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An insight into research on larger fungi in the Democratic Republic of the Congo : challenges and opportunities

Aperçu de la recherche sur les macromycètes en République démocratique du Congo : défis et opportunités

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Résumé : L'évolution de la mycologie au Congo est principalement liée à son histoire coloniale avec la Belgique. Un aperçu actualisé des défis auxquels sont confrontés les mycologues et des possibilités de recherche mycologique dans ce pays fait encore défaut. En mettant l'accent sur les études des macromycètes, cet article présente les progrès réalisés dans ce pays depuis l'époque coloniale. Cette étude historique montre que la plupart des spécimens étudiés ont en fait été récoltés par des explorateurs et des mycologues collaborant ou travaillant au Jardin botanique de Meise (anciennement Jardin botanique de l'Etat, puis Jardin botanique national de Belgique) alors que les études et inventaires réalisés par les mycologues locaux sont encore peu nombreux. La complexité de l'organisation de missions de collecte, le manque de superviseurs locaux, le manque de matériel adéquat pour les travaux de laboratoire et le coût gigantesque pour l'installation et le maintien d'un laboratoire moléculaire, expliquent le faible flux de jeunes mycologues en RDC. Leur force réside pourtant dans leur capacité à effectuer le travail essentiel de l'analyse morphologique (macroscopie, microscopie) des spécimens d'herbiers, combinée à l'accès aux principaux points chauds de diversité fongique et à la possibilité de prendre en charge la logistique. La mise en œuvre des buts/objectifs de l'IPBES et la collaboration avec les laboratoires moléculaires, qui ont besoin de spécimens de qualité provenant d'Afrique tropicale, sont des opportunités majeures pour les mycologues congolais de trouver des partenaires internationaux, d'avoir accès à des financements et de collaborer à des publications internationales.

Mots-clés : Aperçu historique, Mycologie, République démocratique du Congo.

Abstract : The evolution of mycology in the Democratic Republic of the Congo (DRC) is mostly linked to its colonial history with Belgium. An up-to-date overview of the challenges faced by mycologists and opportunities for mycological research in this country is still lacking. With an emphasis on studies of larger fungi, this paper presents the progress made in this country from the colonial era to the present day. This historical survey shows that most of the specimens studied were actually gathered by explorers and mycologists collaborating with or working at Meise Botanic Garden (formerly Jardin botanique de l'Etat, then National Botanic Garden of Belgium) when studies and inventories made by local mycologists are still few. The complexity of organizing collecting field trips, the scarcity of trained local supervisors, the lack of adequate materials for laboratory work, and the gigantic cost for installing and sustaining a molecular lab, explain the low influx of young mycologists from the DRC. Yet their strength lies in their ability to perform the essential work of morphological analysis (macroscopy, microscopy) of herbarium specimens, combined with access to major fungal hotspots and the convenience to arrange logistics. Implementation of IPBES goals/objectives and collaboration with molecular labs, in need of quality specimens from tropical Africa, are major opportunities for Congolese mycologists to find international partners, funding and opportunities of international publications.

Keywords : Historical survey, Mycology, Democratic Republic of the Congo.

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INTRODUCTION

In tropical Africa, the history of mycology mostly goes back to the colonial era (EYI NDONG et al., 2011; PIEPENBRING, 2015; PIEPENBRING & NOUROU, 2017; PIEPENBRING et al. 2018). The mycological investigation in the former Belgian Congo, now the Democratic Republic of the Congo (DRC), is linked to its colonial history (RAMMELOO, 1994). In spite of its extremely high fungal diversity, only few mycological investigations were undertaken during colonial times. With the exception of phytopathology, receiving attention because of its obvious economic impact, other fields of mycology were neglected. This historical lack of interest in mycological research is explained by several reasons. Initially mycological investigations were exclusively carried out by scientists and/or explorers from temperate regions, mostly from Belgium. Usually they stayed in DRC for relatively short periods collecting and inventorying primarily vascular plants and animals, rather than fungi. After its independence in 1960, the country suffered severe political and economic instability, which in turn blocked or hampered most of the scientific activities (SHAPIRO & TOLLENS, 1992).

This paper sheds light on the progress made in the study of larger fungi from DRC, in particular from the colonial era to the present day. We present an up-to-date overview on recent studies conducted by local mycologists, as well as challenges and opportunities for mycological study in DRC.

PIONEERING INVESTIGATIONS AND IMPORTANT PUBLICATIONS AND COLLECTIONS

Most of the pioneering mycological investigations in DRC were done by explorers and/or mycologists working with/at Meise Botanic Garden (Table 1). With 10,152 specimens and 825 type specimens collected in DRC, the collection kept at Meise Botanic Garden (BR, Belgium) is by far the largest worldwide and constitutes the basis of almost all the studies carried out in this country.

Table 1. Publications on larger fungi from the DR Congo in chronological order (in **bold**: Congolese author(s)).

Authors	Publications
De Wildeman & Durand, 1901	Reliquiae Dewevreanae
Gillet & Pâque, 1910	Plantes principales de la région de Kisantu, leur nom indigène, leur nom scientifique, leurs usages
Beeli, 1928a	Contribution à l'étude de la Flore mycologique du Congo. Champignons récoltés par Mme Goossens et déterminés par M. Beeli. Fungi Goossensiani V
Beeli, 1928b	Contribution à l'étude de la flore mycologique du Congo. Fungi Goosseniani VI
Beeli, 1929	Contribution à l'étude de la flore mycologique du Congo. Fungi Goossensiani VII
Beeli, 1931	Contribution à l'étude de la flore mycologique du Congo. Fungi Goossensiani VIII
Beeli, 1932	Contribution à l'étude de la flore mycologique du Congo. Fungi Goosensiani IX
Beeli, 1933	Contribution à l'étude de la flore mycologique du Congo. Fungi Goossensiani X
Beeli, 1935	Flore iconographique des champignons du Congo 1. Amanita, Amanitopsis & Volvaria
Beeli, 1936	Flore iconographique des champignons du Congo 2. Lepiota & Annularia
Beeli, 1938	Contribution à l'étude de la flore mycologique du Congo. Fungi Goossensiani XI

Heim, 1951	Les Termitomyces du Congo belge recueillis par Madame M. Goossens-Fontana
Heinemann, 1954	Flore iconographique des champignons du Congo 3. Boletineae
Heim, 1955a	Flore iconographique des champignons du Congo 4. Lactarius
Heim, 1955b	Les Lactaires d'Afrique intertropicale (Congo Belge et Afrique noire Française)
Heinemann, 1956	Flore iconographique des champignons du Congo 5. Agaricus I
Heinemann & Romagnesi, 1957	Flore iconographique des champignons du Congo 6. Agaricus II et Pilosace, Rhodophyllus
Heim, 1958	Flore iconographique des champignons du Congo 7. Termitomyces
Heinemann, 1959	Flore iconographique des champignons du Congo 8. Cantharellineae
Le Gal, 1960	Flore iconographique des champignons du Congo 9. Discomycetes
Boidin, 1961	Flore iconographique des champignons du Congo 10. Stereum s.l.
Steyaert, 1961	Genus Ganoderma (Polyporaceae). Taxanova 1
Dennis, 1962	Flore iconographique des champignons du Congo 11. Xylarioideae & Thamnomycetoideae
Steyaert, 1962	Genus Ganoderma (Polyporaceae). Taxanova 2
Dissing & Lange, 1963	Flore iconographique des champignons du Congo 12. Gasteromycetales I
Dissing & Lange, 1964	Flore iconographique des champignons du Congo 13. Gasteromycetales II
Singer, 1964	Marasmius congolais recueillis par Mme Goossens-Fontana et d'autres collecteurs belges
Singer, 1965	Flore iconographique des champignons du Congo 14. Marasmius
Heinemann, 1966	Flore iconographique des champignons du Congo 15. Hygrophoraceae, Laccaria et Boletineae II (Complément)
Corner & Heinemann, 1967	Flore iconographique des champignons du Congo 16. Clavaires, Thelephoraceae et Chlorophyllum
Steyaert, 1967	Les Ganoderma palmicoles
Geesteranus & Heinemann, 1970	Flore iconographique des champignons du Congo 17. Hydnum s.l. et Macrolepiota
Pegler, 1971	Lentinus Fr. and related genera from Congo-Kinshasa (Fungi)
Pegler & Heinemann, 1972	Flore illustrée des champignons d'Afrique centrale 1. Lentineae (Polyporaceae), Schyzophyllaceae et espèces lentinoïdes et pleurotoïdes des Tricholomataceae
Zoberi, 1972	Tropical macrofungi.
Heinemann & Thoen, 1973	Flore illustrée des champignons d'Afrique centrale 2. Leucocoprineae (Agaricaceae), Cystoderma (Tricholomataceae)
Thoen, Parent & **Lukungu**, 1973	L'usage des champignons dans le Haut-Shaba (République du Zaïre)
Watling & Heinemann, 1974	Flore illustrée des champignons d'Afrique centrale 3. Bolbitiaceae
Heinemann, 1975	Flore illustrée des champignons d'Afrique centrale 4. Volvariella

Heim, 1977	Termites et champignons. Les champignons termitophiles d'Afrique noire et d'Asie méridionale.
Heinemann & Thoen, 1977	Flore illustrée des champignons d'Afrique centrale 5. Leucocoprinus (Agaricaceae), Asproinocybe (Tricholomataceae)
Parent & Skelton, 1977	Termitomyces microcarpus, champignon comestible et source d'une enzyme protéolytique
Parent & Thoen, 1977	Food value of edible mushrooms from Upper Shaba region
Pegler, 1977	A preliminary agaric flora of East Africa
Horak & Heinemann, 1978	Flore illustrée des champignons d'Afrique centrale 6. Pluteus (Pluteaceae), Volvariella (Pluteaceae). Complements
Heinemann & Rammeloo, 1980	Flore illustrée des champignons d'Afrique centrale 7. Leucocoprineae p.p. (Agaricaceae), Gyrodontaceae p.p. (Boletineae)
Rammeloo, 1980	Flore illustrée des champignons d'Afrique centrale 8 & 9. Trichiales (Myxomycetes)
Buyck & Rammeloo, 1983	Flore illustrée des champignons d'Afrique centrale 11. Diderma (Physarales, Myxomycetes), Echinosteliales & Stemonitales (Myxomycetes)
Heinemann & Rammeloo, 1983	Flore illustrée des champignons d'Afrique centrale 10. Gyrodontaceae (Boletineae)
Pegler, 1983	The genus Lentinus: a world monograph
Heinemann & Rammeloo, 1986	Flore illustrée des champignons d'Afrique centrale 12. Agariceae (Agaricaceae), Paxillaceae (Boletineae)
Heinemann & Rammeloo, 1987	Flore illustrée des champignons d'Afrique centrale 13. Phylloporus (Boletineae)
Buyck, 1989a	New taxa of Central African Russulaceae
Heinemann & Rammeloo, 1989	Flore illustrée des champignons d'Afrique centrale 14. Suillus (Boletaceae, Boletineae), Tubosaeta (Xerocomaceae, Boletinae)
Buyck, 1990	Nouveaux taxons infragénériques dans le genre Russula Persoon en Afrique centrale
Musibono, **Habari** & Paulus, 1991	Essai de culture mycélienne de quelques champignons comestibles zaïrois sur milieu semi-synthétique
Buyck, 1993	Flore illustrée des champignons d'Afrique centrale 15. Russula I (Russulaceae)
Buyck, 1994	Flore illustrée des champignons d'Afrique centrale 16. Russula II (Russulaceae)
Verbeken, 1995	Studies in tropical African Lactarius species. 1. Lactarius gymnocarpus R. Heim ex Singer and allied species
Verbeken, 1996	Studies in tropical African Lactarius species. 4. Species described by P. Hennings and M. Beeli
Buyck, 1997	Flore illustrée des champignons d'Afrique centrale 17. Russula III (Russulaceae)
Degreef, Malaisse, Rammeloo & Baudart, 1997	Edible mushrooms of the Zambezian woodland area. Nutritional and ecological approach

Malaisse, 1997	Se nourrir en forêt claire africaine. Approche écologique et nutritionnelle.
Verbeken & Walleyn, 1999	Studies in tropical African Lactarius species. 7. A synopsis of the section Edules and a review on the edible species
Balezi & Decock, 2009	Inonotus rwenzorianus (Basidiomycetes, Hymenochaetales): an undescribed species from the Rwenzori Mountain range
De Kesel & Malaisse, 2010	Edible Wild Food: Fungi. In: Malaisse F. How to Live and Survive in Zambezian Open Forest (Miombo Ecoregion)
Dibaluka, **Lukoki**, De Kesel & Degreef, 2010	Essais de culture de quelques champignons lignicoles de la région de Kinshasa (RD Congo) sur divers substrats lignocellulosiques
Malaisse, 2010	How to live and survive in Zambezian Open Forest (Miombo Ecoregion)
Diansambu, **Dibaluka**, **Lumande** & Degreef, 2015	Culture de trois espèces fongiques sauvages comestibles du groupement de Kisantu (RD Congo) sur des substrats ligno-cellulosiques compostés
De Kesel, Amalfi, **Kasongo**, Yorou, Raspé, Degreef & Buyck, 2016	New and interesting Cantharellus from tropical Africa.
De Kesel, **Kasongo** & Degreef, 2017	Champignons comestibles du Haut-Katanga (RD Congo)
Milenge, **Nshimba**, **Masumbuko**, Degreef & De Kesel, 2018a	Uses and importance of wild fungi: traditional knowledge from the Tshopo province in the Democratic Republic of the Congo
Milenge, **Nshimba** & De Kesel, 2018b	Macrofungal diversity in Yangambi Biosphere reserve and Yoko reserve rainforests of the Democratic Republic of the Congo
Milenge, **Nshimba**, **Masumbuko**, **Nabahungu**, Degreef & De Kesel, 2019	Host plants and edaphic factors influence the distribution and diversity of ectomycorrhizal fungal fruiting bodies within rainforests from Tshopo, Democratic Republic of the Congo
Degreef, **Kasongo**, Niyongabo & De Kesel, 2020	Edible mushrooms, a vulnerable ecosystem service from African miombo woodlands
Milenge & De Kesel, 2020	Wild edible ectomycorrhizal fungi: an under-utilized food resource from rainforests of Tshopo province in the Democratic Republic of the Congo
Kasongo, De Kesel, Noret, Meerts, Degreef & **Shutcha**, 2020	Trace Metals and Safe Consumption of Edible Fungi from Upper-Katanga (DR Congo)
Kasongo, De Kesel, **Kabange**, Bostoen & Degreef, 2021	Edible fungi consumed by the Lamba and Bemba People of Haut-Katanga (DR Congo)

Table 2 highlights the contributions of 28 collectors, whose material represents 95% of all available collections and includes 97% of the type specimens originating from DRC. The oldest fungal specimen ever collected in DRC is a gift from F. Demeuse dating back to 1891. It originates from "Mont Bangu", renamed Mount Mangengenge and located 10 km from Ndjili airport near Kinshasa. The earliest publication relating to fungi from DRC is the "*Reliquiae Dewevreanae*" (DE WILDEMAN & DURAND, 1901). This publication is based on fungi collected in DRC by A.P. Dewèvre between 1891 and 1895. This botanist collected mostly vascular plants, but also delivered some polypores with descriptions. Almost 30 years later, from 1923 to 1956, Mrs M. Goossens-Fontana produced an impressive collection that still today constitutes the backbone of our knowledge of Congolese fungi. Her collection is deposited at Meise Botanic Garden (BR) and counts 1768

specimens of larger fungi, most of them accompanied with fieldnotes and true-to-life watercolor illustrations. It constitutes the most important fungal collection from DRC. It is particularly rich in type specimens (596 in total) and forms the basis of "*Fungi-Goossensiani*" (BEELI, 1928a, b, 1929, 1931, 1932, 1933, 1938), the first series of publications dedicated to macrofungi from DRC. Later this series was followed by the "*Flore iconographique des champignons du Congo*" (BEELI 1935, 1936; HEINEMANN 1954, 1956, 1958, 1959; HEIM, 1955a, 1958; HEINEMANN & ROMAGNESI, 1957; SINGER, 1965; HEINEMANN, 1966; CORNER & HEINEMANN, 1967; GEESTERANUS & HEINEMANN, 1990). In the early seventies it was followed by the "*Flore illustrée des champignons d'Afrique centrale*" (PEGLER & HEINEMANN, 1972; HEINEMANN & THOEN, 1973, 1977; WATLING & HEINEMANN, 1974; HEINEMANN, 1975; HORAK & HEINEMANN, 1978; HEINEMANN & RAMMELOO, 1980, 1983, 1986, 1987, 1989; BUYCK, 1993, 1994, 1997). The latter included not only the collections made by Mrs. Goossens-Fontana but also material from other researchers, collected in tropical Africa, i.e. outside DRC. With the growing necessity to study and include more material from all over tropical Africa, it was decided in 2007 to replace the "*Flore illustrée des champignons d'Afrique centrale"* by the "*Fungus Flora of Tropical Africa"* (ANTONIN, 2007, 2013; VERBEKEN & WALLEYN, 2010). The series received a new name, format and presentation, and a much larger coverage of the continent.

In order to increase access and promote African mycology, a free and fully searchable online version of the three series (all 37 volumes) was made available in 2018 (www.FFTA-online.org). The website gives access to descriptions, keys and illustrations of about 1500 fungal taxa from tropical Africa.

Table 2. Main collectors of specimens of larger fungi in DR Congo

Collectors	**Years of collection**	**# specimens**	**# types**	**Main collection sites (province)**
Bequaert J.	1914-1915	56	2	Penge (Haut-Uele)
Buyck B.	1984	269	18	Kisangani (Tshopo)
De Kesel A.	2012-2018	1022	4	Mikembo sanctuary (Haut Katanga), Yangambi (Tshopo)
De Loose	1931-1933	41	11	Lubumbashi (Haut-Katanga)
De Witte G.F.	1934-1957	217	14	NP Upemba (Haut-Lomami), NP Virunga (Nord-Kivu)
Degreef J.	1990-2017	398	2	Luiswishi, Mikembo sanctuary (Haut-Katanga), NP Kahuzi-Biega (Sud-Kivu)
Dewèvre A.	1895-1896	39	5	Lukolela (Equateur)
Dibaluka Mpulusu S.	2004-2008	588	0	Kimvula (Kongo-Central)
Fassi B.	1934-1957	710	7	Yangambi (Tshopo)
Ghesquière J.	1922-1926	56	5	Kolwezi (Lualaba)
Gillet J.	1900-1911	80	10	Kisantu (Kongo-Central)
Goossens-Fontana M.	1923-1956	1768	596	Panzi (Sud-Kivu)
Hendrickx F. L.	1938-1953	201	0	NP Kahuzi-Biega (Sud-Kivu)
Lebrun J.	1929-1932	93	0	Bandundu (Kwilu), Angodia (Bas-Uele)
Louis J.	1932-1939	218	17	Yangambi (Tshopo)
Milenge Kamalebo H.	2013-2016	49	0	Yangambi (Tshopo)
Pauwels L.	1975-1979	38	1	Kisantu (Kongo-Central)
Pynaert L.	1906-1907	49	2	Eala (Equateur)
Rammeloo J.	1972-1986	154	12	Irangi (Nord-Kivu)
Rizinde J.C.	2018	70	0	NP Kahuzi-Biega (Sud-Kivu)
Schmitz-Levecq M.C.	1959-1961	306	29	Kipopo (Haut-Katanga)

Schreurs J.	1986	609	14	Shinkolobwe, Biano, Luiswishi (Haut-Katanga)
Soyer D.	1945-1949	244	7	Keyberg-Lubumbashi (Haut-Katanga)
Staner P.	1926-1931	297	5	Bikoro, Eala (Equateur)
Steyaert R.	1921-1948	82	1	Yangambi (Tshopo), Bambesa (Bas-Uele)
Thoen D.	1971-1973	639	7	Kipopo, Luiswishi (Haut-Katanga)
Van Meel L.	1946-1947	129	2	Tumbwe (Tanganyika)
Vanderyst H.	1906-1934	1290	33	Ipamu (Kwilu), Kwango (Maï-Ndombe), Kisantu (Kongo-Central)
Total # specimens		**9712**	**804**	
% from DRC		**95**	**97**	

During the last three decades, most of the publications relating to the larger fungi of DRC focused mainly on taxonomy and diversity of macrofungi (BALEZI & DECOCK, 2009; DE KESEL et al. 2016, 2017; MILENGE et al., 2018b; MILENGE et al., 2019), as well as the edible species and their nutritional value (MALAISSE 1985, 1997; DEGREEF et al. 1997; DE KESEL & MALAISSE, 2010). More recently, identification of edible taxa and factors affecting natural production of larger fungi were studied in both dense rainforest and miombo woodland plots (MILENGE et al., 2018a; MILENGE & DE KESEL, 2020; DE KESEL et al., 2017; DEGREEF et al., 2020). Other mycologists (DIBALUKA et al., 2010; DIANSAMBU et al., 2015) worked on the cultivation of imported but also wild local saprotrophic species, especially taxa in *Auricularia, Lentinus, Pleurotus* and *Schizophyllum*.

FUNGAL DIVERSITY KNOWLEDGE GAPS

The analysis of the BR herbarium mycological database shows the number and the distribution of specimens collected in DRC since 1891 (Fig. 1). The most collected area is the region of Lubumbashi (Upper Katanga) characterized by its miombo vegetation. These open forests are particularly interesting for the study of fungi as they are dominated by trees (Caesalpiniaceae, Phyllanthaceae and some Dipterocarpaceae) that associate with a great number of ectomycorrhizal fungi. Most of the type specimens of *Cantharellus*, *Russula*, Boletales, and milk caps (*Lactarius* and *Lactifluus*), all ectomycorrhizal taxa that were described from DRC originate from this region. In the past, many studies were carried out at Luiswishi (S 11°40' - E 27°27'), a site combining miombo, savannah, and remnants of dry evergreen forest (muhulu). More recently, taxonomic and ecological studies were initiated in the Mikembo reserve (S 11°28' - E 27°40'), a private sanctuary dedicated to miombo preservation.

Other important collection sites are the Kisantu Botanical Garden (S 5°08' E 15°06') and the Kimvula Reserve (S 5°43' E 15°56') in the surroundings of Kinshasa (Kongo-Central). The Kimvula reserve is characterized by a mixture of savannas, woodlands and open forests and even some remnants of dense rainforests from the Guineo-Congolian ecoregion. In the Kisantu Botanical Garden, local trees are mixed with fruit trees and most fungal collections are saprotrophic taxa. The larger fungi in the dense forests around the "Institut National des Etudes et Recherches Agronomiques" of Yangambi (INERA) (formerly INEAC) (N 0°52' - E 24°27') in the Tshopo province, were also largely inventoried. Vegetation in this region is semi-deciduous tropical rainforest with remnants of evergreen rainforest, transition forest, agricultural land, fallow land and swamp forest. Forest regeneration, mostly after slash-and-burn agriculture, results in a mosaic of different stages of secondary forests, mostly dominated by *Musanga cecropioides* R.Br. & Tedlie, and hosting saprotrophic fungi. Climax vegetation in this region is mixed semi-deciduous forest and dense forests dominated by ectomycorrhizal trees. The latter are particularly rich in both saprotrophic and ectomycorrhizal fungi and consist in monodominant forests of *Gilbertiodendron dewevrei* (De Wild.) J. Leonard, monodominant forests of *Brachystegia laurentii* (De Wild.) Hoyle, and gallery forests with Uapaca guineensis Müll.-Arg. (VAN DE PERRE et al. 2018).

The most collected protected areas are Kahuzi-Biega and Virunga National Parks in Eastern DRC. Both are characterized by montane and bamboo forests rich in saprotrophic fungal species. The primary forests and old secondary forests are home for several wood-decaying species belonging namely to the Aphyllophorales, Hymenochaetales and Polyporales orders (BALEZI & DECOCK, 2009).

The collection sites of Mrs Goossens-Fontana which, as noted above, revealed most of the new taxa discovered in DRC, are worth mentioning. She travelled a lot in the country from 1923 to 1956 and collected mainly in Panzi (Sud-Kivu) (S 2°32' - E 28°58'), Eala (Equateur) (N 0°03' - E 18°19'), and Binga (Sud-Ubangi)

(N 2°28' - E 20°31'). Panzi was a site in the south part of Bukavu which was characterized by plantations of exotic trees combined to some remnants of montane forests. Most of specimens of *Agaricus* described from eastern montane region of the DRC originate from this site. The Eala and Binga regions are mainly characterized by lowland rainforests hosting wide range of saprotrophic and ectomycorrhizal fungi.

Fig. 1 clearly indicates that most of the specimens were collected in dense forests from the Congo basin, followed by the wooded savannas and miombo woodlands of the Zambezian region. Wooded savannas of Western DRC and montane forests of Eastern DRC have been relatively well inventoried. Most important gaps in mycological inventories concern the savanna woodlands from the north-east of the country.

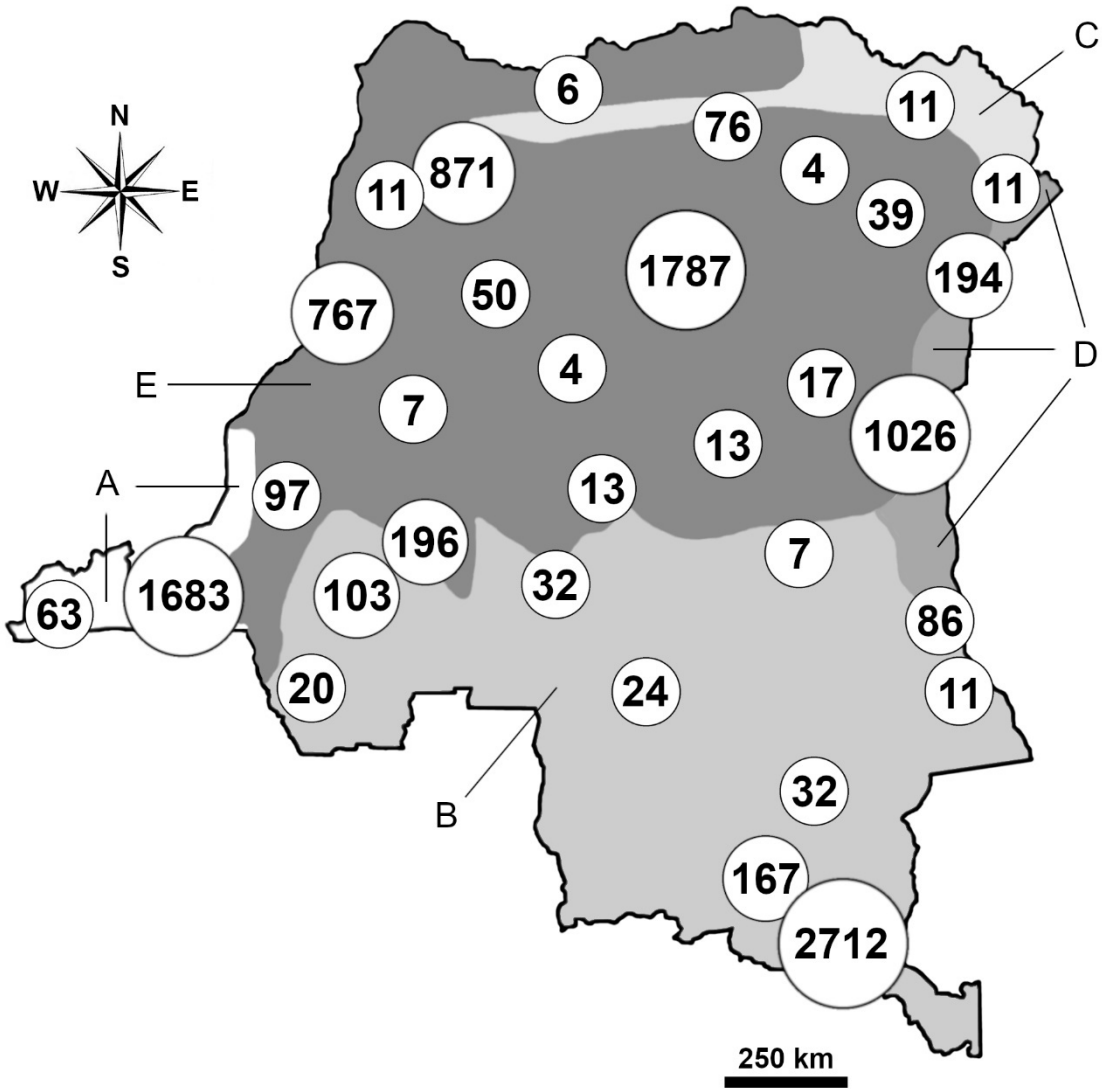

Figure 1. Distribution and number of herbarium specimens of larger fungi from DRC kept in BR herbarium. A. West-Congolese savannas; B. Zambezian savannas and miombo; C. North-East Congolese savannas; D. East-Congolese montane forests; E. Congo Basin dense forests.

The present study of the distribution of fungal specimens in DRC is useful for planning future fungal inventories as it clearly reveals knowledge gaps in the collection sites. Although hosting high number of specimens collected, the dense forests of the Congo Basin are clearly understudied and could reveal many new taxa. Numerous habitats are hardly or not at all screened for fungi. Only very few "complete" inventories of fungi exist in some specific sites (DE KESEL et al., 2018; MILENGE et al., 2019). Due to this severe taxonomical impediment, adequate mycological information is also lacking for several ecoregions. This is the case of the eastern part of the Congo basin, with forests extending between 650 and 1200 m altitude (WHITE, 1983) and dominated by *Michelsonia microphylla, Julbernardia seretii* and *Staudtia stipitata.* There is little

doubt that many fungal species are still undescribed (new for science), and many existing taxa are still only known from the type locality. Several individual species showing an abnormally wide distribution and host range may actually represent a species complex, i.e. grouping different sibling species, each related to different habitats and hosts.

CHALLENGES FOR MYCOLOGISTS

Let there be no doubt that organizing mycological field trips is still a major challenge in most tropical African countries (DE KESEL 2001; PIEPENBRING et al. 2018). During the rainy season, access to sampling sites or areas of mycological interest often becomes problematic as dirt roads become unusable (MILENGE et al. 2019). Local guides are essential as the Congo River and its tributaries often create swamps by flooding large parts of the forest (BEERNAERT 1999, AMANI et al. 2013). In addition, mycologists planning fieldwork in DRC often face bureaucratic challenges in complying to the Nagoya protocol, as well as with national and local regulations. Months are often needed to obtain the obligatory and necessary documents, i.e. visum, access to sites, collecting and exporting permits and certificates. Finally complex and often expensive logistic aspects, as well as health and safety issues, need to be resolved before going camping in remote study sites. Due to high temperatures and air humidity, the preservation of sporocarps is always challenging (DE KESEL 2001; PIEPENBRING et al. 2018). The risk of losing precious collections is not negligible. As electricity is often not available in the field, electric mushroom dryers are not useful. The most suitable field dryers seem to be the ones using a hurricane lamp (DE KESEL 2001). However, the success and reliability of this type of drying systems depends from the user's experience to control the heat. Excessive heat will burn or render specimens useless for molecular analysis, while insufficient heat will extend the drying time to the point that the specimens rot. Since exsiccata are hygroscopic, the freshly dried specimens must be kept dry at all times otherwise they will quickly mold and deteriorate (PIEPENBRING et al. 2018). Local markets do not always offer a good and practical solution for long-term conservation. The best way is to store fully dried specimens in transparent plastic bags, preferably with a nearly air-tight zip lock and some silicagel. As these are often not available at the local market, they need to be brought in from abroad.

The main method for fungal inventories used by most mycologists working in DRC is almost exclusively based on aboveground observations of sporocarps (HUECK 1951; LODGE et al. 2004; EYI NDONG et al. 2011; DE KESEL et al. 2002, 2017). Only one study using below ground samples exists (TEDERSOO et al. 2014). The collected specimens provide information on macroscopical and microscopical characteristics necessary for species identification. Due to a severe taxonomic impediment (lack of literature, experts and a very high percentage of undescribed taxa), adequate identification tools are lacking for the majority of tropical African species (EYI NDONG et al. 2011). This should however not stop local mycologists from collecting, photographing, describing and making exsiccata of all the taxa they find (Fig. 2).

Figure 2. Elisée Mugoli sampling edible *Lentinus squarrosulus* specimens on a dead trunk for enhancing the fungarium of the University of Bukavu.

Due to annual and seasonal fluctuations in the appearance of sporocarps, obtaining a full inventory takes time and requires frequent monitoring of specific sites (EYI NDONG et al. 2011; ANGELINI 2016; HÄRKÖNEN et al. 2015; DE KESEL et al. 2017) or permanent plots (DE KESEL et al. 2002; LODGE et al. 2004; DE KESEL et al. 2017). When properly organized and executed for some extent of time (2-3 years or preferably more), this procedure will give the best possible idea of the local diversity, phenology and even allow to detect associations with vascular plants (trees), soil parameters and land use (LODGE et al. 2004; MILENGE et al. 2019).

Molecular analysis of macrofungi has become an indispensable part in resolving taxonomic problems, and will be needed to place and name the wealth of new taxa in DRC and tropical Africa. Equipping local laboratories for both microscopical and molecular analysis of fungi, as well as the reinforcement of the north-south scientific collaboration, would be ideal for promoting Congolese mycology. As most local research institutes and Universities can't overcome the gigantic cost for installing and sustaining a molecular lab, this technique is only available via collaboration with colleagues abroad. In situations like this, mycologists with different opportunities and skills, should collaborate and look for complementarity. The interest and need for specimens from tropical Africa, expressed by molecular labs conducting global phylogenetic research, is huge and growing. This can easily be deduced from phylogenetic studies (in for example *Amanita*, *Tylopilus, Lentinula*) that actually lack specimens from continental tropical Africa (CAI et al. 2014; CHAKRABORTY et al. 2018; VARGA et al. 2019; LOONEY et al. 2021). This shows the opportunity and the unique role local African mycologists can play in taxonomic and phylogenetic research (Fig. 3).

Figure 3. Back from the field, careful processing and preservation of specimens is necessary for future microscopic and molecular analyses.

It also means that successful collaboration will largely depend from the quality and choice of material they accumulated in their fungarium. It is often not seen this way, but at this moment, the strength of the mycologists from DRC, and the whole of tropical Africa, resides in the access to major fungal hotspots, the convenience to arrange logistics (including permits), and most importantly the capacity to do most (if not all) the classical morphological analysis of specimens (macroscopy, microscopy). It cannot be stressed enough that this classical work is, and always will be, essential and indispensable. Well preserved fungal exsiccata from tropical Africa, accompanied by high quality documentation (descriptions, microscopic analysis, drawings, micro and macro photographs) are very valuable and sought after (VARGA et al. 2019). They are key to: a) joining an international team; b) becoming co-author on papers and; c) getting funded for fieldwork and standard laboratory equipment (computers, microscopes, digital cameras, scanners, driers and other fungarium equipment). Being specialized in identifying fungi, local mycologists are also privileged to use their knowledge (of local languages

and customs) to initiate ethnomycological studies. Local use of fungi in Katanga, as well as aspects related to their quality as a food source, has recently been addressed in DRC (KASONGO et al. 2020, 2021).

Ethnomycology has gained tremendous interest, both internationally and in the DRC. As edible and useful fungi constitute an ecosystem service in DRC (DE KESEL et al. 2017), including ethnomycology in scientific mycological programs is a must for local mycologists. Field collecting experience (Fig. 4), combined with ethnomycological surveys in local villages (Fig. 5), are needed to explain the differential interest local people have for edible fungi. It can also help elaborate whether edible ectomycorrhizal fungi, as an ecosystem service, can be used as an incentive for sustainable use, reafforestation or forest conservation (DE KESEL et al. 2017; MILENGE & DE KESEL 2020).

Figure 4. Jean-Claude Rizinde and Jérôme Degreef examining specimens of edible mushrooms they collected in Kahuzi-Biega National Park.

Figure 5. Héritier Milenge collecting ethnomycological data from villagers during a survey near Yangambi.

In this context the list of edible ectomycorrhizal fungi of the world, counting 970 taxa was erected by PÉREZ-MORENO et al. (2021). Due to numerous omissions of African taxa and the exclusion of some toxic taxa (in *Scleroderma*, *Hebeloma*, *Paxillus* and *Tricholoma*), the list of edible ECM taxa in the world counts at least 1001 species. So far Sub-Saharan tropical Africa (without South Africa) counts 150 edible ectomycorrhizal taxa, 99 (66%) of which occur in DR Congo. The impact of local mycologists, joining research since the nineties, has been important. In fact, since the last complete review from 1994 (RAMMELOO & WALLEYN 1993, WALLEYN & RAMMELOO 1994), the number of edible ECM fungi, known from tropical Africa, has increased from 81 to 150 (+69, 85% increase) taxa, and the ones from DRC from 55 to 99 taxa (+44, 80% increase). Considering the relatively small area covered by ethnomycological surveys in DRC, we are just scratching the surface. Contributing to a better understanding of ecosystem services delivered by useful fungi and proposing science-based solutions for conservation, fully complies with the goals of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES). In order to propose strategies or respond to requests from decision makers, mycologists from DRC should assess the state of biodiversity and of the ecosystem services it provides to people and society. Developing projects of this kind can get funded by organizations interested in combating poverty, sustainable use and conservation of habitats (http://www.taxonomy.be/funding/funding/compendium-funding-africa-2009.pdf).

CONCLUSIONS AND PERSPECTIVES

In DRC, most studies dedicated to macrofungi were conducted by foreign mycologists, primarily interested in systematics and taxonomy. Only recently, local mycologists started to screen specific sites and conducted their own research (Fig. 6, comp. PIEPENBRING et al. 2020). Today, an increasing number of junior and senior mycologists, affiliated to Congolese universities and research centers, make important mycological contributions and actively promote mycology in their academic communities. In order to increase access to data, historically important taxonomic contributions have been placed online, but as many habitats are insufficiently or not explored, the severe taxonomic impediment persists.

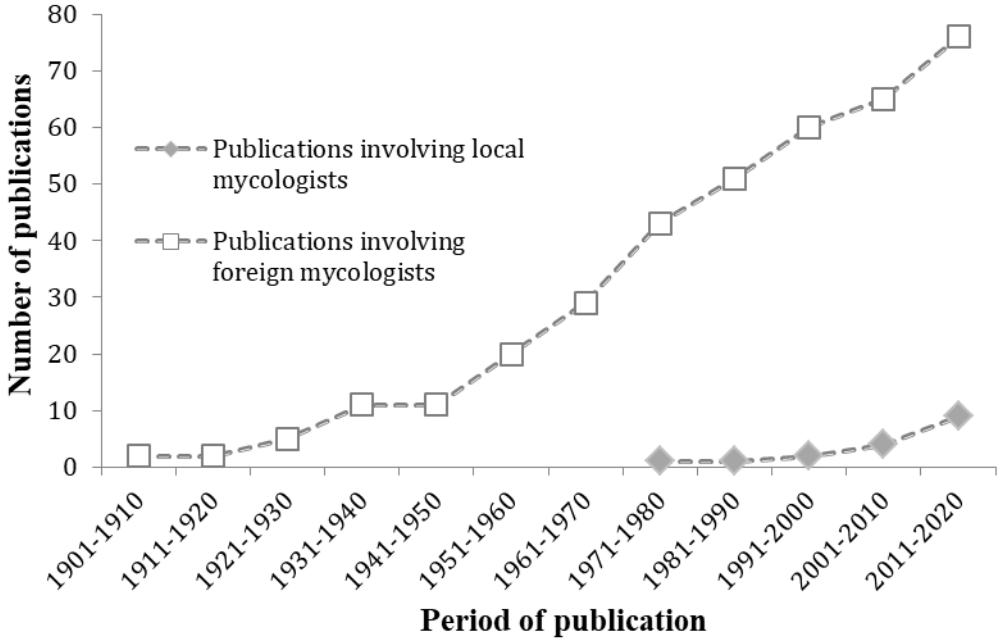

Figure 6. Cumulative curves showing the implication of Congolese and foreign mycologists in publications related to tropical African macrofungi.

The state of mycology in DRC is not really different from other countries in Africa (GRYZENHOUT et al. 2012) or other ill-explored parts of the world. The gap between the number of described species and the estimated number of species is enormous (HAWKSWORTH 2001, 2017; MUELLER & SCHMIT 2007; SCHMIT & MUELLER, 2007). To date a huge fraction of the Congolese fungal species remain undescribed and many taxa are only known from their type locality. The opportunities for mycologists are huge and totally untapped. We analyzed some of the challenges faced by mycologists working in DRC and state that prioritizing the study of ectomycorrhizal and useful fungi from DRC, as a biocultural heritage, can greatly improve the development of strategies for forest conservation and sustainable use. Reafforestation with ectomycorrhizal

trees, supporting a number of locally appreciated edible mushrooms, needs to be considered and studied closely, as it helps mitigate climate change and secures both food and wood supply.

There are not enough mycologists in DRC, at least not for the amount of work ahead. This is partly because the curricula at most Universities (faculties of Biology, Agronomy and Environment and land use), dedicate only very few hours to mycology, and if so, mostly to phytopathology. Considering the huge mycological diversity in DRC and the opportunities mycology offers (HYDE et al. 2019), this should be addressed as soon as possible. We think, as also indicated by PIEPENBRING & NOUROU (2017) and GRYZENHOUT et al. (2012), training young mycologists and students is both essential and effective to boost mycological research in DRC (Fig. 7).

Figure 7. Training session by André De Kesel and Bill Kasongo at the University of Lubumbashi for launching of their key publication on edible fungi of Upper-Katanga.

It seems that the most rewarding strategy is to collaborate with mycologists abroad and to embrace complementarity within teams. Congolese mycologists can attract funding and support, especially by collecting and systematically documenting Congolese fungi. The idea is that obtaining good data and documentation does not necessarily require a huge investment. The opportunity to conduct field work from relatively close-by sites, allows Congolese mycologists to do sound plot and ethnomycological research. The cost may still be considerable, but it is very rewarding, often punctual and incomparable to the one of sustaining an operational molecular lab. By coming forward with essential/interesting material of good quality and fully documented (exsiccata), Congolese mycologists should quickly gain their place as genuine partners in international teams. Moreover, with good ecological data on edible fungi (diversity, natural productions) they can raise awareness by showing the greater value of this ecosystem service and the benefit for local people. Congolese mycologists should write and submit projects to study this complex topic which complies with IPBES and the goals of the UN Convention for Biological Diversity (CBD) and the Aichi biodiversity targets for 2010-2020, and subsequent international conventions.

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REFERENCES

AMANI A.C., MILENGE K.H., LISINGO J. & NSHIMBA H. (2013). Analyse floristique et impact du déterminisme édaphique sur l'organisation de la végétation dans les forêts de l'île Kongolo (R.D. Congo). *Geo-Eco-Trop*, **37**(2): 255-272.

ANGELINI P., BISTOCCHI G., ARCANGELI A., RUBINI A. & VENANZONI R. (2016). Inventory, diversity and communities of macrofungi in the Collestrada forest (Umbria, central Italy). *Plant Biosystems*, **150**(5): 1096-1105, https://doi.org/10.1080/11263504.2015.1108939

ANTONIN V. (2007). Fungus Flora of Tropical Africa. Volume 1. *Monograph of Marasmius, Gloiocephala, Palaeocephala and Setulipes in Tropical Africa*. National Botanic Garden of Belgium, 177 p. + plates.

BALEZI Z.A. & DECOCK C. (2009). Inonotus rwenzorianus (Basidiomycetes, Hymenochaetales): an undescribed species from the Rwenzori Mountain range, *Cryptogamie, Mycologie*, **30**(3): 225-232.

BEELI M. (1928a). Contribution à l'étude de la Flore mycologique du Congo V. Champignons récoltés par Mme Goossens et déterminés par M. Beeli. Fungi Goossensiani. *Bull. Soc. Roy. Bot. Belg*., **60**: 153-174.

BEELI, M. (1928b). Contribution à l'étude de la flore mycologique du Congo VI. Fungi Goossensiani. *Bull. Soc. Roy. Bot. Belg*., **61**: 78-107.

BEELI, M. (1929). Contribution à l'étude de la flore mycologique du Congo VII. Fungi Goossensiani. *Bull. Soc. Roy. Bot. Belg*., **62**: 56-68.

BEELI, M. (1931). Contribution à l'étude de la flore mycologique du Congo VIII. Fungi Goossensiani. *Bull. Soc. Roy. Bot. Belg*., **2**: 100-112.

BEELI, M. (1932). Contribution à l'étude de la flore mycologique du Congo. Fungi Goossensiani IX. *Bull. Soc. Roy. Bot. Belg*., **64**: 206-222.

BEELI, M. (1933). Contribution à l'étude de la flore mycologique du Congo. Fungi Goossensiani X. *Bull. Soc. Roy. Bot. Belg*., **66**: 14-31.

BEELI, M. (1935). Flore iconographique des champignons du Congo 1. Amanita, Amanitopsis & Volvaria. Jardin Botanique National de Belgique: 1-27.

BEELI, M. (1936). Flore iconographique des champignons du Congo 2. Lepiota & Annularia. Jardin Botanique National de Belgique: 29-43.

BEELI, M. (1938). Contribution à l'étude de la flore mycologique du Congo. Fungi Goossensiani XI. *Bull. Soc. Roy. Bot. Belg*., **14**: 83-88.

BERNAERT, F.R. (1999). Democratic Republic of the Congo: Development of a soil and terrain map/database. *Technical report, Institute for Land and Water Management, Catholic University of Leuven (Belgium)*, 202 p.

BERRUTI, A., BORRIELLO, R., ORGAZZI, A., BARBERA, A.C., LUMINI, E. & BIANCIOTTO V. (2014). Arbuscular mycorrhizal fungi and their value for ecosystem management. *Biodiversity - The Dynamic Balance of the Planet*: 159-191.

BOIDIN, J. (1961). Flore iconographique des champignons du Congo 10. Discomycetes. Jardin Botanique National de Belgique: 185-198, pl. 32-34.

BRUNDRETT, M. (2009). Mycorrhizas in Natural Ecosystems. *Advances in Ecological Research*, **21**: 171-313.

BUYCK, B. (1990). Nouveaux taxons infragénériques dans le genre Russula Persoon en Afrique centrale. *Bull. Jard. Bot. Nat. Belg.*, **60**: 191-211.

BUYCK, B. (1993). Flore illustrée des champignons d'Afrique centrale 15. Russula I (Russulaceae). Jardin Botanique National de Belgique: 337-407.

BUYCK, B. (1994). Flore illustrée des champignons d'Afrique centrale 16. Russula II (Russulaceae). Jardin Botanique National de Belgique: 411-542.

BUYCK, B. (1997). Flore illustrée des champignons d'Afrique centrale 17. Russula III (Russulaceae). Jardin Botanique National de Belgique: 545-598.

BUYCK, B. & RAMMELOO, J. (1983). Flore illustrée des champignons d'Afrique centrale 11. Diderma (Physarales, Myxomycetes), Echinosteliales & Stemonitales (Myxomycetes). Jardin Botanique National de Belgique: 201-244.

CAI, Q., TULLOSS, R.E., TANG, L.P., TOLGOR, B., ZHANG, P., CHEN, Z.H. & YANG, Z.L. (2014). Multi-locus phylogeny of lethal amanitas: Implications for species diversity and historical biogeography. *BMC Evolutionary Biology*, **14**: 143, http://www.biomedcentral.com/1471-2148/14/143

CHAKRABORTY, D., VIZZINI, A. & DAS, K. (2018). Two new species and one new record of the genus Tylopilus (Boletaceae) from Indian Himalaya with morphological details and phylogenetic estimations. *MycoKeys*, **33**: 103-124, https://doi:10.3897/mycokeys.33.23703

CORNER, E.J.H. & HEINEMANN, P. (1967). Flore iconographique des champignons du Congo 16. Clavaires, Thelephoraceae & Chlorophyllum. Jardin Botanique National de Belgique: 309-324.

DE KESEL, A. (2001). A mushroom dryer for the travelling mycologist. *Field mycology*, **2**(4): 3 p.

DE KESEL, A., AMALFI, M., KASONGO, B., YOROU, N S., RASPÉ, O., DEGREEF, J. & BUYCK, B. (2016). New and interesting Cantharellus from tropical Africa. *Cryptogamie, Mycologie*, **37**: 283-327, doi/10.7872/crym/v37.iss3.2016.28

DE KESEL, A., CODJIA, J.T.C. & YOROU, N.S. (2002). Guide des champignons comestibles du Bénin. Cotonou, Jardin botanique national de Belgique & Cecodi, 275 p.

DE KESEL, A., KASONGO, B. & DEGREEF J. (2017). Champignons comestibles du Haut-Katanga (RD Congo). *Abc Taxa*, **17**, 290 p.

DE KESEL, A. & MALAISSE, F. (2010). Edible Wild Food: Fungi. In: MALAISSE, F. How to live and survive in Zambezian Open Forest (Miombo Ecoregion). *Gembloux, Presses Agronomiques*: 41-56.

DE WILDEMAN, E. & DURAND, T. (1901). Reliquiae Dewevreanae. *Annales du Musée du Congo, Botanique série III*, **1**(1): 1-291.

DEGREEF, J., KASONGO, B., NIYONGABO, E. & DE KESEL, A. (2020). Edible mushrooms, a vulnerable ecosystem service from African miombo woodlands, *Biotechnol. Agron. Soc. Environ.*, **24**(2): 70-80.

DEGREEF, J., MALAISSE, F., RAMMELOO, J. & BAUDART, E. (1997). Edible mushrooms of the Zambezian woodland area. A nutritional and ecological approach. *Biotechnol. Agron. Soc. Environ.,* **1**(3): 221-231.

DENNIS, R.W.G. (1962). Flore iconographique des champignons du Congo 11. Discomycetes. Jardin Botanique National de Belgique: 199-214, pl. 35-37.

DIANSAMBU, M.I., DIBALUKA, M.S., LUMANDE, K.J. & DEGREEF, J. (2015). Culture de trois espèces fongiques sauvages comestibles du groupement de Kisantu (RD Congo) sur des substrats ligno-cellulosiques compostés. *Afrique Science*, **11**(3): 241-261.

DIBALUKA, M.S., LUKOKI, L.F., DE KESEL, A. & DEGREEF, J. (2010). Essais de culture de quelques champignons lignicoles de la région de Kinshasa (RD Congo) sur divers substrats lignocellulosiques. *Biotechnol. Agron. Soc. Environ.*, **14**(3): 417-422.

DISSING, H. & LANGE, M. (1963). Flore iconographique des champignons du Congo 12. Gasteromycetales I. Jardin Botanique National de Belgique: 215-232.

DISSING, H. & LANGE, M. (1964). Flore iconographique des champignons du Congo 13. Gasteromycetales II. Jardin Botanique National de Belgique: 233-252.

EYI NDONG, H., DEGREEF, J. & DE KESEL, A. (2011). Champignons comestibles des forêts denses d'Afrique centrale. Taxonomie et identification. *Abc Taxa*, **10**, 254 p.

GEESTERANUS, R.A.M. & HEINEMANN, P. (1970). Flore iconographique des champignons du Congo 17. Hydnum s.l. & Macrolepiota, Jardin Botanique National de Belgique: 325-337.

GILLET, J. & PAQUE, E. (1910). Plantes principales de la région de Kisantu, leur nom indigène, leur nom scientifique, leurs usages. *Ann. Mus. Congo*, *Sér. Bot.*, **5**(4): 1-120.

HÄRKÖNEN, M., NIEMELÄ, T., KOTIRANTA, H. & PIEARCE, G. (2015). Zambian mushrooms and mycology. *Norrlinia*, **29**, 207 p.

HAWKSWORTH, D.L. (2001). The magnitude of fungal diversity: the 1±5 million species estimate revisited. *Mycol. Res*., **105**(12): 1422-1432.

HEIM, R. (1951). Les Termitomyces du Congo belge recueillis par Madame M. Goossens-Fontana. *Bull. Jard. Bot. Et., Bruxelles*, **21**(3-4): 205-222.

HEIM, R. (1955a). Flore iconographique des champignons du Congo 4. Lactarius. Jardin Botanique National de Belgique: 83-97.

HEIM, R. (1955b). Les Lactaires d'Afrique intertropicale (Congo Belge et Afrique noire Française). *Bull. Jard. Bot. Et., Bruxelles*, **25**(1): 1-91.

HEIM, R. (1958). Flore iconographique des champignons du Congo 7. Termitomyces. Jardin Botanique National de Belgique: 139-151.

HEIM, R. (1977). Termites et champignons. Les champignons termitophiles d'Afrique noire et d'Asie méridionale. Paris, Boubée: 207 p.

HEINEMANN, P. (1954). Flore iconographique des champignons du Congo 3. Boletineae. Jardin Botanique National de Belgique: 51-80.

HEINEMANN, P. (1956). Flore iconographique des champignons du Congo 5. Agaricus I. Jardin Botanique National de Belgique: 99-119.

HEINEMANN, P. (1958). Flore iconographique des champignons du Congo 8. Cantharellineae. Jardin Botanique National de Belgique: 153-165.

HEINEMANN, P. (1966). Flore iconographique des champignons du Congo 15. Hygrophoraceae, Laccaria et Boletineae II (Complément). Jardin Botanique National de Belgique: 279-308.

HEINEMANN, P. (1975). Flore illustrée des champignons d'Afrique centrale 4. Volvariella. Jardin Botanique National de Belgique: 75-84.

HEINEMANN, P. & RAMMELOO, J. (1980). Flore illustrée des champignons d'Afrique centrale 7. Leucocoprineae p.p. (Agaricaceae), Gyrodontaceae p.p. (Boletineae). Jardin Botanique National de Belgique: 123-131.
HEINEMANN, P. & RAMMELOO, J. (1983). Flore illustrée des champignons d'Afrique centrale 10. Gyrodontaceae (Boletineae). Jardin Botanique National de Belgique: 173-198.
HEINEMANN, P. & RAMMELOO, J. (1986). Flore illustrée des champignons d'Afrique centrale 12. Agariceae (Agaricaceae) & Paxillaceae (Boletineae*)*. Jardin Botanique National de Belgique: 249-271.
HEINEMANN, P. & RAMMELOO, J. (1987). Flore illustrée des champignons d'Afrique centrale 13. Phylloporus (Boletineae). Jardin Botanique National de Belgique: 277-309.
HEINEMANN, P. & RAMMELOO, J. (1989). Flore illustrée des champignons d'Afrique centrale 14. Suillus (Boletaceae, Boletineae) & Tubosaeta (Xerocomaceae, Boletinae). Jardin Botanique National de Belgique: 313-335.
HEINEMANN, P. & ROMAGNESI, H. (1957). Flore iconographique des champignons du Congo 6. Agaricus II & Pilosace, Rhodophyllus. Jardin Botanique National de Belgique: 121-137.
HEINEMANN, P. & THOEN, D. (1973). Flore illustrée des champignons d'Afrique centrale 2. Leucocoprineae (Agaricaceae) & Cystoderma (Tricholomataceae). Jardin Botanique National de Belgique: 29-51.
HEINEMANN, P. & THOEN, D. (1977). Flore illustrée des champignons d'Afrique centrale 5. Leucocoprinus (Agaricaceae) & Asproinocybe (Tricholomataceae). Jardin Botanique National de Belgique: 87-104.
HORAK, E. & HEINEMANN, P. (1978). Flore illustrée des champignons d'Afrique centrale 6. Pluteus (Pluteaceae) & Volvariella (Pluteaceae) (Compléments). Jardin Botanique National de Belgique: 107-120.
HUECK, H.J. (1951). Myco-sociological methods of investigation. *Netherl. Mycol. Soc., Comm.* **30**: 84-101.
HYDE, K.D., XU, J., RAPIOR, S., JEEWON, R., LUMYONG, S., NIEGO, A.G.T., ABEYWICKRAMA, P.D., ALUTHMUHANDIRAM, J.V.S., BRAHAMANAGE, R.S., BROOKS, S., CHAIYASEN, A., CHETHANA, K.W.T., CHOMNUNTI, P., CHEPKIRUI, C., CHUANKID, B., DE SILVA, N.I., DOILOM, M., FAULDS, C., GENTEKAKI, E., GOPALAN, V., KAKUMYAN, P., HARISHCHANDRA, D., HEMACHANDRAN, H., HONGSANAN, S., KARUNARATHNA, A., KARUNARATHNA, S.C., KHAN, S., KUMLA, J., JAYAWARDENA, R.S., LIU, J-K., LIU, N., LUANGHARN, T., MACABEO, A.P.G., MARASINGHE, D.S., MEEKS, D., MORTIMER, P.E., MUELLER, P., NADIR, S., NATARAJA, K.N., NONTACHAIYAPOOM, S., O'BRIEN, M., PENKHRUE, W., PHUKHAMSAKDA, C., RAMANAN, U.S., RATHNAYAKA, A.R., SADABA, R.B., SANDARGO, B., SAMARAKOON, B.C., TENNAKOON, D.S., SIVA, R., SRIPROM, W., SURYANARAYANAN, T.S., SUJARIT, K., SUWANNARACH, N., SUWUNWONG, T., THONGBAI, B., THONGKLANG, N., WEI, D., WIJESINGHE, S.N., YAN, J.W.J., YASANTHIKA, E. & STADLER, M. (2019). The amazing potential of fungi: 50 ways we can exploit fungi industrially. *Fungal Diversity*, **97**: 1-136, https://doi.org/10.1007/s13225-019-00430-9
KASONGO, B., DE KESEL, A., KABANGE, E., BOSTOEN, K. & DEGREEF, J. (2021). Edible fungi consumed by the Lamba and Bemba people of Haut-Katanga (DR Congo). *European J. Agr. and Food Sc.*, https://doi.org/10.24018/ejfood.2021.3.3.289
KASONGO, B., DE KESEL, A., NORET, N., MEERTS, P., DEGREEF, J. & NGOY SHUTCHA, M. (2020). Trace metals and safe consumption of edible fungi from Upper-Katanga (DR Congo). *J. Food Nutr. Disor.*, **9**(2), https://*doi: 10.37532/jfnd.2020.9(2).274*
KERNAGHAN, G. (2005). Mycorrhizal diversity: cause and effect? *Pedobiologia*, **49**: 511-520.
LE GAL, M. (1960). Flore iconographique des champignons du Congo 9. Discomycetes. Jardin Botanique National de Belgique*:* 167-183, pl. 29-31.
LODGE, J., AMMIRATI, J.F., O'DELL, T.E. & MUELLER, G.M. (2004). Collecting and describing macrofungi. In: MUELLER, G.M., BILLS, G. & FOSTER, M.S. (Eds). Biodiversity of fungi: Inventory and monitoring methods. San Diego, Elsevier Academic Press: 128-158.
LOONEY, B.P, BUYCK, B., MENOLLI Jr., N., RANDRIANJOHANY, E. & HIBBETT, D. (2021). Lentinula madagasikarensis sp. nov., a relative of shiitake mushrooms from Madagascar. *Fungal Systematics and Evolution*, **8**: 1-8, https://doi.org/10.3114/fuse.2021.08.01
MALAISSE, F. (1997). Se nourrir en forêt claire africaine. Approche écologique et nutritionnelle. Gembloux, Presses agronomiques & Wageningen, CTA: 384 p.
MALAISSE, F. (2010). How to live and survive in Zambezian Open Forest (Miombo Ecoregion). Gembloux, Presses agronomiques: 422 p.
MALAISSE, F. & PARENT, G. (1985). Edible wild vegetable products in the Zambezian woodland area: a nutritional and ecological approach. *Ecol. Food Nutr.*, **18**: 43-82.

MILENGE, K.H. & DE KESEL, A. (2020). Wild edible ectomycorrhizal fungi: an under-utilized food resource from rainforests of Tshopo province in the Democratic Republic of the Congo. *J. Ethnobiol. Ethnomed.*, **16**: 8, https://doi.org/10.1186/s13002-020-0357-5

MILENGE, K.H., NSHIMBA, S.M.H. & DE KESEL, A. (2018b). Macrofungal diversity in Yangambi Biosphere reserve and Yoko reserve rainforests of the Democratic Republic of the Congo. *Int. J. Biodivers. Conserv.*, **10**(9): 348-356, doi.org/10.5897/IJBC2018.1188

MILENGE, K.H., NSHIMBA, S.M.H., MASUMBUKO, N.C., DEGREEF, J. & DE KESEL, A. (2018a). Uses and importance of wild fungi: traditional knowledge from the Tshopo province in the Democratic Republic of the Congo. *J. Ethnobiol. Ethnomed.*, **14**: 12 p., https://doi.org/10.1186/s13002-017-0203-6

MILENGE, K.H., NSHIMBA, S.M.H., MASUMBUKO, N.C., NABAHUNGU, N.L., DEGREEF, J. & DE KESEL, A. (2019). Host plants and edaphic factors influence the distribution and diversity of ectomycorrhizal fungal fruiting bodies within rainforests Tshopo, Democratic Republic of the Congo. *Afr. J. Ecol.*, **16**: 1-13, doi.org/10.1111/aje.12595

MUELLER, G.M. & SCHMIT, J.P. (2007). Fungal diversity. What do we know, what can we predict? *Biodiversity and Conservation*, **16**: 1-5, doi:10.1007/s10531-006-9117-7

MUSIBONO, E.E., HABARI, M.H. & PAULUS, J.J. (1991). Essai de culture mycélienne de quelques champignons comestibles zaïrois sur milieu semi-synthétique. *Tropicultura*, **9**: 138-139.

PARENT, G. & SKELTON, G.S. (1977). Termitomyces microcarpus, champignon comestible et source d'une enzyme protéolytique. *Les Naturalistes Belges*, **58**: 33-37.

PARENT, G. & THOEN, D. (1977). A preliminary agaric flora of East Africa. *Econ. Bot.*, **31**: 436-445.

PEGLER, D.N. & HEINEMANN, P. (1972) Flore illustrée des champignons d'Afrique centrale 1. Lentineae (Polyporaceae), Schizophyllaceae et espèces lentinoïdes et pleurotoïdes des Tricholomataceae. Jardin Botanique National de Belgique: 1-26.

PEGLER, D.N. (1971). Lentinus Fr. and related genera from Congo-Kinshasa (Fungi). *Bull. Jard. Bot. Nat. Belg.*, **41**: 273-281.

PEGLER, D.N. (1983). The genus Lentinus: a world monograph. *Kew Bull.*, *Add. Ser.*, **10**, 281 p.

PÉREZ-MORENO, J., GUERIN-LAGUETTE, A., RINALDI, A.C., YU, F., VERBEKEN, A., HERNÁNDEZ-SANTIAGO, F. & MARTÍNEZ-REYES, M. (2021). Edible mycorrhizal fungi of the world: What is their role in forest sustainability, food security, biocultural conservation and climate change? *Plants People Planet*: 1-20. https://doi.org/10.1002/ppp3.10199

PIEPENBRING, M. (2015). Introduction to mycology in the tropics. Minnesota, APS press, 366 p.

PIEPENBRING, M., LOTZ-WINTER, H. & HOFMANN, T.A. (2018). Incentives and challenges for mycologists in the tropics. *Biosystematics and Ecology Series*, **34**: 481-514.

PIEPENBRING, M. & YOROU, S.N. (2017). Promoting teaching and research on African fungi by field schools on tropical mycology in Benin. *IMA Fungus*, **8**(2): 63-66.

RAMMELOO, J. & WALLEYN, R. (1993). The edible fungi of Africa south of the Sahara: a literature survey. *Scripta Bot. Belg.*, **5**: 1-62.

RAMMELOO, J. (1994). The contribution of the National Botanic Garden of Belgium to the mycology of Africa. In: SEYANI & CHIKUNI (Eds). *Proceedings of the XIII^e^ Plenary Meeting AETFAT, Malawi*: 671-685.

SCHMIT, J.P. & MUELLER, G.M. (2007). An estimate of the lower limit of global fungal diversity. *Biodiversity and Conservation*, **16**: 99-111.

SHAPIRO, D. & TOLLENS, E. (1992). The agricultural development of Zaire. Aldershot, Ashgate Publishing Ltd, 201 p.

SINGER, R. (1964). Marasmius congolais recueillis par Mme Goossens-Fontana et d'autres collecteurs belges. *Bull. Jard. Bot. Et., Bruxelles*, **34**: 317-388.

SINGER, R. (1965). Flore iconographique des champignons du Congo 14. Marasmius. Jardin Botanique National de Belgique: 253-278.

STEYAERT, R.L. (1961). Genus Ganoderma (Polyporaceae) Taxanova - 1. *Bull. Jard. bot. Etat Brux.*, **31**: 69-83.

STEYAERT, R.L. (1962). Genus Ganoderma (Polyporaceae) Taxanova - 2. *Bull. Jard. bot. Etat Brux.*, **32**: 89-104.

STEYAERT, R.L. (1967). Les Ganoderma palmicoles. *Bull. Jard. bot. Nat. Belg.*, **37**: 465-492.

THOEN, D., PARENT, G. & LUKUNGU, T. (1973). L'usage des champignons dans le Haut-Shaba (République du Zaïre). *Bull. Trim. Centr. Etudes Probl. Soc. Econ.*, **100-101**: 69-85.

VAN DE PERRE, F., WILLIG, M.R., PRESLEY, S.J., BAPEAMONI ANDEMWANA, F., BEECKMAN, H., BOECKX, P., COOLEMAN, S., DE HAAN, M., DE KESEL, A., DESSEIN, S., GROOTAERT, P., HUYGENS, D., JANSSENS, S.B., KEARSLEY, E., KABEYA, P.M., LEPONCE, M., VAN DEN

BROECK, D., VERBEECK, H., WÜRSTEN, B., LEIRS, H. & VERHEYEN, E. (2018). Reconciling biodiversity and carbon stock conservation in an Afrotropical forest landscape. *Sci. Adv.*, **4**, eaar6603.

VARGA, T., KRIZSÁN, K., FÖLDI, C., DIMA, B., SÁNCHEZ-GARCÍA, M., SÁNCHEZ-RAMÍREZ, S., SZÖLLŐSI, G.J., SZARKÁNDI, J.G., PAPP, V., ALBERT, L., ANDREOPOULOS, W., ANGELINI, C., ANTONÍN, V., KERRIE BARRY, K.W., BOUGHER, N.L., BUCHANAN, P., BUYCK, B., BENSE, V., CATCHESIDE, P., CHOVATIA, M., COOPER, J., DÄMON, W., DESJARDIN, D., FINY, P., GEML, J., HARIDAS, S., HUGHES, K., JUSTO, A., KARASIŃSKI, D., KAUTMANOVA, I., KISS, B., KOCSUBÉ, S., KOTIRANTA, H., LABUTTI, K.M., LECHNER, B.E., LIIMATAINEN, K., LIPZEN, A., LUKÁCS, Z., MIHALTCHEVA, S., MORGADO, L.N., NISKANEN, T., NOORDELOOS, M.E., OHM, R.A., ORTIZ-SANTANA, B., OVREBO, C., RÁCZ, N., RILEY, R., SAVCHENKO, A., SHIRYAEV, A., SOOP, K., SPIRIN, V., SZEBENYI, C., TOMŠOVSKÝ, M., TULLOSS, R.E., UEHLING, J., GRIGORIEV, I.V., VÁGVÖLGYI, C., PAPP, T., MARTIN, F.M., MIETTINEN, O., HIBBETT, D.S. & NAGY, L.G. (2019). Megaphylogeny resolves global patterns of mushroom evolution. *Nature, Ecology & Evolution*, https://doi.org/10.1038/s41559-019-0834-1

VERBEKEN, A. (1995). Studies in tropical African Lactarius species. 1. Lactarius gymnocarpus R. Heim ex Singer and allied species. *Mycotaxon*, **55**: 515-542.

VERBEKEN, A. (1996). Studies in tropical African Lactarius species. 4. Species described by P. Hennings and M. Beeli. *Edinb. J. Bot.*, **53**(1): 49-79.

VERBEKEN, A. & WALLEYN, R. (1999). Studies in tropical African Lactarius species. 7. A synopsis of the section Edule and a review on the edible species. *Belg. J. Bot.*, **132**(2): 175-184.

WALLEYN, R. & RAMMELOO, J. (1994). The poisonous and useful fungi of Africa south of the Sahara. *Scripta Bot. Belg.*, **10**: 1-56.

WATLING, R. & HEINEMANN, P. (1974). Flore illustrée des champignons d'Afrique centrale 3. Bolbitiaceae. Jardin Botanique National de Belgique: 55-71.

WHITE, F. (1983). The vegetation of Africa. Natural resources research, Unesco, 356 p.

ZOBERI, M.H. (1972). Tropical macrofungi. London, MacMillan Press, 158 p.