



## An Assemblage of Boletoid Mushrooms Distribution and Diversity in Uttarakhand Himalaya, India

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**Abstract:** The present paper provides a distributional list of representative species of the Boletoid mushrooms in the Uttarakhand Himalaya. A literature survey revealed twenty-five taxa from the state, among these six, belong to the genus *Suillus*, four to *Leccinum*, three each to *Boletus* and *Tylopilus*, two each to *Phylloporus*, *Pulveroboletus*, *Strobilomyces*, and one each to *Austroboletus* and *Xerocomus*. Field photographs for some taxa are also provided herein for a better understanding of Boletoid mushrooms appearance and ecology.

**Keywords:** Boletoid • Diversity • Fleshy pored macrofungi • Himalaya

### Introduction

Uttarakhand Himalaya is home to many kinds of fleshy macrofungi and the group Boletes is one of them. Family Boletaceae Chevall. is consisting of fleshy pored macrofungi which have not received much attention in Uttarakhand Himalaya. Boletaceae is one among the other ectomycorrhizal forming families of wild mushrooms i.e., Amanitaceae, Russulaceae, Cortinariaceae, and Cantharallaceae in Uttarakhand Himalaya. Among these former two families have been studied extensively and reported several new species (Bhatt et al. 2003; Das and Sharma 2005; Das et al. 2005a, b; Joshi et al. 2012; Uniyal et al. 2016, 2017; Ghosh et al. 2016, 2017; Mehmood et al. 2018; Semwal et al. 2020; Kumar et al. 2021), whereas from the latter two families only a few new species were recorded from Uttarakhand (Yuan et al. 2020; Crous et al. 2020a, b; Song et al. 2019; Semwal et al. 2019; Semwal & Bhatt 2018). During the repeated fungal forays over the last couple of years many Boletoid mushroom

species have been collected from the Uttarakhand Himalayas and some of them published viz. *Austroboletus appendiculatus*, *Pulveroboletus auriflammeus*, *Strobilomyces mirandus* with molecular studies and phylogenetic analysis, and a few of them are still under investigation (Tibpromma et al. 2017; Das et al. 2016; Chakraborty et al. 2017a; Semwal unpublished data). In the field, the members of the family Boletaceae can be easily identified due to the pores underside the cap, instead of comb-like structures gills. Although, four genera viz. *Phylloporus* Quél., *Phylloboletellus* Singer, *Phylloporopsis* Angelini et al, and *Erythrophyllporus* Ming Zhang & T.H. Li are the members which form gills instead of pores in Boletaceae (Vadthanarat et al. 2019; Farid et al. 2018; Zhang & Li 2018). Further, the pileate-stipitate (umbrella-like) fruit body is another characteristic feature of the Boletaceae.



Boletes are known for their delicacy viz. *Boletus edulis* (the king Bolete, commonly known as ‘ceps or ‘Porcini’) and the appearance of Boletes seems to be as burger buns. Consuming wild Boletes is in practice in America and Europe but from India, there is a few reports available on the edibility of those by the local peoples from Sikkim (Chakraborty et al. 2017b) and Uttarakhand Himalaya (Shweta et al., 2020). However, a few species of Boletes are poisonous i.e., *Boletus calopus*, *Tylophilus felleus* (Verma & Pandro 2018). A few species are having a medicinal value in Chinese folk medicine, such as *Pulveroboletus ravenelii* (Liu 1984; Wu et al. 2013; Zeng et al. 2017).

With the advancement in molecular tools in studies of Boletes, the numbers of genera enormously increase worldwide in this family. It is interesting to note that till 2014 only 50 genera were known (Kirk et al. 2008; Wu et al. 2014) whereas, after 2014, 20 new genera were added to make it 70 genera and about 800 species (Farid et al. 2017; Orihara et al. 2010; Li et al. 2011; Nuhn et al. 2013; Gelardi et al. 2014). But of these only 9 genera have been reported so far from Uttarakhand (Lloyd 1925, Singer & Singh 1971; Harsh & Bisht 1982, 1985; Das et al. 2016; Kukreti & Bhatt 2016; Tibpromma et al. 2017; Chakraborty et al. 2018a; Kukreti et al. 2020). To know the diversity and distribution of Boletoid mushrooms extensive fungal foray is requisite. In the present communication, a comprehensive list of species and illustrated photographs of some taxa are provided herein (Fig. 1).

### Materials & Methods

A survey of available literature was done from different sources on the internet and research publications until 2021 on the occurrence, diversity, and distribution of fleshy pored fungi. However, the reports of the species were excluded in the present article, wherever the taxonomic description of the reported taxa

was not available. For the species’ current name status, the website Index Fungorum was followed

(<http://www.indexfungorum.org/names/NamesRecord.asp>, 2021).

### List of species, ecological and distributional records

*Austroboletus appendiculatus* Semwal, D. Chakr., K. Das, Indoliya, D. Chakrabarty, S. Adhikari & Karunarathna Fungal Diversity notes 491–602, 83, 1–261 (2017)

Distribution: Dehradun-Tapovan Forest (650 m asl), growing solitary, under *Shorea robusta* tree (Tibpromma et al. 2017).

*Boletus edulis* Bull. *Herb. Fr.* (Paris) 2: tab. 60 (1782) [1781-82]

Distribution: Pauri- Phedhkahl (2000 m asl); Rudraprayag- Manpur (2200 m asl), solitary to scattered, sometimes caespitose, grows in mixed forest, under *Cedrus deodara* and *Quercus leucotrichophora* trees (Semwal & Bhatt, 2019).

*Boletus craspedius* Masee, *Bull. Misc. Inf.*, Kew: 76 (1914)

Distribution: Kumaon- grows in soil, in Oak Forest (Harsh and Bisht, 1982).

*Boletus dissiliens* Corner *Boletus in Malaysia* (Singapore): 98 (1972)

Current name- *Boletellus dissiliens* (Corner) Pegler & T.W.K. Young *Trans. Br. mycol. Soc.* **76**(1): 113 (1981)

Distribution: Kumaon, (Harsh and Bisht, 1982).

*Leccinum areolatum* A.H. Sm. and Thiers, *Boletes of Michigan* (Ann Arbor): 154 (1971)

Distribution: Rudraprayag- Chopta (2550 m asl); Pauri- Bharsar (1950 m asl), solitary to scattered with *Betula* tree and scattered trees of *Rhododendron arboreum*, (Kukreti & Bhatt, 2016).

*Leccinum aurantiacum* (Bull.) Gray, *Nat. Arr. Brit. Pl.* (London) **1**: 646 (1821)

Distribution: Pauri- Mundneshwar (1930 m asl), under the trees of *Quercus leucotrichophora*, *Pinus roxburghii*, solitary to



scattered, grows in mixed forest, mostly under conifer trees, (Semwal & Bhatt, 2019).

***Leccinum oxydabile*** (Singer) Singer, *Am. Midl. Nat.* 37: 123 (1947)

Distribution: Pauri- Bharsar (1950 m asl); Rudraprag- Mandal, (2550 m asl); solitary to scattered; on ground in association with the tree of *Betula*. (Kukreti & Bhatt, 2016)

***Leccinum scabrum*** var. *scabrum* (Bull.) Gray, *Nat. Arr. Brit. Pl.* (London) 1: 647 (1821)

Distribution: Pauri- Bharsar (1950 m asl); Rudraprayag- Mandal (2550 m asl); solitary to scattered with *Betula* and a few scattered trees of *Rhododendron* (Kukreti & Bhatt, 2016).

***Phylloporus rhodoxanthus*** (Schw.) Bres., *Fung. trident.* 2(14): 95 (1900)

Distribution: Rudraprayag- Manpur (2200 m asl); Pauri- Chobattakhal (2000 m asl), grows in oak and coniferous forests, on slant wall with moss, under *Quercus leucotrichophora*, *Cedrus deodara*, and *Cupressus torulosa* trees, solitary to scattered. (Semwal & Bhatt, 2019).

***Phylloporus yunnanensis*** N.K. Zeng, Zhu L. Yang & L.P. Tang, Zeng, Tang, Li, Bau, Zhu, Zhao & Yang, *Fungal Diversity* 58: 95 (2012) [2013]

Distribution: Bageshwar- Dhakuri forest (2857 m asl), under Oak trees (Chakraborty et al. 2018b).

***Pulveroboletus auriflammeus*** (Berk. & M.A. Curtis) Singer. *Am. Midl. Nat.* 37: 10 (1947)

Current name- *Aureoboletus auriflammeus* (Berk. & M.A. Curtis) G. Wu & Zhu L. Yang, in Wu, Li, Zhu, Zhao, Han, Cui, Li, Xu & Yang, *Fungal Diversity* 81: 58 (2016)

Distribution: Champawat (1930 m asl), under the canopy of *Quercus leucotrichophora* and *Rhododendron arboreum* in subtropical to temperate broad-leaved forest; Pauri Garhwal- Dandapani Forest, (2000 m asl), under *Myrica esculenta* and *Q. leucotrichophora*; Mundneshwar forest (1820 m asl.), under *Quercus leucotrichophora* (Das et al. 2016).

***Pulveroboletus shoreae*** Singer & B. Singh, bis, *Mycopath. Mycol. appl.* 43(1): 28 (1971)

Distribution: Dehradun- Forest Research Institute (690 m asl), on the ground, in a plantation of *Shorea robusta* trees (Singer and Singh, 1971).

***Strobilomyces mirandus*** Corner, *Boletus in Malaysia* (Singapore): 61 (1972)

Distribution: Rudraprayag- Kund, (1160 m asl), grows under *Quercus glauca* and *Cinnamomum tamala*; solitary to scattered (Chakraborty et al. 2017a; Semwal & Bhatt, 2019).

***Strobilomyces floccopus*** (Vahl) P. Karst.

Current name- *Strobilomyces strobilaceus* (Scop.) Berk. *Hooker's J. Bot. Kew Gard. Misc.* 3: 78 (1851)

Distribution: Pauri- Dandapani Forest (2000 m asl), under *Q. leucotrichophora* and *Cedrus deodara* trees; Teka Forest, under *Q. leucotrichophora* and *Cupressus torulosa* trees (Semwal & Bhatt, 2019).

***Strobilomyces velutipes*** Cooke & Masee, Cooke, *Grevillea* 18 (85): 5 (1889)

Distribution: Dehradun- Mussoorie (Lloyd, 1925).

***Suillus brevipes*** (Pk.) Kuntze, *Revis. gen. pl.* (Leipzig) 3(3): 535 (1898)

Distribution: Pauri- Lansdown (2100 m asl); Teka (1920 m asl), grows in mixed conifer and broadleaved forest, under *Cedrus deodara*, in soil; solitary to scattered (Semwal & Bhatt, 2019).

***Suillus sibiricus*** (Singer) Singer *Farlowia* 2(2): 260 (1945)

Distribution: Chamoli- Joshimath (1890 m asl); Uttarkashi- Janki Chatti (2650 m asl); Uttarkashi- Harsil (2620 m asl); Tehri Garhwal- Chandrabadni (2277 m asl); Nainital- Mukteshwar (2290 m asl), under *Pinus wallichiana* and *Cedrus deodara* (Verma, 2014, Verma and Reddy, 2016).

***Suillus granulatus*** (L.) Roussel, *Fl. Calvados*: 34 (1796)

Distribution: Uttarkashi- Barkot (1524 m asl); Chamoli- Naagnath (1615 m asl), Gwaldam (1708 m asl); Tehri Garhwal- Dhanaulti (2286



m asl), under *Pinus wallichiana* (Verma, 2014, Verma and Reddy, 2016)

*Suillus pictus* (Peck) Kuntze, *Revis. gen. pl.* (Leipzig) 3(3): 536 (1898)

Current name- *Suillus spraguei* (Berk. & M.A. Curtis) Kuntze, *Revis. gen. pl.* (Leipzig) 3(3): 536 (1898)

Distribution: Pauri- Nagdev (2200 m asl), Kuinkaleshwar (2000 m asl), grows in coniferous forest, under *Cedrus deodara* and *Quercus leucotrichophora*, in soil, solitary to scattered (Semwal & Bhatt, 2019).

*Suillus placidus* (Bonord.) Singer, *Farlowia* 2(1): 42 (1945)

Distribution: Tehri Garhwal- Tehri (1750 m asl), under *Pinus roxburghii* (Verma and Reddy, 2016).

*Suillus triacicularis* B. Verma & M.S. Reddy *Phytotaxa* 162(3): 160 (2014)

Distribution: Dehradun- Mussoorie (1825 m asl); Nainital (2084 m asl), under *Pinus roxburghii* (Verma and Reddy, 2016).

*Tylopilus himalayanus* D. Chakr., K. Das & Vizzini, Chakraborty, Vizzini & Das, *MycKeys* 33: 109 (2018)

Distribution: Champawat- Abbot mount (1933 m asl), under *Cedrus deodara* in temperate coniferous forest (Chakraborty et al. 2018a).

*Tylopilus pseudoballoui* K. Das, D. Chakr & Vizzini, Chakraborty, Vizzini & Das, *MycKeys* 33: 112 (2018)

Distribution: Champawat- Abbot mount (1885 m asl); Pauri Garhwal- Pauri (1971 m asl) under oak trees (Chakraborty et al. 2018a).

*Tylopilus indecisus* (Peck) Murrill, *Mycologia* 1(1): 15 (1909)

Current name- *Porphyrellus indecisus* (Peck) E.-J. Gilbert, *Les Livres du Mycologue Tome I-IV*, Tom. III: Les Bolets: 99 (1931)

Distribution: Kumaon, (Harsh and Bisht, 1982).

*Xerocomus bakshii* Singer & B. Singh, *Mycopath. Mycol. appl.* 43(1): 31 (1971)

Distribution: Dehradun - Forest Research Institute (690 m asl), on soil, in close

association with the roots of *Pinus roxburghii* (Singer and Singh, 1971).

## Discussion

The numbers of genera augmented in the family Boletaceae Chevall. echoes evolutionary differentiation in Boletoid fleshy pored fungi of the world. Incessant systematic revision over the last few years it has been proved that the Boletaceae family and some genera of this fungal family are highly polyphyletic (Nuhn et al. 2013; Farid et al. 2017; Loizides et al. 2019). A few decades back there were 26 genera and later 35 genera have been recognized (Singer, 1986; Kirk et al. 2008) but with the implementation of DNA molecular tools to interpret phylogenetic relationships, the current knowledge of Boletoid fleshy pored fungi has been altered significantly. Currently, about 70 genera are known (Farid et al. 2017; Orihara et al. 2010; Li et al. 2011; Nuhn et al. 2013; Gelardi et al. 2014) in the family Boletaceae from the world. Mere morphological characteristics are not enough to delimit the taxa under a genus in Boletaceae family. Colour change on sectioning of the tissues, smooth or ornamented spores, reticulated stipe, or smooth stipe can be found in the same genus. Only molecular phylogenetic studies can segregate the potential similar-looking Boletoid mushrooms apart. According to Zhao et al. (2014) *Boletus rubripes* reported from India could be a *Caloboletus panniformis* on the basis of data provided by Das (2013). Many species now either rearranged taxonomically in their groups on the genus level or erected with new genus or new combinations or subfamily level accepted as a synonym to other as depicted in Wu et al. (2016) for *Neoboletus* which has been accepted as a synonym for genus *Sutorius* (Arora & Frank, 2014; Crous et al. 2018; Cui et al. 2016; Gelardi et al. 2014; Hosen et al. 2013; Li et al. 2011; 2014, Vizzini et al. 2014; Zeng et al. 2014).



From India a total of 84 Boletoid mushrooms have been reported (Verma & Pandro 2018). A list of Boletoid mushrooms that have been either missed in the earlier compilations or reported after 2018 is provided here. It appropriated the number of Boletoid mushrooms up to 107 in India which includes one new genus *Indoporus*.

*Parvixerocomus matheranensis*, *Phylloporus maculatus*, *P. yunnanensis*, *Indoporus shorae*, *Boletellus shoreae* have been reported recently (Patil et al. 2021; Chakraborty et al. 2018b; Parihar et al. 2018a, b) and *Austroboletus appendiculatus*, *Boletus recapitulatus* *Boletus indoedulis*, *Boletus lakhanpalii*, *Boletus*

*rubripes*, *Gyroporus paramjitii*, *Pulveroboletus auriflammeus*, *Rugiboletus brunneiporus* *Suillus adhikarii* *S. sibiricus* *S. granulatus* *S. flavidus* *S. placidus* *S. triacicularis*, *S. himalayensis*, *S. indicus*, *Strobilomyces longistipitatus*, *Tylopilus pseudoscaber* are also published from Indian soil (Tibpromma et al. 2017; Chakraborty et al. 2015, 2017b; Das 2013; Das et al. 2012, 2015a, b, 2016, 2017; Chakraborty & Das 2015; Verma & Reddy 2015, 2016) during the past decades.





**Figure A- 1.** *Austroboletus appendiculatus* grows in tropical forest, under *Shorea robusta* trees. 2- *Phylloporus rhodoxanthus*, grows in temperate forest, among moss, under *Cedrus deodara*, *Quercus leucotrichophora* trees. 3- *Pulveroboletus aureoflammeus*, grows in temperate forest under *Quercus leucotrichophora*, *Rhododendron arboreum*. 4- *Strobilomyces mirandus*, grows in temperate forest, under *Quercus glauca*, *Cinnamomum tamala*. 5- *Suillus pictus*, found in *Pinus roxburghii* stands. 6- *Leccinum scabrum* var. *scabrum*, grows under *Quercus leucotrichophora*, *Myrica esculenta* and *Rhododendron arboreum* trees.

The representation of Boletoid fleshy pore fungi is expected very high in Uttarakhand Himalaya as the diversity of 13 Boletoid taxa has already been reported (Semwal & Bhatt, 2019), and some more will be added soon (Semwal unpublished data). The gist of the study done by the researchers in Uttarakhand Himalaya the diversity of Boletoid fleshy pored fungi is high and potential for novel species. Implementation of DNA molecular tools is needed to identify novel species in Uttarakhand Himalaya, India.

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