystems. Urgent need for action. Northeast African studies 8: 53-76. https://doi.org/10.1353/nas.2005.0020

Tuno N, 2001. Mushroom utilization by the Majangir, an Ethiopian tribe. Mycologist 15(2): 78-79. https://doi.org/10.1016/S0269-915X(01)80087-2

Vásquez-Gassibe P, Oria-de-Rueda JA, Santos-del-Blanco L, Martín-Pinto P, 2016. The effects of fire severity on ectomycorrhizal colonization and morphometric features in Pinus pinaster Ait. seedlings. Forest Syst 25(1) e050. https://doi.org/10.5424/fs/2016251-07955

Yamada A, Inoue T, Wiwatwitaya D, Ohkuma M, Kudo T, Abe T, Sugimoto A, 2005. Carbon mineralization by termites in tropical forests, with emphasis on fungus-combs. Ecol Res 20:453-460. https://doi.org/10.1007/s11284-005-0062-9

Yehuala K, 2008. Potentials and constraints of mushroom production in Ethiopia. A Paper Presented at national mushroom conference, Addis Ababa University, Ethiopia. January 5.