

# Chapter 16

## A Checklist of Ectomycorrhizal Mushrooms Associated with *Quercus humboldtii* in Colombia



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### 16.1 Introduction

The native *Quercus humboldtii* is a dominant species in the Colombian Andean mountains, expanding from the Darien in Panama (8° N) to the southern montane cordilleras in Colombia (1° N) (Pulido et al. 2006; Cárdenas and Salinas 2006; Orwa et al. 2009), within a wide altitudinal range from 750 to 3450 m asl (Fundación Natura 2007; Avella and Cárdenas 2010). These ecosystems occupy small continuous and discontinuous relicts in the Colombian departments of Antioquia, Boyacá, Caldas, Cauca, Cundinamarca, Chocó, Huila, Nariño, Quindio, Santander, Valle del Cauca, and Tolima (Myers and Lynch 1997; Pulido et al. 2006; Fundación Natura 2007).

Oak forests establish symbiotic relationships with ectomycorrhizal mushrooms (ECM). This beneficial ecological interaction is established between plant roots and fungal mycelium, playing an essential role in the dynamics of forest ecosystems. The association allows the exchange of nutrients, especially phosphorus and nitrogen, from the fungi to the host plant and carbohydrates from the host to the fungi, and it constitutes an overall communication system among several trees by translocating nutrients (Read 1998; Pérez-Moreno and Read 2004).

Most studies related to macrofungi in Colombia have focused on oak forests (*Q. humboldtii*), because it is estimated that fungal diversity in these ecosystems is high (Franco-Molano et al. 2000). Nearly 99% of the local fungal diversity has been reported in the Andean Mountains, including saprotrophic, pathogenic, entomopathogenic, and ectomycorrhizal fungi (Vasco-Palacio and Franco-Molano 2013). Moreover, native oak forests are the habitat for many ectomycorrhizal species with a potential high value, because of their nutritive and medicinal characteristics and their importance to local people as an economic income (Boa 2004, Pérez-Moreno

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2012). This fact raises the attention on managing good practices of the ecosystem products.

In this chapter, we compile information on ECM species and their distribution in Colombia, based on national reports of specimens collected in *Q. humboldtii* forests. Regarding the use of mushrooms, we provide references in which the edibility of some ectomycorrhizal mushrooms was reported. We include 2 national and 16 local species records from the departments of Boyacá, Cundinamarca, and Santander. We suggest that more studies aiming to assess the regional fungal diversity are key components to move forward in the knowledge of the Colombian fungi and their conservation.

## 16.2 Methods

### 16.2.1 Sampling

Fruiting bodies of ECM associated with *Quercus humboldtii* were collected in the forests of Boyacá and Santander. The departments distributed along the Andean mountains present two highest precipitation seasons during the year (Guzmán et al. 2014): April–June and October–December, which favour the fructification of fungal species. We collected specimens during the rainy season of April–May 2014 and 2015 in the departments of Boyacá (Municipio de Villa de Leyva, Vereda Capilla 05°39' 26.78" N, 73°30' 46.41" O; Municipio de Arcabuco, Vereda Piedras Blancas, 05°48.546" N, 73°28.751" O; Municipio de Arcabuco, 5°45' 35.38" N, 73°26' 47.10" O) and Santander (Vereda San José de La Montaña 06°02' 29.82" N, 73°00' 02.8" O). We included records from Cundinamarca based on previously collected specimens stored in the ANDES Herbarium (Universidad de los Andes, Bogotá) and registered in the SPECIFY database version 6.6.02 software ([www.specifysoftware.org](http://www.specifysoftware.org)).

### 16.2.2 Descriptions

Macroscopic and microscopic features were analyzed for each collected sample. Fruit bodies were dried and packaged in plastic bags, stored in the ANDES Herbarium (Universidad de los Andes, Bogotá), and registered in the SPECIFY database. We used taxonomic keys and guides by Arora (1986), Halling (1989), Halling and Mueller (1999), Franco-Molano et al. (2000), Tulloss (2000, 2002, 2005), Mata et al. (2003), Halling and Mueller (2005), and Phillips (2005).

### 16.2.3 Search for ECM Reports in Colombia, the Mycorrhizal Trophic Status and the Edibility of Wild Mushrooms

We made an extensive literature search on fungal diversity lists for the country, with the earliest record by Hooker and Kunth in 1822 and until 2018. We included reports from published papers, field guides, and books. Articles showing the ectomycorrhizal trophic status of fungal genera included in our ECM checklist were searched in the ISI Web of Knowledge ([www.webofknowledge.com](http://www.webofknowledge.com)). The family and author of each species followed Index Fungorum (<http://www.indexfungorum.org/names/names.asp>). Finally, we provide references in which the edibility of some ectomycorrhizal species is reported (Smith 1964, Arnolds 1995, Polese and Lamaison 1999, Boa 2004, Phillips 2005, Pérez-Moreno et al. 2010, Burrola-Aguilar et al. 2012, Eyssartier et al. 2011, Smith and Bonito 2012).

## 16.3 Results and Discussion

A total of 120 ECM species were compiled from reports indicating their association to *Q. humboldtii* forests (Table 16.1). Figure 16.1 shows a map of Colombia with the number of ECM species per family and per department. About 11 out of 14 departments located in the Andean mountain system have records of ECM species, except Risaralda, Chocó, and Norte de Santander. Caldas, Quindío, and Tolima are among the departments with the lowest number of ECM reports. The department with the highest number of reports is Antioquia, followed by Boyacá and Cundinamarca. The fungal families with the major number of ECM species per department were Boletaceae (in five departments), Amanitaceae (in two departments), and Russulaceae (in two departments).

Information on the ectomycorrhizal trophic status of fungal genera was confirmed by literature regarding anatomical, chemical, and/or molecular analyses (Table 16.2).

A total of 18 species are new records: 2 national and 16 local records for the departments of Boyacá, Cundinamarca, and Santander (Table 16.3, Fig. 16.2)

### 16.3.1 Morphological Description of the Two National Records

*Inocybe tahquamenonensis* D.E. Stuntz 1954. Material studied NVE 303 ANDES\_F802 Fig. 2A, A1, A2—Colombia, Boyacá, Municipio de Arcabuco, Vereda Peñas Blancas, 20 May 2012, in *Q. humboldtii*. This species occurs in north temperate regions in eastern North America (Phillips 2005; Matheny and Moreau 2009). *Pileus*: 1.5–4 cm wide, convex to plano-convex to decurved when mature, dark purplish-brown to reddish or blackish-brown, with pronounced scales concolorous

**Table 16.1** Ectomycorrhizal species reported in *Q. humboldtii* in Colombia. Species reported as edible are indicated

Species	Department	References in which the species is reported in Colombia; the references reporting the species associated with <i>Q. humboldtii</i> are in bold. Species reported as edible, without confirmed consumption, are indicated with the word “Edible” (Franco-Molano et al. 2000), followed by the references in brackets [].
Basidiomycota		
<i>Agaricales</i>		
Amanitaceae		
<i>Amanita</i>		
<i>A. advena</i> (Tulloss et al. 1992)	ANT	<b>Tulloss et al. (1992)</b> , Franco-Molano and Uribe-Calle (2000), Vasco-Palacio and Franco-Molano (2013)
<i>A. archoeae</i> (Tulloss et al. 1992)	ANT	<b>Tulloss et al. (1992)</b> , Franco-Molano and Uribe-Calle (2000), <b>Halling and Mueller (2005)</b> , Vasco-Palacio and Franco-Molano (2013)
<i>A. aureomonile</i> (Tulloss and Franco-Mol. 1992)	VAL	<b>Tulloss et al. (1992)</b> , Franco-Molano and Uribe-Calle (2000), Vasco-Palacio and Franco-Molano (2013)
<i>A. brunneolocularis</i> (Tulloss et al. 1992)	ANT, BOY, VAL	Saldarriaga et al. (1988), <b>Tulloss et al. (1992)</b> , <b>Franco-Molano and Uribe-Calle (2000)</b> , Franco-Molano et al. (2000), Halling and Mueller (2005), Vasco-Palacio and Franco-Molano (2013), Soto-Medina and Bolaños-Rojas (2013).
<i>A. citrina</i> (Pers. 1797)	BOY	<b>Vargas et al. (2017)</b> .
<i>A. colombiana</i> (Tulloss et al. 1992)	ANT, BOY, SAN	<b>Tulloss et al. (1992)</b> , <b>Franco-Molano et al. (2000)</b> , Franco-Molano and Uribe-Calle (2000), Vasco-Palacio and Franco-Molano (2013), <b>Vargas et al. (2017)</b> , <b>Vargas and Restrepo (2019)</b> .
<i>A. flavoconia</i> (G.F. Atk. 1902)	ANT, CUN, BOY, SAN	Saldarriaga et al. (1988), <b>Tulloss et al. (1992)</b> , Franco-Molano and Uribe-Calle (2000), <b>Franco-Molano et al. (2000)</b> , <b>Halling and Mueller (2005)</b> , Cepero de García et al. (2012), Vasco-Palacio and Franco-Molano (2013), <b>Vargas et al. (2017)</b> .
<i>A. fulgineodisca</i> (Tulloss et al. 1992)	ANT, BOY, CUN, NAR, SAN	Saldarriaga et al. (1988), <b>Tulloss et al. (1992)</b> , Franco-Molano and Uribe-Calle (2000), <b>Franco-Molano et al. (2000)</b> , <b>Halling and Mueller (2005)</b> , Vasco-Palacio and Franco-Molano (2013), <b>Vargas et al. (2017)</b> , <b>this study</b> .
<i>A. gemmata</i> (Fr.) Bertill. 1866	CUN	Nasi (1977), <b>Guzmán and Varela (1978)</b> , Tulloss et al. (1992), Franco-Molano and Uribe-Calle (2000), Vasco-Palacio and Franco-Molano (2013). Edible [Boa 2004, Hall et al. 2011, Burrola-Aguilar et al. 2012]
<i>A. humboldtii</i> (Singer 1963)	CUN, NAR	<b>Singer (1963)</b> , Denis (1970), <b>Guzmán and Varela (1978)</b> , Pulido (1983), Tulloss et al. (1992), Wu et al. (1997), Vasco-Palacio and Franco-Molano (2013)
<i>A. inaurata</i> Secr. 1833	BOY	<b>Singer (1963)</b> , Denis (1970), Pulido (1983), Tulloss et al. (1992), Vasco-Palacio and Franco-Molano (2013)

(continued)

**Table 16.1** (continued)

Species	Department	References in which the species is reported in Colombia; the references reporting the species associated with <i>Q. humboldtii</i> are in bold. Species reported as edible, without confirmed consumption, are indicated with the word “Edible” (Franco-Molano et al. 2000), followed by the references in brackets [].
<i>A. muscaria</i> (L.) Lam. 1783	SAN	<b>Vargas et al. (2019)</b>
<i>A. picea</i> (Tulloss et al. 1992)	BOY	<b>Tulloss et al. (1992)</b> , Franco-Molano and Uribe-Calle (2000), Vasco-Palacio and Franco-Molano (2013)
<i>A. sepultipes</i> (Vargas and Restrepo 2019)	BOY, SAN	<b>Vargas and Restrepo (2019)</b>
<i>A. sororcula</i> (Tulloss et al. 1992)	ANT, BOY, SAN	<b>Tulloss et al. (1992)</b> , <b>Franco-Molano et al. (2000)</b> , Franco-Molano and Uribe-Calle (2000), Vasco-Palacio and Franco-Molano (2013), <b>Vargas et al. (2017)</b> , <b>Vargas and Restrepo (2019)</b>
<i>A. virosa</i>	BOY	<b>Vargas et al. (2017)</b> .
<i>A. xylinivolva</i> (Tulloss et al. 1992)	ANT, CAU, CUN, NAR, BOY, SAN	Saldarriaga et al. (1988), <b>Tulloss et al. (1992)</b> , Franco-Molano and Uribe-Calle (2000), <b>Franco-Molano et al. (2000)</b> , Vasco-Palacio and Franco-Molano (2013), <b>Vargas et al. (2017)</b> .
Cortinariaceae		
<i>Cortinarius</i>		
<i>C. aurantiobrunneus</i> (Ammirati et al. 2007)	SAN	<b>Vargas and Restrepo (2019)</b>
<i>C. boyacensis</i> Singer	BOY	<b>Singer (1963)</b> , Denis (1970), Wu et al. (1997), Franco-Molano and Uribe-Calle (2000), Vasco-Palacio and Franco-Molano (2013)
<i>C. harrisonii</i> (Ammirati et al.)	SAN	<b>Vargas and Restrepo (2019)</b>
<i>C. iodes</i> (Berk. and M.A. Curtis 1853)	ANT, CUN, NAR, BOY, SAN	<b>Franco-Molano et al. (2000, 2010)</b> , López-Quintero et al. (2007), Cepero de García et al. (2012), Vasco-Palacio and Franco-Molano (2013), <b>this study</b> .
<i>C. violaceus</i> (L.) (Gray 1821)	ANT, BOY	<b>Franco-Molano et al. (2000, 2010)</b> , Vasco-Palacio and Franco-Molano (2013). Edible [Smith 1964, Pérez-Moreno et al. 2010, Eyssartier et al. 2011, Burrola-Aguilar et al. 2012]. Not edible according to Phillips (2005)
<i>Rozites colombiana</i> (Halling and Ovrebø 1987)	ANT	Halling and Ovrebø (1987), Saldarriaga et al. (1988), Franco-Molano and Uribe-Calle (2000), <b>Franco-Molano et al. (2000)</b> , <b>Halling and Mueller (2005)</b> , Vasco-Palacio and Franco-Molano (2013)

(continued)

**Table 16.1** (continued)

Species	Department	References in which the species is reported in Colombia; the references reporting the species associated with <i>Q. humboldtii</i> are in bold. Species reported as edible, without confirmed consumption, are indicated with the word “Edible” (Franco-Molano et al. 2000), followed by the references in brackets [].
<b>Hydnangiaceae</b>		
<i>Laccaria</i>		
<i>L. amethystina</i> Cooke	ANT, CUN	<b>Guzmán and Varela (1978)</b> , Mueller (1996), <b>Franco-Molano et al. (2000)</b> , Halling and Mueller (2005), Vasco-Palacio and Franco-Molano (2013). Edible [Boa 2004, Garibay-Orijel et al. 2007, Pérez-Moreno et al. 2010, Eyssartier et al. 2011, Burrola-Aguilar et al. 2012]
<i>L. gomezii</i> (Singer and Mueller 1988)	ANT, HUI	<b>Mueller and Singer (1988)</b> , Mueller (1996), Franco-Molano and Uribe-Calle (2000), Franco-Molano et al. (2000), Halling and Mueller (2005), Vasco-Palacio and Franco-Molano (2013)
<i>L. laccata</i> (Scop.) (Cooke 1884)	ANT, BOY, CAL, CUN, QUI	<b>Pulido (1983)</b> , Saldarriaga et al. (1988), Mueller (1996), Nieves-Rivera et al. (1997), Franco-Molano and Uribe-Calle (2000), <b>Franco-Molano et al. (2000)</b> , <b>Halling and Mueller (2005)</b> , Montoya et al. (2005), Betancur et al. (2007), López-Quintero et al. (2007), Vasco-Palacio and Franco-Molano (2013). Edible [Smith 1964, Polese and Lamaison 1999, Boa 2004, Phillips 2005, Pérez-Moreno et al. 2010, Eyssartier et al. 2011, Hall et al. 2011, Burrola-Aguilar et al. 2012]
<i>L. ohlensis</i> (Mont.) (Singer 1947)	VAL	<b>Mueller (1996)</b> , Soto-Medina and Bolaños-Rojas (2013), Vasco-Palacio and Franco-Molano (2013)
<i>L. proxima</i> (Boud.) Pat. 1887		<b>Mueller (1996)</b> , Vasco-Palacio and Franco-Molano (2013). Edible [Phillips 2005, Pérez-Moreno et al. 2010, Burrola-Aguilar et al. 2012].
<b>Hygrophoraceae</b>		
<i>Hygrophorus</i>		
<i>H. hondurensis</i> (Murrill) (Murrill 1912)	PNN	<b>Boekout and Pulido (1989)</b> , Franco-Molano et al. (2010), Vasco-Palacio and Franco-Molano (2013)
<i>H. obconicus</i> (Peck 1909)	PNN	<b>Boekout and Pulido (1989)</b> , Franco-Molano et al. (2010), Vasco-Palacio and Franco-Molano (2013)
<i>H. quercuum</i> (Singer 1973)	BOY	<b>Singer (1973)</b> , Wu et al. (1997), Franco-Molano and Uribe-Calle (2000)
<b>Inocybaceae</b>		
<i>Inocybe</i>		
<i>I. calamistrata</i> (Fr.) (Gillet 1876)	ANT	Franco-Molano et al. (2010)
<i>I. fastigiata</i> (Schaeff.) (Quéf. 1872)	CUN	<b>Guzmán and Varela (1978)</b>

(continued)

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<i>I. hystrix</i> (Fr.) (P. Karst. 1879)	ANT	<b>López-Quintero et al. (2007)</b> , Vasco-Palacio and Franco-Molano (2013)
<i>I. jalopensis</i> (Murrill) (Singer 1958)	CUN	<b>Singer (1963)</b> , Denis (1970), <b>Guzmán and Varela (1978)</b> , Franco-Molano and Uribe-Calle (2000), Vasco-Palacio and Franco-Molano (2013)
<i>I. rimosa</i> (Bull.) P. (Kumm. 1871)	CUN	Guzmán and Varela (1978), Franco-Molano and Uribe-Calle (2000), Vasco-Palacio and Franco-Molano (2013)
<i>I. tequendamae</i> (Singer 1963)	CUN	<b>Singer (1963)</b> , Denis (1970), Guzmán and Varela (1978), Wu et al. (1997), Franco-Molano and Uribe-Calle (2000), Vasco-Palacio and Franco-Molano (2013)
<i>I. tahquamenonensis</i> (Stuntz 1954)	<b>BOY</b>	<b>This study</b>
Tricholomataceae		
<i>Tricholoma</i>		
<i>T. cystidiosum</i> (A.H. Sm. 1941)	ANT	<b>Saldarriaga et al. (1988)</b> , Franco-Molano and Uribe-Calle (2000), Vasco-Palacio and Franco-Molano (2013)
<i>T. caligatum</i> (Viv.) Ricken 1914	<b>BOY</b>	Cepero de García et al. (2012), <b>this study</b> . Edible [Boa 2004, Phillips 2005]
<i>Tricholomopsis humboldtii</i> Singer, Ovrebo and Halling 1990	ANT	Singer et al. (1990), Franco-Molina et al. (2000)
<i>Boletales</i>		
Boletaceae		
<i>Aureoboletus auriporus</i> (Peck) (Pouzar 1957)	ANT	<b>Franco-Molano et al. (2000)</b> , Franco-Molano and Uribe-Calle (2000), Vasco-Palacio and Franco-Molano (2013)
<i>Austroboletus subvirens</i> (Hongo) (Wolfe 1980)	ANT, HUI	<b>Halling (1989)</b> , <b>Franco-Molano et al. (2000)</b> , Franco-Molano and Uribe-Calle (2000), Vasco-Palacio and Franco-Molano (2013)
<i>Boletellus</i>		
<i>B. ananas</i> (M.A. Curtis) (Murrill 1909)	ANT, VAL	Halling (1989, 1996), <b>Franco-Molano et al. (2000)</b> , Franco-Molano and Uribe-Calle (2000), Vasco-Palacio and Franco-Molano (2013). Edible [Burrola-Aguilar et al. 2012]
<i>B. russellii</i> (Frost) Gilbert	CAU	<b>Halling (1989)</b> , Franco-Molano and Uribe-Calle (2000), Vasco-Palacio and Franco-Molano (2013). Edible [Smith 1964, Boa 2004, Burrola-Aguilar et al. 2012, Kuo and Methven 2014]

(continued)

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<i>Boletus</i>		
<i>B. atkinsonianus</i> (Murrill) Sacc. and (Trotter 1912)	ANT	<b>Halling (1989)</b> , 1996), Vasco-Palacio and Franco-Molano (2013)
<i>B. fuligineotomentosus</i> (Singer 1973)	VAL	<b>Singer (1973)</b> , Halling (1989), Wu et al. (1997), Franco-Molano and Uribe-Calle (2000), Vasco-Palacio and Franco-Molano (2013)
<i>B. neoregius</i> (Halling and Muell. 1999)	ANT, CUN, <b>BOY</b>	<b>Franco-Molano et al. (2000, 2010); Halling and Mueller (2005)</b> ; Vasco-Palacio and Franco-Molano (2013), <b>This study.</b>
<i>B. orquidianus</i> (Halling 1989)	ANT	Halling (1989), <b>Franco-Molano et al. (2000)</b> , Franco-Molano and Uribe-Calle (2000), Vasco-Palacio and Franco-Molano (2013)
<i>B. pseudorubinellus</i> (A.H. Sm. and Thiers 1971)	ANT, CAU	<b>Halling (1989), Franco-Molano et al. (2000)</b> , Franco-Molano and Uribe-Calle (2000), Vasco-Palacio and Franco-Molano (2013)
<i>B. pulverulentus</i> (Opat. 1836)	CUN	<b>Halling (1989), Franco-Molano et al. (2000)</b> , Franco-Molano and Uribe-Calle (2000), Vasco-Palacio and Franco-Molano (2013). Edible [Phillips 2005, Hall et al. 2011]
<i>B. pyrrosocoles</i> (Halling 1992)	ANT, NAR	Halling (1989), <b>Franco-Molano et al. (2000)</b> , Franco-Molano and Uribe-Calle (2000), Vasco-Palacio and Franco-Molano (2013)
<i>B. reticulatus</i> (Schaeff. 1763)	CAU	Hooker and Kunth (1822), NA. Edible [Boa 2004, Kuo and Methven 2014]
<i>B. subtomentosus</i> L. 1753	ANT, BOY	<b>Halling (1989)</b> , Franco-Molano and Uribe-Calle (2000), Vasco-Palacio and Franco-Molano (2013). Edible [Arnolds 1995, Phillips 2005]
<i>B. truncatus</i> (Singer, Snell and E.A. Dick) (Pouzar 1966)	ANT, BOY	<b>Halling (1989)</b> , Franco-Molano and Uribe-Calle (2000), Cepero de García et al. (2012), Vasco-Palacio and Franco-Molano (2013). Edible [Boa 2004, Hall et al. 2011]
<i>Xerocomellus chrysenteron</i> (Bull.) (Sutara 2008)	ANT, NAR, <b>BOY</b>	Saldarriaga et al. (1988), Franco-Molano et al. (2010), Vasco-Palacio and Franco-Molano (2013), <b>this study.</b> Edible [Arnolds 1995, Boa 2004, Phillips 2005, Hall et al. 2011, Burrola-Aguilar et al. 2012]. Sinonimo: <i>Boletus chrysenteron</i> Bull 1791
<i>Leccinum</i>		
<i>L. andinum</i> Halling	ANT	<b>Halling (1989), Franco-Molano et al. (2000)</b> , Franco-Molano and Uribe-Calle (2000), Halling and Mueller (2005), Cepero de García et al. (2012), Vasco-Palacio and Franco-Molano (2013).

(continued)



**Table 16.1** (continued)

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<i>L. rugosiceps</i> (Peck) Singer	ANT, CAU, TOL	Halling (1996), <b>Franco-Molano et al. (2000, 2010)</b> , Halling and Mueller (2005), Vasco-Palacio and Franco-Molano (2013). Edible [Boa 2004, Phillips 2005, Hall et al. 2011]
<i>L. talamancae</i> Halling, L.D. Gómez and Lannoy	ANT	<b>Franco-Molano et al. (2000, 2010)</b> , Halling and Mueller (2005), López-Quintero et al. (2007), Vasco-Palacio and Franco-Molano (2013)
<i>Phylloporus</i>		
<i>P. phaeoxanthus</i> Singer and L.D Gómez	ANT	<b>Franco-Molano et al. (2000, 2010)</b> , Halling and Mueller (2005), Vasco-Palacio and Franco-Molano (2013)
<i>P. fibulatus</i> Singer, Ovrebø and Halling	ANT, NAR	<b>Singer et al. (1990)</b> , Halling et al. (1999), Wu et al. (1997), <b>Franco-Molano et al. (2000)</b> , Franco-Molano and Uribe-Calle (2000), Vasco-Palacio and Franco-Molano (2013)
<i>P. centroamericanus</i> (Singer and Gómez 1984)	ANT, <b>BOY</b>	<b>Franco-Molano et al. (2000, 2010)</b> , Halling and Mueller (2005), Vasco-Palacio and Franco-Molano (2013)
<i>P. purpurellus</i> Singer	CAU	<b>Singer (1973)</b> , Wu et al. (1997), Halling et al. (1999), Franco-Molano and Uribe-Calle (2000), Vasco-Palacio and Franco-Molano (2013)
<i>Pulveroboletus ravenelii</i> (Berk. and M.A. Curtis) (Murrill 1909)	ANT, VAL	Boekout and Pulido (1989), <b>Franco-Molano et al. (2000, 2010)</b> , Soto-Medina and Bolaños-Rojas (2013)
<i>Strobilomyces confusus</i> (Singer 1945)	HUI	<b>Halling (1989)</b> , Franco-Molano and Uribe-Calle (2000), Halling and Mueller (2005), Cepero de García et al. (2012), Vasco-Palacio and Franco-Molano (2013). Edible [Boa 2004, Phillips 2005, Hall et al. 2011, Burrola-Aguilar et al. 2012].
<i>Tylopilus</i>		
<i>T. bulbosus</i> (Halling and Muell. 2001)	ANT	<b>Sierra et al. (2011)</b>
<i>T. indecisus</i> (Peck) (Murrill 1909)	BOY	<b>Peña-Cañón and Henao-Mejía (2014)</b> . Edible [Peña-Cañón and Henao-Mejía 2014]
<i>T. obscurus</i> (Halling 1989)	ANT, <b>HUI</b> , SAN	<b>Halling (1989)</b> , <b>Franco-Molano et al. (2000, 2010)</b> , <b>Halling and Mueller (2005)</b> , Vasco-Palacio and Franco-Molano (2013), <b>Vargas and Restrepo (2019)</b> , <b>this study</b> .
<i>T. umbrosus</i> (G.F. Atk) A.H. Sm. and Thiers	NAR	Franco-Molano et al. (2010), NA

(continued)

**Table 16.1** (continued)

Species	Department	References in which the species is reported in Colombia; the references reporting the species associated with <i>Q. humboldtii</i> are in bold. Species reported as edible, without confirmed consumption, are indicated with the word “Edible” (Franco-Molano et al. 2000), followed by the references in brackets [].
<i>Calostoma cinnabarinum</i> Desv. 1809	ANT, HUI, CAL, <b>BOY</b>	Saldarriaga et al. (1988), Dumont and Umaña (1978), <b>López-Quintero et al. (2007)</b> , Betancur et al. (2007), Cepero de García et al. (2012), Vasco-Palacio and Franco-Molano (2013), <b>this study</b> .
<i>Xanthoconium separans</i> (Peck) halling and Both.	ANT, NAR	<b>Franco-Molano et al. (2000, 2010)</b> . Edible [Boa 2004]
Gyroporaceae		
<i>Gyroporus castaneus</i> (Bull.) Quéf. 1886	CAU	<b>Halling and Mueller (2005)</b> , Franco-Molano et al. (2010). Edible [Smith 1964, Polese and Lamaison 1999, Boa 2004, Phillips 2005, Hall et al. 2011]
Sclerodermataceae		
<i>Scleroderma</i>		
<i>S. albidum</i> Pat. and Trab.	CUN	<b>Guzmán and Varela (1978)</b>
Cantharellales		
Cantharellaceae		
<i>Cantharellus</i>		
<i>C. cibarius</i> Fr. 1821	ANT, CUN	<b>Guzmán and Varela (1978)</b> , Franco-Molano and Uribe-Calle (2000), <b>López-Quintero et al. (2007)</b> , Vasco-Palacio and Franco-Molano (2013). Edible [Smith 1964, Arnolds 1995, Polese and Lamaison 1999, Boa 2004, Phillips 2005, Garibay-Orijel et al. 2007, Pérez-Moreno et al. 2010, Eyssartier et al. 2011, Hall et al. 2011, Burrola-Aguilar et al. 2012, Kuo and Methven 2014]
<i>C. cinnabarinus</i> (Schwein.) Schwein. 1832	CUN	<b>Guzmán and Varela (1978)</b> , Franco-Molano and Uribe-Calle (2000), Vasco-Palacio and Franco-Molano (2013). Edible [Smith 1964, Boa 2004, Phillips 2005, Garibay-Orijel et al. 2007,
<i>C. lateritius</i> (Berk.) (Singer 1951)	CUN, NAR	<b>Petersen and Mueller (1992)</b> , Franco-Molano and Uribe-Calle (2000), Cepero de García et al. (2012), Vasco-Palacio and Franco-Molano (2013), Henkel et al. (2014), <b>this study</b> . Edible [Phillips 2005]
<i>Craterellus</i>		
<i>C. boyacensis</i> Singer 1963	ANT, BOY, HUI, SAN	<b>Singer (1963)</b> , Denis (1970), Wu et al. (1997), Franco-Molano and Uribe-Calle (2000), Halling and Mueller (2005), Vasco-Palacio and Franco-Molano (2013), Henkel et al. (2014), <b>Vargas and Restrepo (2019)</b> .
<i>C. fallax</i> A.H. Sm. 1968	CUN, <b>BOY</b>	Wu and Mueller (1995), Franco-Molano and Uribe-Calle (2000), Vasco-Palacio and Franco-Molano (2013), Henkel et al. (2014), <b>this study</b> . Edible [Boa 2004, Phillips 2005, Hall et al. 2011]

(continued)

**Table 16.1** (continued)

Species	Department	References in which the species is reported in Colombia; the references reporting the species associated with <i>Q. humboldtii</i> are in bold. Species reported as edible, without confirmed consumption, are indicated with the word “Edible” (Franco-Molano et al. 2000), followed by the references in brackets [].
<i>Pseudocraterellus sinuosus</i> (Fr.) (Corner 1958)	ANT	<b>Wu and Mueller (1995)</b> , Franco-Molano and Uribe-Calle (2000), Vasco-Palacio and Franco-Molano (2013), Henkel et al. (2014).
Hydnaceae		
<i>Hydnum repandum</i> L. 1753	ANT	Henao (1989), <b>López-Quintero et al. (2007)</b> , Cepero de García et al. (2012), Vasco-Palacio and Franco-Molano (2013). Edible [Arnolds 1995, Polese and Lamaison 1999, Boa 2004, Phillips 2005, Garibay-Orijel et al. 2007, Pérez-Moreno et al. 2010, Eyssartier et al. 2011, Burrola-Aguilar et al. 2012]
Gomphales		
Gomphaceae		
<i>Ramaria</i>		
<i>R. botrytis</i> (Pers.) (Ricken 1918)	BOY	<b>Peña-Cañón and Henao-Mejía (2014)</b> . Edible [Polese and Lamaison 1999, Boa 2004, Pérez-Moreno et al. 2010, Eyssartier et al. 2011, Hall et al. 2011, Burrola-Aguilar et al. 2012, Peña-Cañón and Henao-Mejía 2014]
<i>R. cyaneigranosa</i> (Marr and Stuntz 1974)	BOY	<b>Peña-Cañón and Henao-Mejía (2014)</b> . Edible [Peña-Cañón and Henao-Mejía 2014]
<i>R. flava</i> (Schaeff.) Quél. 1888	BOY	<b>Peña-Cañón and Henao-Mejía (2014)</b> . Edible [Boa 2004, Garibay-Orijel et al. 2007, Pérez-Moreno et al. 2010, Burrola-Aguilar et al. 2012, Peña-Cañón and Henao-Mejía 2014]
<i>R. formosa</i> (Pers.) Quél. 1888	CAL	<b>Betancur et al. (2007)</b> , Vasco-Palacio and Franco-Molano (2013). Edible [Boa 2004, Hall et al. 2011, Burrola-Aguilar et al. 2012, Peña-Cañón and Henao-Mejía 2014]. Eyssartier et al. (2011) report the species as toxic.
<i>R. secunda</i> (Berk.) Corner	BOY	<b>Ruíz and Henao-Mejía (2006)</b> . Edible [Hall et al. 2011, Peña-Cañón and Henao-Mejía 2014]
Hymenochaetales		
Hymenochaetaeaceae		
<i>Coltricia</i>		
<i>C. cinnamomea</i> (Jacq.) (Murrill 1904)	ANT	<b>Henao (1989)</b> , Vasco-Palacio and Franco-Molano (2013)
<i>C. folicola</i> (Berk. and M.A. Curtis) (Murrill 1908)	CUN	<b>Guzmán and Varela (1978)</b> , Vasco-Palacio and Franco-Molano (2013)
<i>C. perennis</i> (L.) Murrill 1903	ANT	<b>Henao (1989)</b> , Vasco-Palacio and Franco-Molano (2013)
Russulales		

(continued)

**Table 16.1** (continued)

Species	Department	References in which the species is reported in Colombia; the references reporting the species associated with <i>Q. humboldtii</i> are in bold. Species reported as edible, without confirmed consumption, are indicated with the word “Edible” (Franco-Molano et al. 2000), followed by the references in brackets [].
Russulaceae		
<i>Lactarius</i>		
<i>L. atroviridis</i> Peck	ANT, BOY	<b>Franco-Molano et al. (2000, 2010)</b> , Halling and Mueller (2005), Vasco-Palacio and Franco-Molano (2013)
<i>L. caucae</i> Singer	CAU	<b>Singer (1973)</b> , Wu et al. (1997), Franco-Molano and Uribe-Calle (2000), Vasco-Palacio and Franco-Molano (2013)
<i>L. costaricensis</i> Singer	NAR	Franco-Molano et al. (2010), <b>Halling and Mueller (2005)</b> , Vasco-Palacio and Franco-Molano (2013)
<i>L. chrysorrheus</i> Fr. 1838	ANT, CUN, <b>BOY</b> , SAN	<b>Guzmán and Varela (1978)</b> , <b>Franco-Molano et al. (2000)</b> , Franco-Molano and Uribe-Calle (2000), Vasco-Palacio and Franco-Molano (2013), <b>Vargas and Restrepo (2019)</b> , <b>this study</b> .
<i>L. fragilis</i> (Burl.) Hersler and A.H Sm.	ANT, SAN	<b>Franco-Molano et al. (2000, 2010)</b> , Vasco-Palacio and Franco-Molano (2013), <b>Vargas and Restrepo (2019)</b> .
<i>L. gerardii</i> Peck	ANT	<b>Franco-Molano et al. (2000)</b> , Vasco-Palacio and Franco-Molano (2013). Edible [Wang et al. 2004, Phillips 2005, Stubbe et al. 2010, Hall et al. 2011]
<i>L. lignyotus</i> (Fr.) (Kuntze 1891)	SAN	<b>Vargas and Restrepo (2019)</b>
<i>L. quercuum</i> Singer	BOY	<b>Singer (1963)</b> , Denis (1970), Wu et al. (1997), Vasco-Palacio and Franco-Molano (2013).
<i>L. rimosellus</i> (Peck 1906)	ANT, SAN	<b>Franco-Molano et al. (2000, 2010)</b> , <b>Vargas and Restrepo (2019)</b> .
<i>Lactifluus</i>		
<i>Lf. deceptivus</i> Peck	ANT, BOY, <b>SAN</b>	Franco-Molano et al. (2000, 2010), <b>Halling and Mueller (2005)</b> , Vasco-Palacio and Franco-Molano (2013), <b>this study</b> .
<i>Lf. indigo</i> (Schwein)	ANT, BOY, CUN, NAR	<b>Franco-Molano et al. (2000, 2010)</b> ; Halling and Mueller (2005); Cepero de García et al. (2012), Vasco-Palacio and Franco-Molano (2013). Edible [Smith 1964, Boa 2004, Phillips 2005, Pérez-Moreno et al. 2010, Hall et al. 2011, Burrola-Aguilar et al. 2012]
<i>Russula</i>		
<i>R. boyacensis</i> Singer	BOY	<b>Singer (1963)</b> , Denis (1970), Wu et al. (1997), Franco-Molano and Uribe-Calle (2000), Vasco-Palacio and Franco-Molano (2013)
<i>R. brevipes</i> Peck	CAL, CUN	<b>Guzmán and Varela (1978)</b> , Montoya et al. (2005), Vasco-Palacio and Franco-Molano (2013). Edible [Boa 2004]

(continued)

**Table 16.1** (continued)

Species	Department	References in which the species is reported in Colombia; the references reporting the species associated with <i>Q. humboldtii</i> are in bold. Species reported as edible, without confirmed consumption, are indicated with the word “Edible” (Franco-Molano et al. 2000), followed by the references in brackets [].
<i>R. caucaensis</i> (Singer 1989)	CAU	<b>Singer (1989)</b> , Franco-Molano and Uribe-Calle (2000), Wu et al. (1997), Vasco-Palacio and Franco-Molano (2013).
<i>R. columbiana</i> Singer	CUN	<b>Singer (1963)</b> , Wu et al. (1997), Franco-Molano and Uribe-Calle (2000), Vasco-Palacio and Franco-Molano (2013)
<i>R. compacta</i> Frost	ANT	Franco-Molano et al. (2010), <b>Halling and Mueller (2005)</b> , Vasco-Palacio and Franco-Molano (2013)
<i>R. cremoricolor</i> (Earle 1902)	SAN	<b>Vargas and Restrepo (2019)</b>
<i>R. cyanoxantha</i> (Schaeff) Fr.	CUN, <b>BOY</b> , SAN	<b>Guzmán and Varela (1978)</b> , Franco-Molano and Uribe-Calle (2000), Vasco-Palacio and Franco-Molano (2013), <b>Vargas and Restrepo (2019)</b> . Edible [Boa 2004, Hall et al. 2011]
<i>R. emetica</i> (Schaeff) Fr.	ANT, <b>BOY</b>	<b>Singer (1963)</b> , Saldarriaga et al. (1988), Franco-Molano and Uribe-Calle (2000), Sierra et al. (2011), Vasco-Palacio and Franco-Molano (2013)
<i>R. humboldtii</i> Singer	CUN	<b>Singer (1963)</b> , Denis (1970), Wu et al. (1997), Franco-Molano and Uribe-Calle (2000), Vasco-Palacio and Franco-Molano (2013)
<i>R. idroboi</i> Singer	CUN	<b>Singer (1963)</b> , Wu et al. (1997), Franco-Molano and Uribe-Calle (2000), Vasco-Palacio and Franco-Molano (2013)
<i>R. peckii</i> Singer	ANT	Franco-Molano et al. (2010), Vasco-Palacio and Franco-Molano (2013), NA
<i>R. puiggarii</i> (Speg.) Sing.	ANT	<b>López-Quintero et al. (2007)</b> , Vasco-Palacio and Franco-Molano (2013)
<i>R. sardonía</i> Fr. 1838	<b>BOY</b>	<b>This study</b> . Edible [Boa 2004, Hall et al. 2011]. Edibility suspected [Phillips 2005]
<i>R. semililacea</i> Singer	CUN	<b>Singer (1989)</b> , Wu et al. (1997), Franco-Molano and Uribe-Calle (2000), Vasco-Palacio and Franco-Molano (2013)
<i>R. silvestris</i> (Singer) Reumaux	ANT	<b>López-Quintero et al. (2007)</b> , Vasco-Palacio and Franco-Molano (2013)
<i>R. virescens</i> (Schaeff) Fr.	ANT	<b>Franco-Molano et al. (2000, 2010)</b> , Vasco-Palacio and Franco-Molano (2013). Edible [Smith 1964, Boa 2004, Phillips 2005, Sitta and Davoli 2012, Hall et al. 2011]
Thelephorales		
Thelephoraceae		
<i>Thelephora</i>		
<i>T. cervicornis</i> (Corner 1968)	QUI	Vasco-Palacio and Franco-Molano (2013), NA

(continued)

**Table 16.1** (continued)

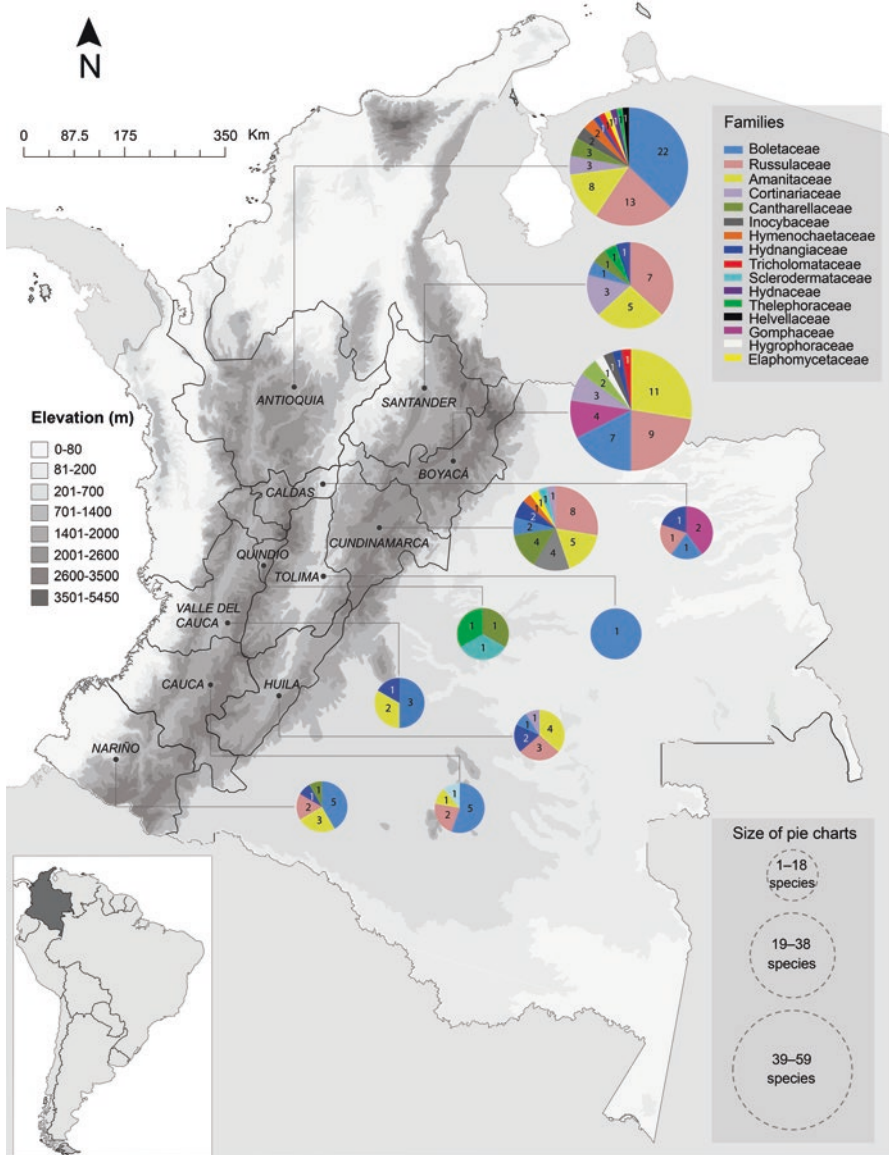
Species	Department	References in which the species is reported in Colombia; the references reporting the species associated with <i>Q. humboldtii</i> are in bold. Species reported as edible, without confirmed consumption, are indicated with the word “Edible” (Franco-Molano et al. 2000), followed by the references in brackets [].
<i>T. palmata</i> (Scop.) Fr. 1821	ANT, SAN	<b>Henaó (1989)</b> , Vasco-Palacio and Franco-Molano (2013), <b>Vargas and Restrepo (2019)</b> .
Ascomycota		
Eurotiales		
Elaphomycetaceae		
<i>Elaphomyces muricatus</i> Fr. 1829	CUN	<b>Guzmán and Varela (1978)</b> , Vasco-Palacio and Franco-Molano (2013).
Pezizales		
Helvellaceae		
<i>Helvella</i>		
<i>H. lacunosa</i> (Afzel. 1783)	ANT	<b>Tobón (1991)</b> , Vasco-Palacio and Franco-Molano (2013). Edible [Polese and Lamaison 1999, Boa 2004, Pérez-Moreno et al. 2010, Burrola-Aguilar et al. 2012]. Not recommended according to Smith (1964),
<i>H. macropus</i> (Pers.) P. Karst	ANT	<b>Tobón (1991)</b> , Vasco-Palacio and Franco-Molano (2013)

<sup>a</sup>Abbreviations for the departments: Antioquia (ANT), Boyacá (BOY), Caldas (CAL), Cauca (CAU), Cundinamarca (CUN), Huila (HUI), Nariño (NAR), Quindío (QUI), Santander (SAN), Tolima (TOL), and Valle del Cauca (VAL). The new reports found in this study with distributions in the departments of Boyacá, Cundinamarca, and Santander are in bold letters (*BOY*, *CUN*, and *SAN*). *NA* no available information on the host species

with the pileus surface; margin even with scales. *Context* reddish-purple, 4 mm wide. *Lamellae* adnexed to adnated, concolorous with the pileus surface, close to slightly distant. *Spore print* brown. *Stipe* 3–6 × 0.4–0.7 cm, concolorous with the pileus surface, cylindrical, with abrupt scales. *Basidiospores*: 6–9 × 5–7.5 µm, cruciform. *Basidia*: 24–31 × 13–16 µm. *Hymenophoral trama* interwoven hyphae.

*Russula sardonía* Fr. 1838. Material studied NVE 633 ANDES\_F650 Fig. 2C, C1—Colombia, Boyacá, Municipio de Arcabuco, km 5 via Arcabuco-Gachantiva. 15 Dec. 2013, in *Q. humboldtii*. This species occurs in north temperate regions, found in Europe and western North America (Phillips 2005).

*Pileus*: 4–6.5 cm wide, convex, to flat in mature specimens and with a depression, violet, purplish or brownish-red, greenish or ochre to yellowish, hard, glabrous. *Context* white, 1–2 cm wide. *Lamellae* adnexed to slightly decurrent, at first cream to pale golden yellow, narrow. *Stipe*: 3.0–8.0 cm long × 1.0–1.5 cm wide, whitish to very pale lilac upper half, to greyish dark lilac in the lower half, uniform; surface fibrillose to slightly pruinose. *Spore print* cream. *Basidiospores*: 7–9 × 6–8 µm, ovoid with warts up to 0.5 µm high, joined into ridges forming fine irregular lines or rugose ornamentation. *Basidia*: 50–60 × 10–14 µm. *Hymenophoral trama*: ovoid cells up to 30 µm long, regularly arranged. *Pleurocystidia* spindle-shaped or cylindrical, without septa.



**Fig. 16.1** The departments of Colombia where ECM species have been reported with *Quercus humboldtii*. The number of ECM species per family is indicated inside each pie chart. The delineated departments in the map encompass the Andean cordillera and are a part of the total departments in Colombia



**Table 16.2** References reporting the ectomycorrhizal characteristic of fungal genera included in this study

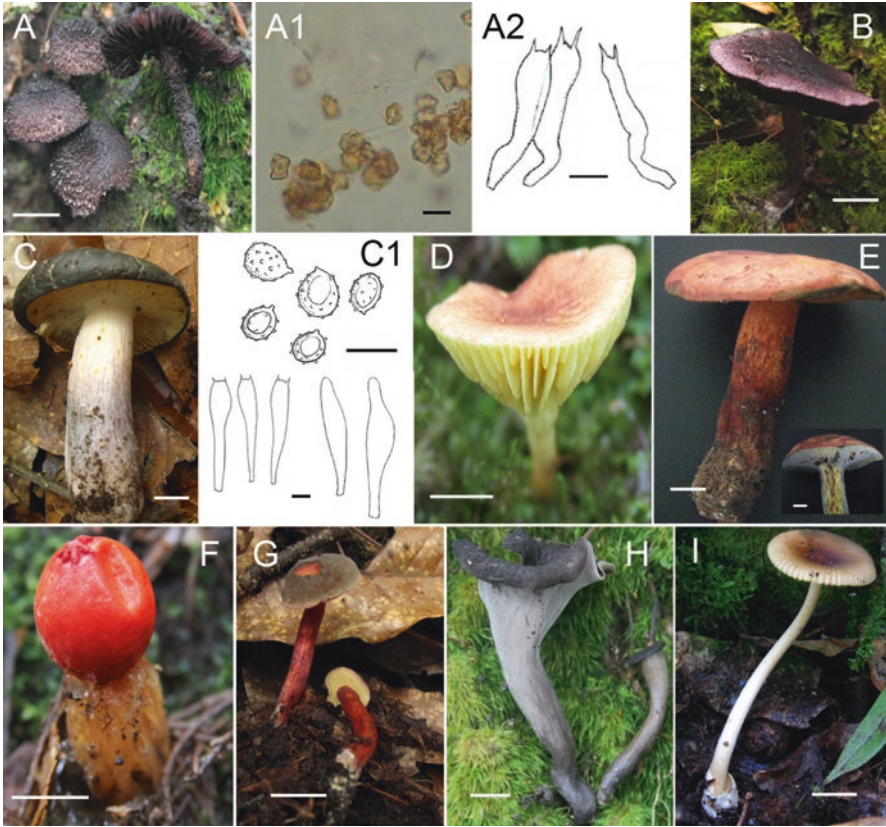
Species	References
<i>Amanita</i>	Trappe (1962), Cripps and Miller (1995), Högberg et al. (1999), Hobbie et al. (2001, 2002), Rinaldi et al. (2008), Tedersoo et al. (2010), Wolfe et al. (2012).
<i>Aureoboletus</i>	Rinaldi et al. (2008), Tedersoo et al. (2010).
<i>Austroboletus</i>	Rinaldi et al. (2008), Tedersoo et al. (2010).
<i>Boletellus</i>	Trappe (1962), Rinaldi et al. (2008), Tedersoo et al. (2010).
<i>Boletus</i>	Trappe (1962), Högberg et al. (1999), Hobbie et al. (2001), Rinaldi et al. (2008), Tedersoo et al. (2010).
<i>Calostoma</i>	Wilson et al. (2007), Tedersoo et al. (2010).
<i>Cantharellus</i>	Trappe (1962), Högberg et al. (1999), Hobbie et al. (2001, 2002), Rinaldi et al. (2008), Tedersoo et al. (2010).
<i>Coltricia</i>	Agerer (2006), Tedersoo et al. (2007), Rinaldi et al. (2008), Tedersoo et al. (2010).
<i>Cortinarius</i>	Trappe (1962), Högberg et al. (1999), Rinaldi et al. (2008), Tedersoo et al. (2010).
<i>Craterellus</i>	Trappe (1962), Rinaldi et al. (2008), Tedersoo et al. (2010).
<i>Elaphomyces</i>	Trappe (1962), Tedersoo et al. (2003), Rinaldi et al. (2008), Tedersoo et al. (2010).
<i>Gyroporus</i>	Trappe (1962), Rinaldi et al. (2008), Tedersoo et al. (2010).
<i>Helvella</i>	Trappe (1962), Tedersoo et al. (2006), Rinaldi et al. (2008), Tedersoo et al. (2010).
<i>Hydnum</i>	Trappe (1962), Högberg et al. (1999), Rinaldi et al. (2008), Tedersoo et al. (2010).
<i>Hygrophorus</i>	Trappe (1962), Högberg et al. (1999), Rinaldi et al. (2008), Tedersoo et al. (2010).
<i>Inocybe</i>	Trappe (1962), Cripps and Miller (1995), Högberg et al. (1999), Hobbie et al. (2001), Rinaldi et al. (2008), Tedersoo et al. (2010).
<i>Laccaria</i>	Trappe (1962), Högberg et al. (1999), Hobbie et al. (2001), Rinaldi et al. (2008), Tedersoo et al. (2010).
<i>Lactarius</i>	Trappe (1962), Flores et al. (2005), Högberg et al. (1999), Hobbie et al. (2001), Miller et al. (2006), Rinaldi et al. (2008), Tedersoo et al. (2010).
<i>Leccinum</i>	Trappe (1962), Molina and Trappe (1982), Den Bakker et al. (2004), Rinaldi et al. (2008), Tedersoo et al. (2010).
<i>Phylloporus</i>	Trappe (1962), Rinaldi et al. (2008), Tedersoo et al. (2010).
<i>Pulveroboletus</i>	Rinaldi et al. (2008), Tedersoo et al. (2010).
<i>Ramaria</i>	Trappe (1962), Humpert et al. (2001), Nouhra et al. (2005), Hobbie et al. (2002), Hosaka et al. (2006), Rinaldi et al. (2008), Tedersoo et al. (2010).
<i>Russula</i>	Trappe (1962), Högberg et al. (1999), Hobbie et al. (2001), Miller et al. (2006), Rinaldi et al. (2008), Tedersoo et al. (2010).
<i>Scleroderma</i>	Trappe (1962), Hosaka et al. (2006), Tedersoo et al. (2010).
<i>Strobilomyces</i>	Trappe (1962), Sato et al. (2007), Rinaldi et al. (2008), Tedersoo et al. (2010).
<i>Suillus</i>	Trappe (1962), Högberg et al. (1999), Rinaldi et al. (2008), Tedersoo et al. (2010).
<i>Thelephora</i>	Trappe (1962), Agerer and Weiss (1989), Rinaldi et al. (2008), Tedersoo et al. (2010).
<i>Tricholoma</i>	Trappe (1962), Högberg et al. (1999), Hobbie et al. (2001), Rinaldi et al. (2008), Tedersoo et al. (2010).
<i>Tylopilus</i>	Trappe (1962), Rinaldi et al. (2008), Tedersoo et al. (2010).
<i>Xanthoconium</i>	Rinaldi et al. (2008), Tedersoo et al. (2010).
<i>Xerocomellus</i>	Trappe (1962)



**Table 16.3** New records of ECM fungi collected in *Q. humboldtii* forests, in the departments of Boyacá, Cundinamarca, and Santander

Species	Collection(s)/Herbarium Catalog number <sup>a</sup>	Department <sup>b</sup>	Locality
<i>Amanita fuligineodisca</i>	Observation	CUN	Vereda Santa Barbara, km 19 via Mosquera-La Mesa
<i>Boletus neoregius</i>	NVE474/ANDES_F974	BOY	Vereda Capilla, Municipio de Villa de Leyva
<i>Calostoma cinnabarinum</i>	NVE315/ANDES_F814, NVE462/ANDES_F962	BOY	Km 0.7, via Arcabuco-Gachantiva, Municipio de Arcabuco; Vereda Capilla, Municipio de Villa de Leyva
<i>Cantharellus lateritius</i>	ANDES_F71–72	CUN	Parque Nacional natural Chicaque, Municipio de San Antonio del Tequendama
<i>Cortinarius iodes</i>	NVE233–235/ANDES_F732–734. ANDES_F523, ANDES_F529. NVE482–483/ANDES_F982–983	BOY, CUN, SAN	Vereda Peñas Blancas, Municipio de Arcabuco; Vereda Santa Barbara, Municipio de Bojacá; Vereda San José de la Montaña
<i>Cortinarius violaceus</i>	NVE405/ANDES_F905	BOY	Vereda Peñas Blancas, Municipio de Arcabuco
<i>Craterellus falax</i>	NVE307/ANDES_F806	BOY	Vereda Peñas Blancas, Municipio de Arcabuco
<i>Inocybe tahquamenonensis</i>	NVE303/ANDES_F802	BOY	Vereda Peñas Blancas, Municipio de Arcabuco
<i>Laccaria laccata</i>	NVE291/ANDES_F791	SAN	Vereda San José de la Montaña
<i>Lactifluus chrysorrheus</i>	NVE358/ANDES_F857,	BOY	Vereda Peñas Blancas, Municipio de Arcabuco
<i>Lactifluus deceptivus</i>	NVE508/ANDES_F2008	SAN	Vereda San José de la Montaña
<i>Phylloporus centroamericanus</i>	NVE429/ANDES_F929	BOY	Vereda Capilla, Municipio de Villa de Leyva
<i>Russula cyanoxantha</i>	NVE244/ANDES_F743, NVE460/ANDES_F960	BOY	Vereda Peñas Blancas, Municipio de Arcabuco
<i>Russula sardonica</i>	NVE 633/ANDES_F650	BOY	Km 5, via Arcabuco-Gachantiva, Municipio de Arcabuco
<i>Tricholoma caligatum</i>	Observation	BOY	Vereda Capilla, Municipio de Villa de Leyva
<i>Xerocomellus chrysenteron</i>	NVE 449/ANDES_F949	BOY	Km 2, via Gachantiva-Arcabuco

<sup>a</sup>Collections made by Natalia Vargas Estupiñán (NVE)<sup>b</sup>Departments: Boyacá (BOY), Cundinamarca (CUN), and Santander (SAN)



**Fig. 16.2** Basidiome and microscopy of new national and some local records. (a) Basidiomes of *Inocybe tahquamenonensis*, (a1) Spores of *I. tahquamenonensis*, (a2) Basidia of *I. tahquamenonensis*; (b) *Cortinarius violaceus*; (c) Basidiome of *Russula sardoniana*, (c1) Spores, basidia and pleurocystidia of *R. sardoniana*; (d) *Phylloporus centroamericanus*; (e) *Boletus neoregius*; (f) *Calostoma cinnabarinum*; (g) *Xerocomellus chrysenteron*; (h) *Craterellus fallax*; (i) *Amanita fuliginoidisca*. White scale bars correspond to 1 cm. Black scale bars correspond to 10  $\mu\text{m}$

## 16.3.2 Notes on Some Taxa Not Included in the Checklist

### 16.3.2.1 Basidiomycota

Amanitaceae: All the species in Colombia, with the exception of *A. savannae* (described from a wet savanna by Tulloss and Franco-Molano, 2008), belong to a clade of symbiotic species (Subgenera *Lepidella* and *Amanita*) (Wolfe et al. 2012). We did not include the species *A. ceciliae* in the list, because the Colombian and Mesoamerican species for “*A. ceciliae*” probably is *A. sororcula* Tulloss, Ovrebo & Halling (<http://amanitaceae.org/?Amanita%20ceciliae>). The species *A. muscaria*

has been widely reported in exotic pine plantations (Pulido 1983; Franco-Molano et al. 2000; Franco-Molano and Uribe-Calle 2000; Montoya et al. 2005), but Vargas et al. (2019) reported it in association with *Q. humboldtii* in Santander.

**Cortinariaceae:** The genus *Cortinarius* is one of the most diverse genera containing over 2000 spp. (Kirk et al. 2008), and a large number of taxa occurring in Colombia have not been determined yet to species level.

**Entolomataceae:** The species *E. ferrugineogranulatum* reported by Soto-Medina and Bolaños-Rojas (2013) and Horak (1977) was not included in the checklist, since it was reported in open lands (*potreros*) and on rotten wood in rain forests. The same occurs for the species *E. lyophylliforme* reported by Horak (1977) in a tropical rain forest near Buenaventura at 180 m asl. The species *E. venezuelanum* (Dennis) E. Horak 1978 was collected in forests dominated by *Colombobalanus excelsa* (Soto-Medina and Bolaños-Rojas 2013) and was not included in the checklist. The genus *Entoloma* is reported to have ectomycorrhizal species (Rinaldi et al. 2008; Tedersoo et al. 2010); however, the subgenera *Nolanea* and *Leptonia* are nonmycorrhizal (Tedersoo et al. 2010).

**Hydnangiaceae:** The species *Laccaria ohiensis* has been collected in forests dominated by the native oak species *Colombobalanus excelsa* in the department Valle del Cauca (Soto-Medina and Bolaños-Rojas 2013). A report of *Laccaria lac-cata* was made by Sánchez (2006) in Norte de Santander; however, there is no specification on its host.

**Boletaceae:** the species *Boletus orquidianus* (= *Xerocomus orquidianus*) was reported for the country but not associated with Fagaceae (Halling 1989). However, it was later collected in an oak forest in Antioquia (Franco-Molano et al. 2000). The species *Boletus pavonius* and *B. purpurascens* are reported from Santander (Hooker and Kunth 1822; Vasco-Palacio and Franco-Molano 2013) on the banks of the Magdalena river growing on decomposed wood (Hooker and Kunth 1822), and was not included in this checklist. A specimen identified as *B. reticulatus* was collected in a temperate region between Popayán and Almaguer (Hooker and Kunth 1822), probably in oak forests; however, no vegetation information for this specimen was reported.

We did not include species in the genus *Phlebopus*, since the ecology of the genus is ambiguous showing some species cultivated as saprotrophs (Thoen and Ducouso 1990; Wilson et al. 2012) or engaging in multipartite symbiotic interactions (Zhang et al. 2015).

The genus *Chalciporus* has been reported as ectomycorrhizal by Rinaldi et al. (2008); however, Tedersoo et al. (2010) concluded that there is not enough evidence to show its mycorrhizal habit. For this reason, we did not include in the checklist two species reported in Colombia: *Chalciporus piperatus* (Bull.) Bataille and *Chalciporus caribaesus* Pegler reported by López-Quintero et al. (2007) and Franco-Molano et al. (2010), respectively.

*Suillus luteus* NVE425 Andes\_F925, was collected in *Q. humboldtii* in the department of Boyacá. However, species in this genus are restricted to Pinaceae, and therefore *S. luteus* was not included in the present ECM checklist. Anatomical, chemical, and molecular analyses must be performed to confirm the association

with *Q. humboldtii*. Previous studies have reported this species in Colombia associated with conifers (Franco-Molano et al. 2000) and introduced with *Pinus* spp. (Guzmán and Varela 1978) in Antioquia, Caldas, and Cundinamarca.

Cantharellaceae: the species *Cantharellus cinereus* was previously reported by Vasco-Palacio and Franco-Molano (2013), but was not included in this checklist, since the study by Guzmán and Varela (1978) did not report it.

Gomphales: Species in the genus *Ramaria* are reported both as ectomycorrhizal and saprotroph (Humpert et al. 2001; Tedersoo et al. 2010). We include in the checklist the species *R. cyaneigranosa* whose mycorrhizal status was confirmed by Nouhra et al. (2005); it belongs to the subgenus *Laeticolora* characterized by a terricolous habit (Humpert et al. 2001). Other species included in the checklist (Table 16.1) belong to the subgenera *Ramaria* (*R. botrytis*, *R. secunda*, *R. flava*) and the subgenus *Laeticolora* (*R. formosa*), have terricolous habit, and are suggested to be mycorrhizal (Humpert et al. 2001; Hobbie et al. 2002; Smith and Read 2008). In contrast, the saprotrophic species *Ramaria stricta* grows on wood debris (Hosaka et al. 2006), belongs to a phylogenetic clade of lignicolous taxa (Humpert et al. 2001), and is not included in the checklist.

### 16.3.2.2 Ascomycota

Pezizales: Within this order several species are expected to form ectomycorrhizal symbiosis including species in the genera *Humaria*, *Genea*, *Trichophaea*, *Geopora*, *Helvella*, *Hydnotria*, *Peziza*, and *Sarcosphaera* (Tedersoo et al. 2006). The species *Peziza patena* has been reported in Colombia by Vasco-Palacios and Franco-Molano (2013), but there is no specific data on its distribution or host.

### 16.3.3 Notes on Other Orders

Geastrales: According to the studies referenced by Rinaldi et al. (2008) and the phylogenetic analysis by Hosaka et al. (2006), we did not include *Geastrum* as ECM.

Trechisporales: Dunham et al. (2007) observed some traits that characterize ECM formation in species from the genus *Trechispora*. In Colombia, eight species of this genus are reported, but they were not included here; further analyses on the trophic status must be made for this particular genus.

### 16.3.4 Edible Ectomycorrhizal Fungi in Native Oak Forests

Regarding our search on previous reports on edibility of wild fungi, 37 ectomycorrhizal species associated with *Q. humboldtii* forests in the Andean mountains in Colombia are potentially edible (Table 16.1). Among them, some are locally

reported as edible for the department of Boyacá: *Ramaria secunda* and *Lactifluus indigo* by Ruíz and Henao-Mejía (2006), *Tylopilus indecisis*, *Ramaria flava*, *R. cyaneigranosa*, *R. botrytis*, and the other five species of *Ramaria* by Peña-Cañon and Henao-Mejía (2014), *Lactifluus deceptivus* (pers. comm. Yeina Niño Fernández, March 2014) and *Russula cyanoxantha* (pers. comm. Angélica Ruíz, May 2012).

Given that the native oak forests provide environmental benefits and services, their maintenance and protection are vital (Chaves et al. 2007). Encouraging public awareness on the importance of fungal diversity and its conservation, in localities where its edibility is traditionally known, might allow a sustainable production. In countries such as the United States, and some countries in Europe, conservation activities have been proposed based on the impact of intense harvesting of edible mushrooms over long time periods (Pilz and Molina 2002).

## 16.4 Concluding Remarks

The conservation of ectomycorrhizal fungi associated to oak ecosystems is a priority, regarding that oak forests suffered habitat loss, rare fungal species are associated with this host, and a potential use of ECM species is known. Moreover, ectomycorrhizal fungi play a key role in sequestering carbon in soils (Soudzilovskaia et al. 2019), hence their conservation and restoration might be one strategy to act on when considering actions for climate change mitigation.

Following the evaluation criteria provided by the *Micheli Guide to Fungal Conservation* (<http://www.fungal-conservation.org/micheli.htm>), in this report we accomplished the following criteria: mentioning ECM fungi in a conservation context, listing departments in the Colombian Andes where ECM fungal species occur with native *Q. humboldtii*, and showing different regions in the Andean cordillera where there is a lack of knowledge on fungal diversity and where exploration of ECM diversity should be enhanced.

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