



Chapter 2

Two Centuries of Mycological History in Colombia

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Anthropozoomorphic pendant
[Robert Lücking]



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ABSTRACT

Current knowledge about the Colombian funga results from countless expeditions, researchers, and national and foreign institutions that have contributed to the development of mycology in Colombia for more than two centuries. This historical timeline will probably remain incomplete because several historical accounts are difficult to track down, but four different periods are highlighted: 1. Fungal knowledge from pre-Hispanic times is still incomplete despite efforts to compile the biocultural heritage of ancestral knowledge of indigenous, root, and traditional farming populations; 2. The 19th century's study of the funga started with The Royal Botanical Expedition to New Granada and was followed by other important expeditions; 3. The 20th century was a period marked by expeditions of European naturalists, but Colombian mycologists also started to develop areas such as phytopathology and clinical mycology; 4. From the 1970s to today, the knowledge on Colombian funga has grown due to the contributions of foreign and national mycologists, with about 80 Colombian research groups studying fungi nowadays. In each of these periods, some notable events and influential figures left their mark on the historical memory of Colombian mycology.

RESUMEN

El conocimiento sobre la funga colombiana es el resultado de innumerables expediciones, investigadores e instituciones nacionales y extranjeras que por más de dos siglos han aportado a su desarrollo. En este capítulo se presenta un breve recuento de esta historia dividiéndola en cuatro períodos, mencionando hechos destacados y personajes influyentes que han dejado huella en la memoria histórica de la micología colombiana. En el primer periodo se reconoce la relación de las diferentes comunidades ancestrales colombianas con los hongos, vestigios que se pueden encontrar en piezas prehispánicas en el Museo del Oro de Bogotá y en publicaciones iconográficas. A pesar de los esfuerzos en la recopilación del patrimonio biocultural de conocimientos ancestrales de poblaciones indígenas, raizales y campesinas tradicionales, aún está lejos de completarse. El segundo período denominado siglo XIX, coincide con la participación de Francisco José de Caldas en la Real Expedición Botánica del Nuevo Reino de Granada, quien reporta el primer hongo para Colombia. Posteriormente Sir William Jackson Hooker describe varias especies de hongos y líquenes de las colecciones realizadas por Alexander von Humboldt y Aimé Jacques Alexandre Bonpland durante sus viajes por el país. Y finalmente, la edición del *Prodromus Florae Novo-Granatensis* de José Jerónimo Triana y Jules Émile Planchon (1863–1867), con las colaboraciones de Joseph-Henri Léveillé (Hongos) y William Nylander (Líquenes). El tercer período, del siglo XX hasta 1970, inicia con la Expedición de Otto Fuhrmann y Eugène Mayor conocida como la expedición Helvética, inspirando a micólogos como Carlos Chardón y Rafael Toro, quienes lideraron el primer inventario de hongos de Colombia. Posteriormente, el establecimiento de la carrera en ciencias agrícolas en la Universidad Nacional sede Medellín en 1927, contribuyó sustancialmente a la formación de micólogos y al conocimiento de los hongos fitopatógenos. Así mismo, la micología clínica tuvo su inicio con las investigaciones de Alfredo Correa y Alfonso Jaramillo; hacia los años sesenta aparece la primera micóloga médica Angela Restrepo-Moreno, creadora de una de las más importantes escuelas micológicas de América Latina, posteriormente, en Bogotá, la reconocida micóloga Elizabeth Castañeda ha liderado el estudio de los hongos que causan enfermedades. El cuarto período comprendido entre los 70s y la segunda década del siglo XXI, debería considerarse el periodo de iluminación micológica, pues no solamente fue el tiempo con mayores visitas de especialistas internacionales, sino también el despertar de la micología nacional en todas las áreas conocidas hoy. Especialistas en diversos grupos y líneas conformaron sus propias escuelas y han formado a las nuevas generaciones de investigadores. Reciente dos hechos han transformado la historia de la micología, ambos involucrando el trabajo en equipo como fuente de progreso. El primero de ellos, la conformación de grupos de investigación que ha fortalecido los procesos de investigación y formación de capital humano,

además de generar un reconocimiento colectivo de las actividades de investigación a nivel nacional e internacional. Y Finalmente, en el 2019, la consolidación de la Asociación Colombiana de Micología (ASCOLMIC) que tiene como misión, además de conectar a todos aquellos que investigan en hongos en Colombia, generar resultados científicos que puedan integrarse a las políticas públicas nacionales, y conlleven a la inclusión de los hongos en las agendas nacionales a fin de orientar y gestionar la protección, manejo y uso de la funga del país.

INTRODUCTION

Summarizing the history of mycological studies in Colombia is not a simple task. This historical timeline will probably remain incomplete as several historical accounts come from extensive grey literature and historical archives that are difficult to track down. Nonetheless, the relationship between fungi and the indigenous people of Colombia is ancient and evidenced by pre-Hispanic art pieces in the Bogotá Gold Museum and iconographies in some historical books (e.g., Pérez de Barradas, 1954; Schultes & Bright, 1979). The biological heritage of Colombia's extant indigenous and traditional farmers has been compiled by ethnomycologists but is still far from being fully documented. However, the known history of mycological studies in Colombia starts, as far as we know, in 1785 with la Real Expedición Botánica del Nuevo Reino de Granada (the Royal Botanical Expedition to New Granada, which was a former jurisdiction of the Spanish Empire corresponding to modern Colombia, Ecuador, Panama, and Venezuela) and continues to this day. In these 236 years, mycology in Colombia has significantly developed thanks to foreign naturalists who carried out expeditions collecting specimens in the national territory and who contributed to the knowledge of the Colombian funga during the first 200 years.

In recent times, Colombian mycology has been in the hands of renowned national and international researchers. Studies in Colombian arbuscular mycorrhiza, macrofungi, microfungi, and lichens, little known until recently, were accelerated after the visits of specialists such as Carlos Chardon and Rafael Toro (Puerto Rico), Ewald Sieverding (Germany), Kent Dummont, Rolf Singer, Roy Halling, and Greg Mueller (all from the United States), Gastón Guzman (México), Leif Ryvar den (Norway), and Harrie Sipman (Germany). In turn, these foreign researchers trained countless Colombian mycologists over the years. As advances in science prevailed, fungi were not left behind, and it is towards the end of the 20th century and at the beginning of the 21st studies in clinical mycology, biotechnology, and bioprospecting took off. Even today, these areas are studied by the greatest number of researchers in the country after those studying fungal biodiversity. The instatement of research groups focusing on fungi brought with it the association of specialists, strengthening the development of research and human resources, and generating a collective recognition of research activities at the national level. Recently, the Asociación Colombiana de Micología (Colombian Association of Mycology) - ASCOLMIC facilitates connections between the groups and researchers working with fungi. We hope this network, along with this book, will help develop mycology and fill the information gaps we detected.

FUNGI IN PRE-HISPANIC TIMES AND THEIR BIO-CULTURAL HERITAGE

The documented history of mycology in Colombia spans a little over 200 years. However, there is evidence of the traditional use of fungi, especially macrofungi, by indigenous communities before pre-Hispanic times in various regions of Colombia. Pérez de Barradas (1954) documented pectorals and pieces that contained figures allusive to fungi in his work entitled *Pre-Hispanic Goldsmithing of Colombia*. Schultes & Bright (1979) revisited the gold pectorals of the *Museo del Oro* in Bogotá, presenting evidence for the use of mushrooms by the indigenous cultures of the Darien, Sinú, and Quimbaya regions (Figure 1). Later, Schultes et al. (2000), in their book entitled *Plants of the Gods*, further pointed out the use of mushrooms by various communities, including in magical-religious rituals. Fungal representations are found in the iconography of several pre-Hispanic cultures throughout the country, showing their knowledge and close cultural relationship with fungi (Velandia et al., 2008).



FIGURE 1. Anthropozoomorphic pendant. Caribbean Plains - Serranía de San Jacinto / Bajo Magdalena. 1000 AD to 1700 AD. Found in Betancí, Córdoba, Colombia. 10.7 x 8.6 cm. Gold Museum Collection, Bank of the Republic. Photograph by Robert Lücking.

The traditional use of fungi by Colombian indigenous communities continues until the present. Colombia comprises an enormous cultural diversity, including 85 indigenous peoples, three distinct Afro-Colombian ethnicities, the Romani people, and traditional farming communities (DANE, 2007). These communities primarily depend on environmental resources, hunting, fishing, and gathering wild products such as fruits, buds, and mushrooms, and producing food using fermentation. The use of mushrooms as food, in traditional medicine, and for societal and religious rituals has been recorded for the Uitoto, Andoke, Muinane, Bora-Miraña, and Yukuna-Matapí of the Amazon (e.g., Landaburu & Pineda, 1984; Urbina, 1986; Vasco-Palacios *et al.*, 2008), as well as for the Ingas in Putumayo (Sanjuan, 1999), the Embera-chamí in the Pacific tropical forests (Cayón & Aristizábal, 1980), the U'wa in the eastern foothills of the mountain range in the Nevado del Cocuy (Rocheraux, 1959), the Kokonucos in Cauca (Gonzalez-Cuellaret *et al.*, 2021), and the Wayuu in the upper Guajira, who use fungal spores as facial sunscreen (Villalobos *et al.*, 2017). Traditional farmers from Boyacá and Santander use mainly ectomycorrhizal species associated with oaks (*Quercus humboldtii*) as a food source (Peña-Cañón & Eno-Mejía, 2014).

19TH CENTURY

Until July 20th of 1810, Modern Colombian territory was known as part of the Viceroyalty of the New Kingdom of Granada. The first inventory of Colombia's biodiversity dates to 1783–1816 when *The Royal Botanical Expedition* to New Granada was led by the Spanish priest José Celestino Mutis (Díaz-Piedrahita, 1991). Around 20,000 plants and 7,000 animals were collected and documented. The specimens collected in this expedition were published in a series of books, in which volume 2, published *a posteriori* (Aguirre & Calonge 1985), entitled *Algae, Lichens, Fungi, Liverworts, and Mosses*, included 15 fungi (seven *Basidiomycota* and eight *Ascomycota*, three of them being lichenised). The original illustrations were edited with complementary texts and scientific determinations were done by Jaime Aguirre (Colombian bryologist and lichenologist) and Francisco de Diego Calonge (Spanish mycologist). Unfortunately, the original plates of this volume do not have information on the place, date, collector, or artist, except plate VI, called *a posteriori* *Cookeina sulcipes*, made by the Colombian artist Francisco Javier Matis on April 14th, 1785 (Figure 2e). This plate was documented for the first time by Calonge (1986). As an update to Volume II, we have compiled plates III, IV, VI, and VIII, added photographs of the species “*in situ*,” and updated their taxonomy (Figure 2).

Francisco José de Caldas (1803) provided the first known report on a phytopathogenic fungus, a description that coincides with the wheat leaf rust, *Puccinia graminis* (Figure 2). Later, the Italian botanist and naturalist Luigi Carlo Giuseppe Bertero, during his expedition to the Antilles and the Caribbean coast of Colombia (1816–1821), made considerable collections of plants, algae, and fungi from Santa Marta (Magdalena), Barranquilla (Atlántico), Mompóx

(Bolívar), and part of the Río Magdalena (1820–1821) (Delprete *et al.*, 2002; Baldini & Guglielmone, 2012). In 1882, Sir William Jackson Hooker described 73 species of fungi, 12 new to science, collected by Alexander von Humboldt and Aimé Jacques Alexandre Bonpland in Venezuela and deposited at the Kew Gardens herbarium (K).

Shortly after the middle of the 19th century, José Jerónimo Triana and Jules Émile Planchon (1863–1867) published the *Prodromus Florae Novo-Granatensis*, including a lengthy chapter on lichens (*Lichenes*) elaborated by the Finish lichenologist and mycologist William Nylander (Nylander, 1863). He described numerous new species based on the collections of the German botanist Alexander Lindig, who lived in Bogotá and undertook botanical expeditions to the surroundings and other areas, including Choachí, Fusagasugá, Tibacuy, and Villeta (Cundinamarca), Honda (Tolima), and Muzo (Boyacá). Another chapter of non-lichenised fungi, by the French mycologist Joseph-Henri Lévillé (1863), enumerating 63 species, was based on collections by Hooker, Justin Goudot, and Lindig (Herbarium, Muséum National d' Histoire Naturelle).

20TH CENTURY TO THE 1970S

At the beginning of the 20th century, field expeditions to Colombia were very popular among European naturalists. The Swiss parasitologist Otto Fuhrmann and the Swiss mycologist Eugène Mayor undertook further scientific exploration in Colombia within the *Helvetic Expedition* (Fuhrmann & Mayor, 1914). Their results contributed to the knowledge of various groups of fungi, mainly pathogens and lichens. This work constituted the first extensive systematic treatment of *Uredinales* (rusts) studied by Mayor, and *Pucciniales*, by the German mycologist Paul Sydow and his son Hans Sydow, from Berlin (Gómez-Gutiérrez, 2011; Buritica-Céspedes *et al.*, 2014). The collected materials represent 156 species currently deposited at the University of Neuchatel herbarium (NEU) in Switzerland (Pardo-Cardona, 2001; Gómez-Gutiérrez, 2011). The German lichenologist and mycologist Gustav Lindau, also from Berlin, studied the lichens collected in this expedition reporting 64 taxa, including the then-new species *Lecidea mayorii*. The holotype of this species was unfortunately destroyed during the 1943 bombing in the Berlin herbarium (Botanischer Garten und Botanisches Museum Berlin, B).

The *Helvetic Expedition* inspired the Puerto Rican mycologists and pathologists Carlos Chardón and Rafael Toro to carry out the *Mycological Explorations of Colombia* supported by the Colombian government (Chardón & Toro, 1930). They registered 610 species of fungi collected between 1926 and 1930 in the surroundings of Medellín, the Magdalena Valley, the Pacific coast, the Valle del Cauca, and the mountain ranges of the departments of Cundinamarca and Tolima. This work included mostly phytopathogenic fungi and some macrofungi, later recognised as the first modern inventory of Colombian fungi. Frank D. Kern and Herbert Whetzel (*Uredinales*), Julian Miller (*Xylariaceae*), and Jay Seaver (*Discomycetes*), Dr. L.O. Overholts (Higher



FIGURE 2. Species drawn in *Flora de la Real Expedición Botánica Tomo II* and their possibly corresponding or similar species. A-B *Cladonia meridensis*, previously identified as *Cladonia didyma*. C-D *Stereocaulon ramulosum*. E-F *Cookeina sulcipes*. and G-H *Trametes versicolor* (*Jar. Bot. Mad.* 86).

Basidiomycetes), Dr. IY. Fl. Weston Jr. (Phycomycetes), Dr. Charles Chupp (*Cercospora*) collaborated in that publication. Most of these collections were deposited in foreign herbaria, especially at Cornell University (CUP) and Pennsylvania State University (PACMA) herbaria, the latter now transferred to the US National Fungus Collections, USDA-ARS (BPI). In addition to the contributions of Chardon, in 1927, higher education in agricultural science was established at the Faculty of Agricultural Science in Medellín and at the Plant Health Service (PHF) of Colombia (Ministry of Industries). These developments were fundamental to the development of phytopathology in Colombia. Enrique Pérez Arbeláez, botanist and catholic priest, head of the Botany Department at the PHF, implemented a methodology suggested by Chardón and Toro, both recognised for initiating phytopathology in Colombia. This method includes drawings of plant host, the symptoms, and the different stages of pathogenic fungi. Part of those drawings (1940–1944) was rescued by Pablo Buriticá-Céspedes and published in 1996

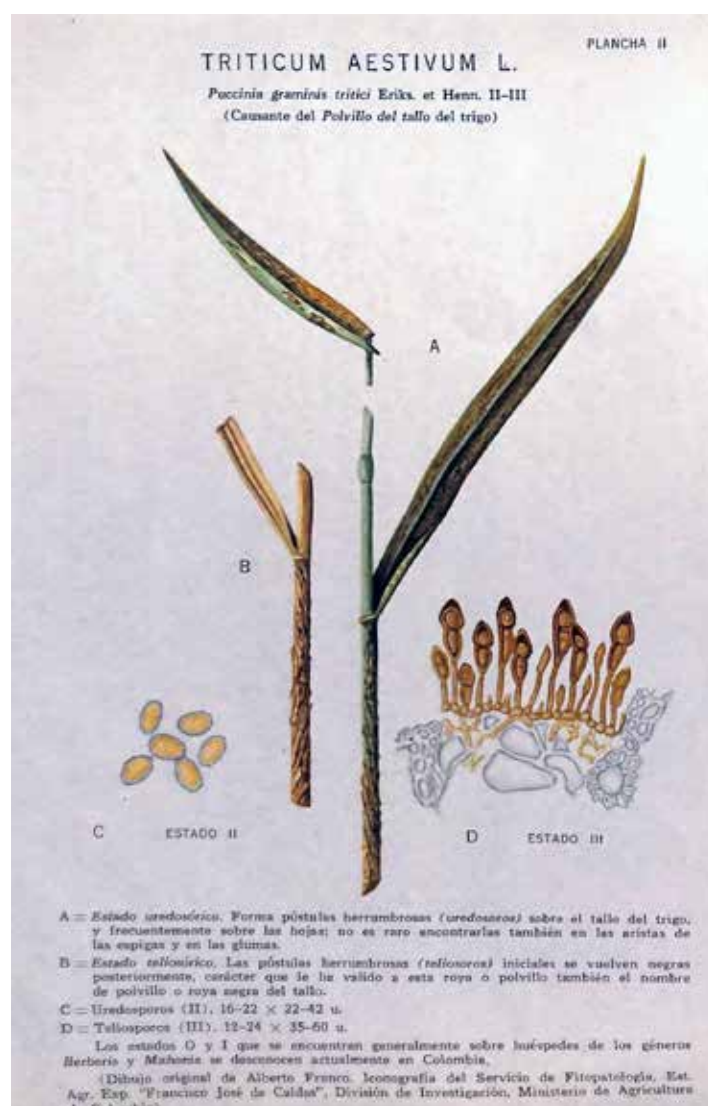


FIGURE 3. Illustration of *Puccinia graminis* Pers. (Pucciniaceae) made by Alberto Franco 1940. Iconography of the National Phytopathology Service, personal collection of Dr. Pablo Buriticá.

(Figure 3). The collection of phytopathogenic fungi gave rise to the Tibaitatá collection, currently at Corporación Colombiana de Investigación Agropecuaria - AGROSAVIA.

A few years later, in 1936, the Spanish botanist and pharmacist José Cuatrecasas, motivated by the celebration of the second centenary of the birth of Mutis, reported two species of fungi and 22 lichens, collected by himself and currently held in the National Herbarium, Smithsonian Institution (US) (Cuatrecasas, 1936). Between 1937–1939, George Willard Martin (1937, 1938, 1939a, 1939b) published a serial publication on the “New or noteworthy fungi from Panama and Colombia”. His collections from the Sierra Nevada of Santa Marta in the Magdalena department enriched our knowledge about the funga of this biodiversity “hotspot”. Martin described eight new species of microfungi from this area. The exploration of parasitic fungi associated with plants of agronomic importance continued during the 1950s with Carlos Garcés and Rafael Obregón, both professors at the Facultad de Agronomía (Faculty of Agronomy), which was integrated into the Universidad Nacional de Colombia, as their Medellín headquarters, and of some of their students (Pardo-Cardona, 2001).

Clinical mycology arises from the need to know the fungi that cause diseases, including endemic diseases. In the 1930s, the study of human pathogenic fungi in Colombia focused on skin diseases and their annexes. One of the first important contributions is the monograph *Contribution to the study of mycosis in Antioquia* (1929), by doctors Alfredo Correa and Alfonso Jaramillo, from the Universidad de Antioquia, which included aspects of the classification, laboratory science, and clinical relevance of medically important fungi. In this same period, dermatologists were particularly interested in systemic mycoses, the study of how fungi affect internal organs. Around the 1940s, publications on systemic mycosis started with the publications on *Blastomycosis* by Miguel Serrano (Serrano, 1943). In this first stage, microscopic examination and isolation in culture were used. Still, the initiation of pathophysiology changed the orientation of the diagnosis of mycoses, with clinicians trying to identify the fungus causing the disease and its mechanisms of action or alteration (Galvis-Pérez *et al.*, 2013). In the early 1960s, research in paracoccidioidomycosis was consolidated thanks to Angela Restrepo-Moreno. She was the first woman in medical mycology in Colombia, a field previously exclusively male-dominated. In 1962, she compiled a series of cases of various mycoses, giving the first overview of the state of the art, including cases caused by *Cryptococcus* and *Sporothrix*. Thanks to her dedication to teaching, Restrepo-Moreno formed one of the most important schools in this area in Latin America. In Bogotá DC, Elizabeth Castañeda del Gordo studied fungi that cause human diseases from a very young age. Later, at the National Institute of Health, she and her team made Colombia one of the leaders in Latin America in identifying this type of agent. Currently, Colombia is well established and recognised worldwide in this area, with many research groups dedicated to the study of mycoses, thanks to the efforts of these two women.

THE 70S TO THE SECOND DECADE OF THE 21ST CENTURY

During the last third of the 20th century, knowledge on the Colombian fungi increased largely due to contributions by foreign mycologists visiting the country. Some of these scientists left their legacy by training Colombian mycologists. Particularly, during this period, the expeditions of Kent P. Dumont (New York Botanical Garden – NYBG) in Colombia during 1968 provided the base for further unveiling of the richness of Colombian fungi. The project *Mycological Flora of Colombia* was a program established in 1974 between the New York Botanical Garden and the Instituto de Ciencias Naturales — ICN (Institute of Natural Sciences) at Universidad Nacional de Colombia. From 1978 to 1983, this project amassed about 4,000 collections from the departments of Antioquia, Boyacá, Cauca, Cundinamarca Boyacá, Caquetá, and Valle del Cauca. It was the first international project for which the main collections were deposited in a Colombian herbarium (Herbario Nacional Colombiano, COL). As a result of this project, ten publications have been produced under the title *Los Hongos de Colombia I–X*, with descriptions and records of macrofungi in the *Ascomycota* and *Basidiomycota*, as well as phytopathogenic fungi, moulds, lichens, and myxomycetes (e.g., Dumont *et al.*, 1978; Guzmán & Varela, 1978; Pulido-L., 1983).

Another significant contribution to mycology, particularly lichenology and macrofungi in Colombia, was the binational framework ECOANDES project between the Netherlands and Colombia (1980–1983). This has been the most comprehensive large-scale ecological project developed in the Colombian Andes to date. Systematic expeditions were developed along transects in four mountain ranges, including the three Cordilleras (Parque Nacional Natural los Nevados – PNNN, Tatamá and Sumapaz) and the Sierra Nevada de Santa Marta. Lichens (Sipman, 1986, 1989, 2005; Aguirre, 2008b) and macrofungi were studied (Pulido-L. & Boekhout, 1989a, 1989b; Pulido-L., 2005, 2008), contributing to the knowledge of these groups in altitudinal gradients, and considerably increasing the number of species known for the country.

The first Colombian studies on foliicolous lichens were done by the German ecologist Sieghard Winkler and his student Rainer Nowak, both in the Sierra Nevada de Santa Marta and the Chocó region (Nowak & Winkler, 1970, 1975). During this period, the Dutch lichenologist Harrie Sipman, based at the Botanical Garden and Botanical Museum (BGBM) in Berlin, emerged as a leader of lichenological studies in Colombia, supporting the Dutch ecologist Jan Wolf in his pioneering studies of canopy epiphyte communities (Wolf, 1993, 1994, 1995). Sipman also mentored and consolidated Jaime Aguirre as the first Colombian lichenologist. Sipman and Aguirre made important contributions among which are the first key to the lichens of Colombia (Sipman & Aguirre, 1982), and three lichen catalogues and checklists (Aguirre, 2008a; Sipman *et al.*, 2008; Sipman & Aguirre, 2016). Towards the end of the 1980s, Juan Luis Rubiano began to work in bioindication using lichens as model organisms (Rubiano, 1987, 1988).

One of the most important recent events in the study of lichenised fungi was the creation of the Grupo Colombiano de

Liquenología- GCOL (Colombian Group of Lichenology), with the support of the German mycologist Robert Lücking in 2010. This prompted the study of lichenology with great contributions such as: the consolidation of reference collections in several Colombian herbaria such as Herbario Forestal Gilberto Emilio Mahecha Vega, Sección no Vasculares, Universidad Distrital, (UDBC), Herbario Luis Sigifredo Espinal-Tascón, Universidad del Valle (CUVC), and Herbario Universidad de Caldas (FAUC); the description of new species (Lücking *et al.*, 2017); the publication of several ecological (Soto *et al.*, 2012; Chilito *et al.*, 2016; Simijaca *et al.*, 2018), phylogenetic/systematic (Lücking *et al.*, 2014; Moncada *et al.*, 2014; Coca *et al.*, 2018), bioindication (Díaz-Escandón *et al.*, 2016; Correa-Ochoa *et al.*, 2020), microbiome (Sierra *et al.*, 2020), and conservation (IAVH, 2019) studies; besides training specialised Colombian personnel (see Chapters 6, 14). At the same time, Norma Valencia-Islas and Leopoldo Rojas, with their research group, began their studies in bioprospecting of lichen substances (e.g., Rojas *et al.*, 2015; Leal *et al.*, 2018). Lichens went from being one of the least known groups of fungi in Colombia to one of the most well-studied (Lücking *et al.*, 2021).

In addition to the Mycological Flora of Colombia project and ECOANDES, numerous international researchers have visited the country. One of the relevant mycologists in the 20th century, Rolf Singer, travelled around the country and described more than 200 new species from Colombia (Mueller & Wu, 1997). Dennis (1970) presented a brief contribution to Colombia's fungi, including macrofungi species and various taxonomic groups and non-true fungi (myxomycetes). Later, Roy Halling (NYBG, USA), Greg Mueller (Field Museum, USA), and other colleagues conducted pioneering studies of fungi associated with montane oak in Colombia and Costa Rica (1986 – 1988). Collections of those expeditions are deposited in the Herbaria of the Universidad de Antioquia (HUA), NY, and F (see Chapter 15). Other important mycologists that contributed to the knowledge of Colombian fungi were Dennis Desjardin (University of Tennessee, USA), Tim Baroni (SUNY Cortland, USA), Gaston Guzmán (Instituto de Ecología de Xalapa, México), a specialist in agaricoid fungi, and Leif Ryvarden, working with polypore fungi (University of Oslo, Norway). More recently, Colombian mycologists have carried out studies on macrofungi (Chapters 4, 5). Important contributions to the fungi from the Amazon ecosystem have been made since 2001 by a project focused on exploring the diversity and ecology of saprotrophic, ectomycorrhizal, and entomopathogenic fungi (e.g. Franco-Molano *et al.*, 2005; López-Quintero *et al.*, 2012; Vasco-Palacios *et al.*, 2018, 2019, 2020; Sanjuan *et al.*, 2015). This initiative has been widely supported by Dr Teun Boekhout, a Dutch mycologist who was part of the ECOANDES and visited Colombia in the 80s. The best-studied regions are the Andean region of the central, eastern, and western cordillera, mainly in places close to the large cities and both ectomycorrhizal fungi associated with *Quercus humboldtii* and saprotrophic fungi (Vasco-Palacios & Franco-Molano, 2013; Peña-Venegas & Vasco-Palacios, 2019; Vargas & Restrepo, 2019; Chapter 10). Colombian mycologists and lichenologists are actively working on the threat assessment of fungal species and are among the leaders in these efforts in South America (Chapter 14).

Studies in arbuscular mycorrhizae (AM) also started in the 1970s. Colombia was one of the first countries in South America to study these organisms. At the end of the 1970s, studies of AM in crops began at The International Centre for Tropical Agriculture (CIAT) with Reinhardt Howeler and James Spain, who isolated for the first time the species *Glomus manihotis*, and *Entrophospora colombiana* (Schenck *et al.*, 1984). During the 1980s, Ewald Sieverding, considered the father of AM studies in Colombia, in a cooperation project supported by the German Technical Cooperation Agency (GTZ), collected almost 1,200 ecotypes (Sieverding, 1984, 1989a, 1989b; Sieverding & Howeler, 1985). This was a starting point for the “Mycorrhizal Collection”, one of the most important AM collections in the world and Latin America during the eighties. The collection preserves 44 species of AM, of which 86% are from Colombia (García *et al.*, 2000). Those AM strains had been used as reference cultures to develop a new AM fungal taxonomic classification that includes molecular data, resulting in 12 new species from Colombia (Peña-Venegas & Vasco-Palacios, 2019). Important contributions in AM have also been made by Colombian researchers such as Marina Sanchez de Prager (Marina Sanchez, 2007, 2010), Marina Correa de Restrepo (Romero *et al.*, 2004) and Eduardo Guerrero Forero (Guerrero, 1996), among others. Peña-Venegas *et al.* (2006) made an essential contribution to the *Illustrated Catalogue of Arbuscular Mycorrhizae of the Colombian Amazon*.

With the rise of studies on pathogenic fungi in the country during the 1960s and early 1970s, the Asociación Colombiana de Fitopatología y Ciencias Afines (Colombian Association of Phytopathology and Related Sciences) was organised in 1974, bringing together experts on the subject and generating the *Colombian Phytopathology* journal, still active and with wide recognition in the country. Probably one of its most prominent members was Dr. Pablo Buriticá Céspedes, who published on rusts from the late 1960s until a few years ago (e.g., Buriticá-Céspedes, 1978, 1991; Buriticá-Céspedes & Hennen, 1980; Buriticá-Céspedes & Pardo-Cardona, 1996; Buriticá-Céspedes & Salazar, 2007; Buriticá-Céspedes *et al.*, 2014). Buriticá-Céspedes (2014) was the first to describe genera and native species of Uredinales directly collected by him throughout the Colombian territory and covering hitherto unexplored areas. His work includes “Buriticá’s collection”, which constitutes more than 3,000 specimens deposited at the Museo Micológico, Universidad Nacional de Colombia, Medellín (MMUNM). Rusts are currently one of the best-studied groups in Colombia, thanks also to Luis Molina-Valero, Víctor Manuel Pardo-Cardona, and Mauricio Salazar-Yepes (Chapter 9). The smut fungi (Ustilaginales) were studied by Meike Piepenbring, who published an annotated checklist in 2002, after visiting Colombia in 1998 (Chapter 9).

Inquiries into the historical development of microfungi studies are very difficult. This group of fungi includes soil fungi, endophytes, crithidia, and moulds, which belong to various phylogenetic groups within the *Fungi* kingdom (e.g., Ascomycota, Basidiomycota, Zygomycota, Mucoromycota, Chytridiomycota) (Chapter 8). In 1971, Alvin Lee Rogers studied keratinophilic species comparing the mycobiota of

environments separated by important geographical barriers such as the Andes or different latitudes. Two years later, Llanos & Kjøller (1976) presented microorganisms that attack crude oil and hydrocarbons. As part of the series *Hongos de Colombia*, John Veerkamp & Walter Gams (1983) described three new species of soil fungi. Several species of *Penicillium*, *Trichoderma*, and *Talaromyces* have been described from isolates of Amazonian soils (Houbraken *et al.*, 2010; López-Quintero *et al.*, 2013; Yilmaz *et al.*, 2016). Since the 1980s, María Caridad Cepero de García has dedicated her professional life to the study of fungal biology, training several microbiologists and biologists in this area.

Biological control using microorganisms has a long history in Colombia, emphasising the biological control of insects in crops. The development of this field began in the 1970s when microorganisms were imported from the USA to control insect diseases in cotton (Cotes, 2014). Now, the entomopathogenic fungus *Lecanicillium lecanii* is routinely used to control whitefly in this crop. *Trichoderma* was incorporated into the production of cut flowers in Colombia to control *Fusarium oxysporum* in cloves. Later, in the 1990s, the Centro Nacional de Investigaciones de Café – Cenicafé (National Coffee Research Centre) – promoted the production of *Beauveria bassiana* for the control of the Coffee Berry Borer (*Hypothenemus hampei*). This project promoted the development of biological control with microorganisms and encouraged producers and research institutes to dedicate a large part of their efforts to developing biopesticides (Cadena, 2005). The Corporación Colombiana de Investigaciones Agropecuarias (Colombian Agricultural Research Corporation), led by Dra Alba Marina Cotes since 1994, defined a comprehensive research strategy for biological control, including a multidisciplinary team of researchers. They also established infrastructure, including a pilot plant, for the semi-commercial scaling of biopesticides, making Colombia the leading country in South America in the development, production, and commercialisation of biopesticides (Cotes, 2014)

For more than three decades, biotechnology has been a guide for developing areas such as medicine, agriculture, and the food industry, among others, in Colombia. The use of fungi in this area has been led by Dr Lucia Atehortua from the Universidad de Antioquia and Dr Sandra Montoya from the Universidad de Caldas. Production of edible mushrooms has also been important in Colombia, and we can mention Carmenza Jaramillo from Manizales, Caldas in this context. This topic is developed in more detail in Chapters 12 and 13.

Fungi have been part of the biocultural heritage of pre-Hispanic and current groups of the country. At the beginning of this chapter, we referenced most of the current studies published on this topic. Part of this traditional knowledge has been lost due to the acculturation of communities and the loss of ecosystems. Therefore, collecting ancestral knowledge has become important in different regions of the country. For example, at the Universidad Pedagógica y Tecnológica de Tunja (UPTC), Universidad del Cauca, and Universidad de Antioquia, there are research groups and hotbeds in ethnomycology, and several training courses have been conducted in this discipline (Vasco-Palacios, 2021).

AT PRESENT

In the early 21st century, Colombian mycology was substantially strengthened by the creation of several research groups affiliated with universities, research centres, the government, and non-government organisations. To date, there are around 97 mycological research groups in Colombia, most of them (55%) concentrated in Antioquia, Bogotá DC, and Valle del Cauca (Figure 4a). These research groups carry out activities in all known areas of mycology, whereas those working on specific topics include: Grupo Colombiano de Liqueología, Grupo de Investigación en Micología, Grupo de Micología y Fitopatología, Grupo Micólogos de Colombia, Micología Médica, Micología Médica y Experimental, Química de Hongos Macromicetos Colombianos, and Taxonomía y Ecología de Hongos, among others. Other groups are

more generalists and include fungi in their research lines of research. Most groups belong to public universities and institutions in areas such as biodiversity, systematics, taxonomy, and conservation. Meanwhile, the activities of private entities tend to develop research focused mainly on clinical mycology and biotechnology (Figure 4b).

The 97 mycological research groups in Colombia represent only 1.66% of the total number of research groups in the country (Figure 4c), underlining the need to increase the number of researchers in this field. However, 40 of these are classified in the highest categories of the MinCiencias (Science Ministry) (Figure 4d), demonstrating their productivity and high level of research, as well as their important contributions to science. Participation of male versus female researchers in the leadership of these groups is surprisingly only slightly disproportionate, with 56% of led by men and 44% by women (Figure 4e).

Although the mycological community has grown substantially, it has been very scattered and isolated. In 2019, the Colombian Association of Mycology, ASCOLMIC, was consolidated under the leadership of Tatiana Sanjuán, Viviana Motato, and Aída Vasco. The aim of the association is to group people and organisations whose scientific, technical, and educational activities are related to mycology to promote its development in Colombia. Currently, the association brings together about 80 mycologists belonging to 62 of the 97 groups registered in MinCiencias and active in the field of Colombian mycology, and we hope to continue growing and consolidating in the upcoming years. The initial results of ASCOLMIC were the First Colombian Mycology Colloquium in 2020, its second edition in 2021, and the cooperative participation of some of its members in the Project of Useful Plants and Fungi of Colombia (UPFC, led by the Royal Botanic Gardens, Kew and Alexander von Humboldt Biological Resources Research Institute (IAVH; Gaya *et al.*, 2021 and this Book). The result of this joint work is this catalogue and updated list of fungi of Colombia, written by national specialists and international colleagues, whose efforts have contributed significantly with their efforts to the knowledge of the Colombian fungi.

After signing the peace agreement with the Armed Revolutionary Forces of Colombia (FARC), the Colombian government launched the project Colombia Bio to explore the biological

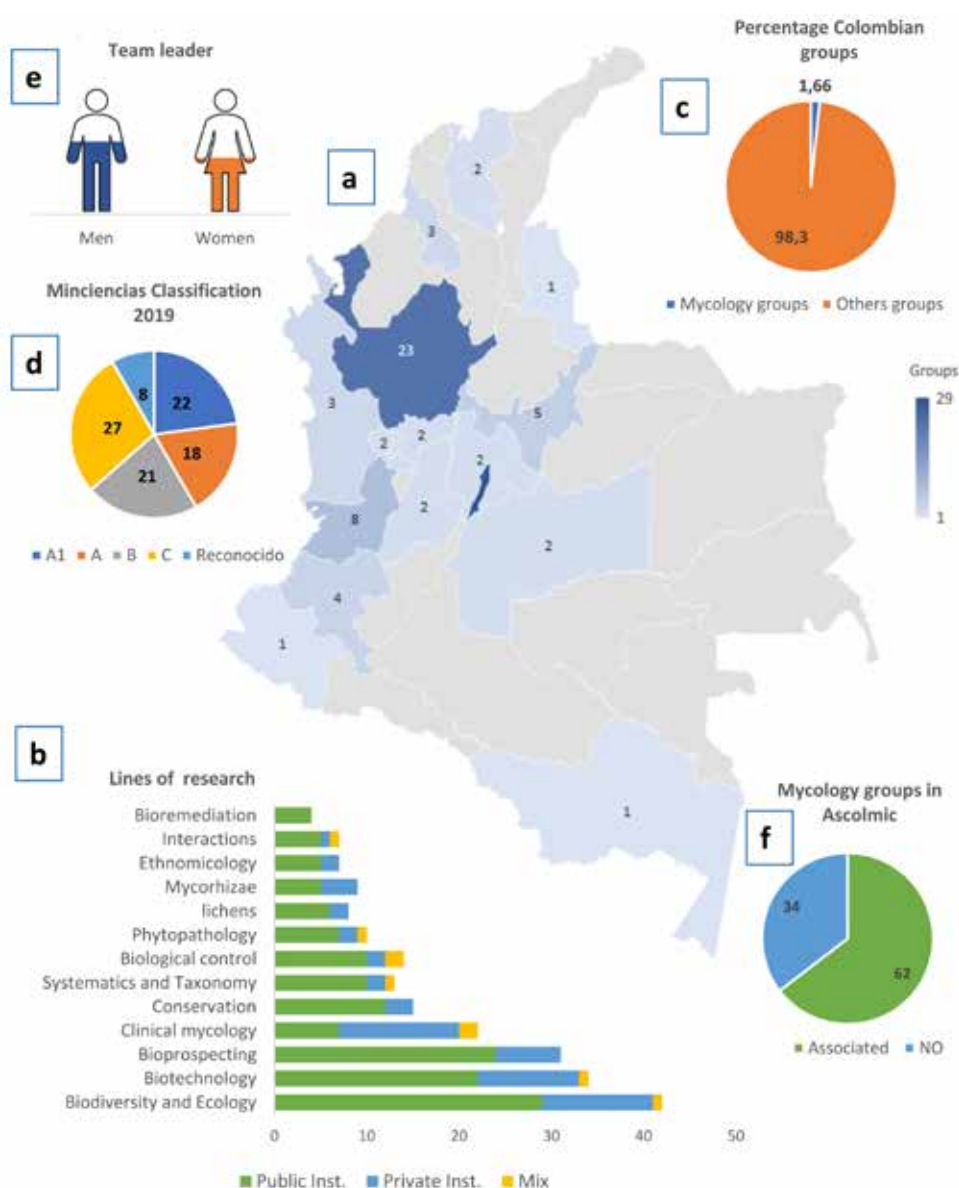


FIGURE 4. A Mycological Research groups in Colombia (MRGC) 2019-2021. B Research lines vs affiliation of the groups to the public (in green), private (in blue) and mixed research entities (in yellow) (see supplementary file 1 for additional information). C Percentage MRGC with others. D MRGC Classified Minciencias 2019-2020. E MRGC Leadership. F MRGC associated with ASCOLMIC.

diversity in territories previously under the control of this guerrilla force. These biological inventories have brought great discoveries in all fields, including new species of plants. Interest in fungal diversity has only been included in a few expeditions, such as the Andean-Amazonian expedition of the department of Caquetá led by Instituto Amazónico de Investigaciones Científicas - SINCHI (Amazonic Institute of Scientific Research) (arbuscular mycorrhizae); the expedition to the municipality of Medina (Cundinamarca, Anorí) Antioquia, Vichada, and Santander (macrofungi) and the Boyacá-Bio expedition led by the IAVH and Royal Botanic Gardens, Kew, which included several national and international specialists in different groups (macrofungi, arbuscular mycorrhizae, and lichens). Unfortunately, part of the material collected in that expedition was lost during shipment, but the remaining material includes several new species and multiple reports for that Colombian department.

CONCLUSIONS

The current knowledge of the Colombian funga has been the result of efforts by national and international researchers in the past 230 years. Mycology has had a historical development, completely dominated by foreigners in the early stages similar to those of other biological disciplines, with products of these investigations deposited in European and North American herbaria. Decolonisation of science began practically in the second decade of the 20th century with the creation of higher education in agricultural sciences at the Facultad de Ciencias Agrarias de Medellín (Faculty of Agrarian Sciences of Medellín) and the Servicio de Sanidad Vegetal (Plant Health Service of Colombia) of the Ministry of Industries, together with Colombian scientists trained locally or abroad who began to work locally in different areas of mycology. However, mycology has flourished in the past 50 years, thanks to Colombian mycologists. During this time, the current research lines and groups have been established, and collaborations have also been established with foreign colleagues from various parts of the world, but mostly from North America and Europe. Currently, Colombian mycologists have organised their work as a group, mimicking fungi themselves, which have established multiple types of interactions with other organisms throughout time, making them one of the most successful groups of organisms and important ecosystem drivers. We hope this new mycology network will help us continue filling in the gaps in the knowledge about Colombian Funga and their uses that have been detected during the preparation of this book.

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Catalogue of Fungi of Colombia

Royal
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The *Catalogue of Fungi of Colombia* is the first comprehensive listing of the known Colombian fungi. Compiled by a team of Colombian and international mycologists from the Royal Botanic Gardens, Kew, the Humboldt Institute and numerous partner institutions, it consolidates expert-generated information linked and accessible through an online portal (*ColFungi*). The checklist is accompanied by 15 chapters written by specialists, providing perspectives on the state of knowledge on the Colombian fungi, covering a range of topics, from the diversity of the main groups of fungi and the history of mycological studies in this country, to aspects of the biogeography, ecology, biotechnology, conservation, and uses of Colombian fungi and their presence in national and international biological collections. The Catalogue is further enriched by diverse supplementary material, allowing users to explore further open questions and opportunities, to develop new ideas on the use of fungi and their conservation, and to foster social and environmental awareness.



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