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REVIEW

Dynamics of the worldwide number of fungi with emphasis on fungal diversity in China

Yu-Cheng Dai[1] · Bao-Kai Cui[1] · Jing Si[1] · Shuang-Hui He[1] · Kevin D. Hyde[3] · Hai-Sheng Yuan[2] · Xiao-Yong Liu[4] · Li-Wei Zhou[2]

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Abstract A survey and analysis of fungal taxa introduced over seven decades is presented. The numbers of introduced taxa were collated from ten editions of the *Dictionary of the Fungi* as well as from the *Index of Fungi*. In total, around 9100 genera and 108,000 species had been introduced by 2014. Between 1943 and 2008, the average numbers of introduced novel genera increased annually by 73 and species by 950. However, between 2008 and 2012, the average numbers of introduced novel genera increased annually by 110 and species by 1430. There were 1203 novel genera and 16,912 novel species described between 2001 and 2012, with an average of 100 new genera and 1397 new species published annually during the period. Advances in molecular techniques have accelerated the discovery of novel taxa; it therefore seems likely that many more novel taxa will be described in the future. Between 2001 and 2012, 1529 novel species were described from China, accounting for 9.2 % of all novel species descriptions worldwide. Around 17,000 fungal species had been recorded in China by 2014 with 5700 basidiomycete species, and 6700 species from important fungal groups being documented in *Flora Fungorum Sinicorum* with detailed descriptions, microscopic drawings and lists of voucher collections. An overview of studies on fungal diversity in China is presented.

Keywords New genera · New species · Statistics

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✉ Yu-Cheng Dai
daiyucheng2013@gmail.com

✉ Li-Wei Zhou
liwei_zhou1982@163.com

[1] Institute of Microbiology, Beijing Forestry University, P.O. Box 61, Beijing 100083, China

[2] State Key Laboratory of Forest and Soil Ecology, Institute of Applied Ecology, Chinese Academy of Sciences, Shenyang 110164, China

[3] Centre of Excellence in Fungal Research, Mae Fah Luang University, Chiang Rai 57100, Thailand

[4] State Key Laboratory of Mycology, Institute of Microbiology, Chinese Academy of Sciences, Beijing 100101, China

Introduction

According to the ratio of vascular plants and fungi in different regions, Hawksworth (1991) conservatively estimated that there were 1,500,000 fungal species worldwide, with about 69,000 species known at that time. Two decades later, with 97,861 known species, fungal species numbers were estimated to be as high as 5,100,000 (Blackwell 2011). However, the number currently accepted by many mycologists is between 1,500,000 and 3,000,000 (Hawksworth 2012), with the former being an acceptable working figure. Schmit and Mueller (2007) estimated there to be at least 712,000 fungal species, explaining that this figure could be revised upwards, as more pertinent information became available.

These revised estimates partially result from an increase in specialized knowledge, made available by new techniques. For example, high-throughput sequencing of soil samples from two forest plots yielded a much higher ratio of fungi to plants than that used by Hawksworth (1991); extrapolations from this new ratio resulted in a much higher estimate of fungal species numbers (O'Brien et al. 2005). Because the number of known fungal species forms the basis of estimates (Hawksworth 1991; O'Brien et al. 2005), it is important that the known species number is precise when estimating total fungal numbers.

Although several papers have estimated global fungal species numbers (Hawksworth 1991, 2001, 2012; O'Brien et al. 2005;

Schmit and Mueller 2007; Blackwell 2011), there is no documentation summarizing the numbers of fungal genera and species introduced at different times. One way to provide data for estimating the extent of fungal diversity is to add up the numbers of introduced genera and species listed in the *Dictionary of the Fungi* and the *Index of Fungi*. In this paper, we collate the taxa at the generic and species levels from the *Dictionary of the Fungi*, from the first edition of 1943 through to the tenth edition in 2008 (Ainsworth and Bisby 1943, 1945, 1950, 1954; Ainsworth 1961, 1971; Hawksworth et al. 1983, 1995; Kirk et al. 2001, 2008), as well as listing novel genera and species listed in *Index of Fungi* from 2002 to 2014 (Anonymous 2002a, b, 2003a, b, 2004a, b, 2005a, b, 2006a, b, 2007a, b, 2008a, b, 2009a, b, 2010a, b, 2011a, b, 2012a, b, 2013a, b, 2014). The *Dictionary of the Fungi* lists known numbers of genera and species, while the *Index of Fungi* provides lists that include novel genera and species published annually from 2001 to 2012. The estimated number of known fungal species at the end of 2014 is provided. In addition, data on studies of fungal diversity in China are presented.

Dynamics of introduced fungal taxa

The number of introduced fungal taxa has generally increased (Fig. 1). The number of genera increased from 3503 in 1943 to 8283 in 2008, i.e., an increase of around 73 genera annually, while the number of species increased from 36,100 in 1943 to 97,861 in 2008, corresponding to an increase of 950 annually during the period. One exception is that the number of fungal species decreases from 50,000 in 1961 to 45,000 in 1971, suggesting that 1961 was an unusual year for fungal introductions. This unusual phenomenon might be partially caused by the names of both perfect and imperfect states being simultaneously used for a single deuteromycetes species in the fifth edition of the *Dictionary of the Fungi* published in 1961, where one-third of 15,000 imperfect fungal species also have names of perfect states (Ainsworth 1961). The International Code of Nomenclature in 1956 sanctioned the use of different names applied to the perfect and imperfect states of a single species; however, certain names of imperfect states were excluded from Deuteromycotina in the sixth edition of the *Dictionary of the Fungi* (Ainsworth 1971), because the names of the perfect state take precedence. Another possible reason is that the species number was overestimated in the fifth edition of the *Dictionary of the Fungi*, published 1961. For example, Basidiomycetes was introduced to accommodate 15,000 species belonging to nine orders, viz. Agaricales, Hymenogastrales, Lycoperdales, Nidulariales, Phallales, Sclerodermatales, Tremellales, Uredinales and Ustilaginales, but the sum of species numbers introduced in these nine orders was actually 13,145 (Ainsworth 1961).

Ascomycetes and basidiomycetes are the main groups of *Fungi*, and their generic numbers increased in each edition of the *Dictionary of the Fungi* (Tables 1 and 2). Similar to all fungal groups, the species numbers of ascomycetes and basidiomycetes both decreased in 1971 (Tables 1 and 2). The number of ascomycetes as a percentage of all known fungi almost doubled from 1943 to 2008 (Table 1), whereas the number of basidiomycetes as a percentage of all fungi was approximately constant (Table 2).

There was an increase in the number of introduced genera (3217) and species (33,024) from 2001 to 2008, as extracted from the *Dictionary of the Fungi* (Fig. 1). However, according to the *Index of Fungi*, 654 novel genera and 9494 novel species were published during the same period (Table 3). So most of the increased genera and species in the *Dictionary of the Fungi* from 2001 to 2008 are not novel.

When combining the data from the tenth edition of the *Dictionary of the Fungi* and the *Index of Fungi*, the total number of fungal genera known by 2012 is 8283+550 (the number

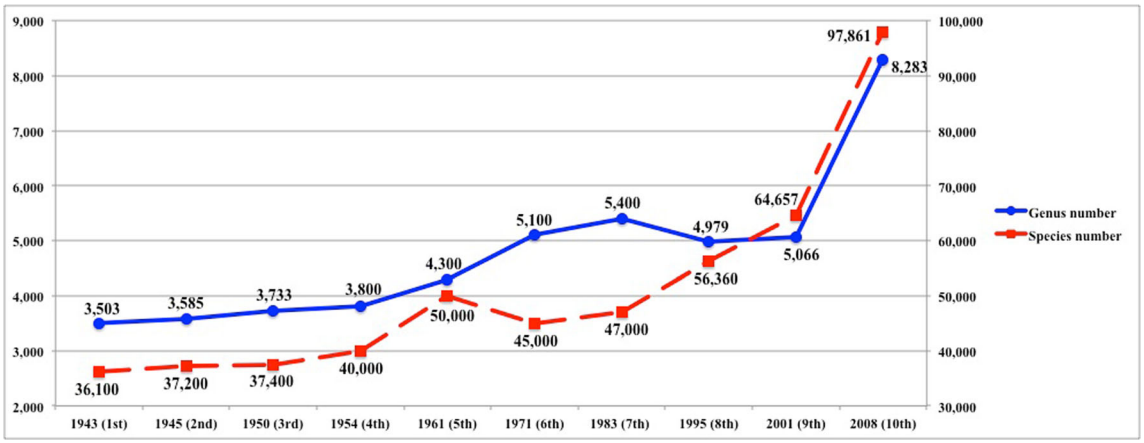

Fig. 1 The number of fungal genera and species recorded in the *Dictionary of the Fungi*

Table 1 The genera and species of ascomycetes recorded in the *Dictionary of the Fungi*

The edition	Published year	Genera	Species	Percentage (ascomycetes/all fungi)
1st	1943	1564	12,000	33.2 %
2nd	1945	1597	12,100	32.5 %
3rd	1950	1680	12,300	32.9 %
4th	1954	1700	15,000	37.5 %
5th	1961	1820	15,500	31.0 %
6th	1971	1950	15,000	33.5 %
7th	1983	2720	28,650	60.9 %
8th	1995	3266	32,267	57.2 %
9th	2001	3409	32,739	50.6 %
10th	2008	6355	64,163	65.6 %

of novel genera reported from 2008 to 2012, Table 4)=8833, and the total number of fungal species known by 2012 is 97, 861+7148 (the number of novel species reported from 2008 to 2012, Table 4)=105,009.

The numbers of novel genera introduced from 2008 to 2012 was 550 and species was 7148; around 110 genera and 1430 species were described annually during this period (Table 4). Thus, a greater number of novel genera and species were described per year between 2008 and 2012 than between 1943 and 2008. These increases can be accounted for by the large increase in investigations in tropical areas (Hawksworth 2012), and, more importantly, by the application of molecular techniques (Yang 2011; Du et al. 2012a; Dai et al. 2014; Liu et al. 2014; Wu et al. 2015; Zhou et al. 2015a), especially in the pathogenic genera (Maharachchikumbura et al. 2011, 2012; Hyde et al. 2014). High-throughput sequencing of environmental samples also indicates there are a greater number of fungi than the traditional techniques reveal (Lindahl et al. 2013; Peršoh 2015). With advanced techniques used to discover fungal diversity, the rate of introducing novel taxa could increase sharply in the future (Yang 2013).

Table 2 The genera and species of basidiomycetes recorded in the *Dictionary of the Fungi*

The edition	Published year	Genera	Species	Percentage (basidiomycetes/fungi)
1st	1943	495	13,500	37.4 %
2nd	1945	499	13,500	36.3 %
3rd	1950	521	13,500	36.1 %
4th	1954	550	15,000	37.5 %
5th	1961	550	15,000	31.0 %
6th	1971	900	12,000	26.7 %
7th	1983	1100	16,000	34 %
8th	1995	1428	22,244	39.5 %
9th	2001	1533	29,914	46.3 %
10th	2008	1589	31,515	32.2 %

Table 3 The number of novel genera and species of fungi listed in the *Index of Fungi*

Year[a]	Number of novel genera	Number of novel species
2001	98	1360
2002	78	1275
2003	105	1438
2004	105	1575
2005	74	1056
2006	80	1278
2007	114	1512
Total/ average annually	654/93	9494/1356

[a] The year for the publication of new genus and species

At the time of writing, the *Index of Fungi* Volume 8 (issue 7), provides details of novel taxa published before 2013 (Anonymous 2014), and data on novel taxa published after this issue are not included in the data. However, we estimate the numbers of novel genera and species published in 2013 and 2014 to be around 220 and 2860, based on the average numbers of new genera and species per year, that is, 110 and 1430, respectively, from 2008 to 2012. Therefore, we estimate that by the end of 2014, the numbers of known fungal genera will be around 9100 and species to be 108,000.

Fungal diversity studies in China

Publications dealing with Chinese fungal species were systematically reviewed in 2010, by which time, 16,046 species and 297 varieties, including 300 species of Chromista and 340 of Protozoa, had been recorded in the Chinese territories (Dai and Zhuang 2010). However, 10 % of these species were synonyms; thus, the number of known Chinese fungal species

Table 4 The number of novel genera and species of fungi listed in the *Index of Fungi*

Year[a]	Number of novel genera	Number of novel species
2008	109	1491
2009	116	1552
2010	126	1397
2011	107	1392
2012	92	1334
Total/average annually	550/110	7148/1430

[a] The year for the publication of new genus and species

Table 5 Taxonomical groups and species numbers documented in *Flora Fungorum Sinicorum*

Volume	Taxonomical group	Number of documented species	Reference
1	Erysiphales	253	Zheng and Yu (1987)
2	Tremellales, Dacrymycetales	119	Liu (1992)
3	Polyporaceae	313	Zhao (1998)
4	Meliolales	167	Hu (1996)
5	*Aspergillus* et teleomorphi cognati	89	Qi (1997)
6	Peronosporales	232	Yu (1998)
7	Hymenogastrales, Melanogastrales, Gautieriales	80	Liu (1998)
8	Sclerotiniaceae, Geoglossaceae	53	Zhuang (1998)
9	*Pseudocercospora*	345	Liu and Guo (1998)
10	Uredinales	203	Wang and Zhuang (1998)
11	Meliolales	154	Hu (1999)
12	Ustilaginaceae	139	Guo (2000)
13	Entomophthorales	59	Li (2000)
14	*Cladosporium*, *Fusicladium*, *Pyricularia*	136	Zhang (2003a)
15	*Phoma*, *Phyllosticta*	160	Bai (2003a)
16	*Alternaria*	123	Zhang (2003b)
17	*Ascochyta*, *Septoria*	216	Bai (2003b)
18	Ganodermataceae	98	Zhao and Zhang (2000)
19	Uredinales	237	Zhuang (2003)
20	*Mycoveillosielia*, *Passalora*, *Phaeoramularia*	102	Guo and Liu (2003)
21	Hyaloscyphaceae, Sarcoscyphaceae, Sarcosomataceae	145	Zhuang (2004)
22	Boletaceae	129	Zang (2006)
23	Sclerodermatales, Tulostomatales, Phallales, Podaxales	132	Liu (2005)
24	*Cercospora*	252	Guo and Liu (2005)
25	Uredinales	108	Zhuang (2005)
26	*Botrytis*, *Ramularia*	107	Zhang (2006)
27	Amanitaceae	84	Yang (2005b)
28	Laboulbeniales	182	Shen and Ye (2006)
29	Hymenochaetaceae	106	Zhang and Dai (2005)
30	Helminthosporioid Hyphomycetes	120	Zhang (2010)
31	Dematiaceous, Dictyosporous Hyphomycetes excluding *Alternaria*	131	Zhang (2009)
32	*Cordyceps*	71	Liang (2007)
33	*Arthrobotrys* et genera cetera cognata	80	Zhang and Mo (2006)
34	*Phomopsis*	133	Qin et al. (2007)
35	*Penicilium* et teleomorphi cognati	97	Kong (2007)
36	Geastraceae, Nidulariaceae	55	Zhou (2007)
37	*Sporidesmium* et genera cognata	161	Wu (2009)
38	*Pestalotiopsis*	55	Ge et al. (2009)
39	Tilietiales, Urocystidales, Entorrhizales, Doassansiales, Entylomatales, Georgefischeriales	115	Guo (2011)
40	Rhytismatales	127	Lin (2012)
41	Uredinales	123	Zhuang (2012)
42	Cortiaceae s.l.	109	Dai and Xiong (2012)
43	Paecilomyces, *Isaria*, *Taifanglania*	55	Liang (2013)
44	Boletaceae	115	Zang (2013)
45	Pleurotoid-lentinoid fungi	78	Li and Tolgor (2014)
46	*Phyllachora*	109	Zhang and Zhang (2014)
47	Nectriaceae et Bionectriaceae	112	Zhuang (2013)

Table 5 (continued)

Volume	Taxonomical group	Number of documented species	Reference
48	Pyronemataceae	140	Zhuang (2014)
49	Strophariaceae	112	Tolgor (2015)
50	Exobasidiales, Septobasidiales	92	Guo (2015)

was estimated to be around 14,700 (Dai and Zhuang 2010). Most of the descriptions of these species were morphology based. Recently, phylogenetic studies have demonstrated that many morphologically similar taxa might represent distinct lineages, and numerous well-known species are in fact species complexes (Li et al. 2009; Du et al. 2012a, b; Chen et al. 2015); many plant pathogen species comprise cryptic species (Hyde et al. 2009; Cui et al. 2015). Therefore, the assumption that 10 % of Chinese fungal species are synonyms is probably unrealistic and the fungal diversity in China was in fact underestimated. From 2010 to 2014, details of 912 novel species and 614 new records were introduced for China, based on Chinese materials. Given the above, by the end of 2014, the number of known *Fungi* in China was approximately 17,000 (16,046−300–340+912+614), accounting for approximately 16 % of known species worldwide. Among the 17,000 Chinese species, around 5700 species, accounting for around 33.7 % of the total, are basidiomycetes; this ratio is almost the same as that found globally in 2008 (32.2 %, Table 2). A total of 50 volumes of *Flora Fungorum Sinicorum* have been published, and 6700 species were documented with detailed descriptions, drawings of microscopy and lists of voucher collections (Table 5).

There are many universities and institutes working on fungal diversity in China. Among them, the State Key Laboratory of Mycology, Institute of Microbiology, Chinese Academy of Sciences (HMAS), Kunming Institute of Botany, Chinese Academy of Sciences (HKAS), Institute of Applied Ecology, Chinese Academy of Sciences (IFP), Guizhou Academy of Agricultural Science, Beijing Academy of Agriculture and Forestry Sciences, Beijing Forestry University (BJFC), Jilin Agricultural University (HMJAU), Guangdong Institute of Microbiology (GDGM), Shandong Agricultural University (SDAU), Guizhou University (GACP), Hunan Normal University (HNNU), Shanxi University (SXU), Capital Normal University (BJTC), Anhui Agricultural University (AAUB), Yunnan University (PYU), Qingdao Agricultural University (LYAC), and National Museum of Natural Science in Taichung (TNM) have made major contributions to the understanding of the diversity of *Fungi* in China, and their herbaria (acronyms given in brackets after host names) conserve most of available Chinese fungal collections and cultures. The University of Hong Kong previously had an active research group, but this was not continued when K.D. Hyde retired and the herbarium at the university, HKU (M), was moved to IFRDC in Kunming (Chen et al. 2010).

Mycosystema, the first official journal of the Mycological Society of China (MSC), was first published quarterly in 1982 as *Acta Mycologica Sinica*, and then bimonthly since 2008. This journal accepts both Chinese and English papers. *Mycosystema* paper numbers increased from 48 in 1983 to 136 in 2014. Moreover, the *Journal of Fungal Research* in 2002 and *Mycology—an International Journal on Fungal Biology* in 2010 are published by MSC; the latter is an exclusively English journal. The English language journal *Fungal Diversity*, with a good reputation worldwide, also became the journal of Kunming Institute of Botany, Chinese Academy of Sciences in 2011, while Mycosphere has recently become the journal of Guizhou Academy of Agricultural Science. In addition, studies on fungal diversity and related studies are scattered in other journals, such as *Fungal Science*, *Acta Edulis Fungi*, *Edible and Medicinal Mushrooms* and *Edible Fungi of China*. These journals play an essential role in reporting the advances in fungal diversity research in China. In addition, Fungal Names (http://www.fungalinfo.net/fungalname/fungalname.html), one of the three repositories for new fungal names, is located in China. This database together with the Chinese version of MycoBank (http://cn.mycobank.org/) indicate the importance of the Chinese contribution to fungal biodiversity.

Compared to other countries, the Chinese government has increased funding for exploring fungal diversity in recent years. For example, the National Natural Science Foundation of China provided 25,280,000 RMB for 36 projects in 2012, while the numbers were 240,000 RMB for two projects in 1999; the funds increased more than 100 times in 13 years.

More and more new taxa have been described from China, and there were almost twice as many newly introduced species in 2014 (208) as in 2004 (109). Accordingly, many more publications reporting on Chinese fungal diversity have been published in recent years. For example, around 210 papers related to fungal diversity research were published from 1950 to 1980, with most being published in the Chinese journals, while the number in 2014 was not less than 220, with

more than half published in the international journals (Table 6).

With the accumulation of knowledge of fungal diversity, other research fields have also benefitted. Thirty-seven species, most belonging to Mucorales, are aetiological agents of rhino-orbital-cerebral mycosis (Li et al. 2014); 24 are involved in cerebral phaeohyphomycosis, and most are from Chaetothyriales (Li and de Hoog 2009). The identification of aetiological agents is important for treatment of disease. Grape is one of the most important agricultural crops in China, but yields may be affected by grape disease. Anthracnose is a serious disease of grapes caused by *Colletotrichum* Corda species and has been reported by Yan et al. (2013, 2015). Other grape diseases have also been surveyed and published, and these data may help in disease control (Dissanayake et al. 2015; Jayawardena et al. 2015). Dai et al. (2007) recorded 102 potential forest pathogens as a result of field surveys throughout China, which are important for protection of forest resources. The genus *Amanita* Pers. comprises valued edible mushrooms, but also deadly poisonous species, and their morphological delimitation is ambiguous even for specialists (Yang 2005b); thus, several poisoning cases caused by lethal amanitas occur annually (Chen et al. 2014). Cai et al. (2014) identified the diversity and found some cryptic species of lethal amanitas, which undoubtedly helps to reduce cases of fungal poisoning. The true morels (*Morchella* Dill. ex Pers.) are prized edible mushrooms, which are delicious, but produce small amounts of fruiting bodies. Du et al. (2012a) elucidated the phylogeny of *Morchella* and identified several new lineages from China. This information will be helpful in advancing morel conservation and commercial harvests. Zhou et al. (2015a, b) clarified the global diversity of two important medicinal fungal complexes, 'sanghuang' and 'lingzhi', and provided insights for further utilization of these genera of medicinal mushrooms.

Table 6 The number of papers on Chinese fungal diversity published in main taxonomical journals in 2014

Journal name	Number of papers
Mycosystema	47
Mycotaxon	38
Journal of fungal research	25
Mycological progress	25
Phytotaxa	19
Mycoscience	16
Nova Hedwigia	10
Chiang Mai Journal of Science	7
Fungal diversity	7
Fungal science	7
Cryptogamie Mycologie	6
Mycologia	6
Sydowia	4
Botanical studies	2
Persoonia	1

More than 1800 macrofungal resources, including many edible and medicinal species, were recently documented for China, with colour photographs and descriptions (Li et al. 2015), and many have the potential to be cultivated (Thawthong et al. 2014). Around 20 species have been commercially cultivated in China, and the Chinese production of edible mushrooms in 2013 is about 32 million tons, which accounted for more than 75 % of the world production; the direct product value is 170.7 billion RMB (=28 billion $). The most important cultivated species are *Agaricus bisporus* (J.E. Lange) Imbach, *Agrocybe cylindracea* (DC.) Maire, *Auricularia cornea* Ehrenb., *A. heimuer* F. Wu, B.K. Cui & Y.C. Dai, *Coprinus comatus* (O.F. Müll.) Pers., *Flammulina velutipes* (Curtis) Singer, *Hericium erinaceus* (Bull.) Pers., *Lentinula edodes* (Berk.) Pegler, *Pholiota microspora* (Berk.) Sacc., *Pleurotus eryngii* (DC.) Quél., *P. eryngii* var. *tuoliensis* C.J. Mou, *P. ostreatus* (Jacq.) P. Kumm., *Tremella fuciformis* Berk. and *Volvariella volvacea* (Bull.) Singer (Zhang et al. 2015). Among 540 medicinal fungi recorded from China (Dai et al. 2009), the most important species are *Ganoderma lingzhi* Sheng H. Wu, Y. Cao & Y.C. Dai, *Ophiocordyceps sinensis* (Berk.) G.H. Sung, J.M. Sung, Hywel-Jones & Spatafora and *Taiwanofungus camphoratus* (M. Zang & C.H. Su) Sheng H. Wu, Z.H. Yu, Y.C. Dai & C.H. Su, and the biogeographical centre of these species is in East Asia (Wu et al. 2004; Cao et al. 2012; Zhang et al. 2013).

Although having contributed to the understanding of global diversity of *Fungi*, Chinese mycologists have much work to do. China possesses large land areas, with numerous ecological niches, where almost all fungal groups can be found (Yang 2005a). However, many of these niches have been poorly or never studied. Many groups of fungi, such as the Ascomycota, have also been poorly investigated, and studies will likely result in the discovery of numerous new taxa. There is a strong need to explore unique ecological niches to fully understand Chinese fungal diversity and utilize these resources. For some hotspots of biodiversity, certain groups of fungi might be extensively surveyed, but a joint field trip for collecting most, or all, fungal groups would be better to understand fungal diversity in a special ecological region. Funding for such joint surveys has been initiated by National Science and Technology Foundation Project, now focusing on the Qinghai-Tibet Plateau and the Xinjiang Region, Greater and Lesser Khingan Mountains, and Karst regions in southwestern China. We can expect further contributions from China that will help to improve the understanding of fungal diversity worldwide, with the efforts of Chinese mycologists and Chinese government financial support.

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References

Ainsworth GC (1961) Ainsworth & Bisby's dictionary of the fungi, 5th edn. Commonwealth Mycological Institute, Kew

Ainsworth GC (1971) Ainsworth & Bisby's dictionary of the fungi, 6th edn. Commonwealth Mycological Institute, Kew

Ainsworth GC, Bisby GR (1943) A dictionary of the fungi, 1st edn. Imperial Mycological Institute, Kew

Ainsworth GC, Bisby GR (1945) A dictionary of the fungi, 2nd edn. Commonwealth Mycological Institute, Kew

Ainsworth GC, Bisby GR (1950) A dictionary of the fungi, 3rd edn. Commonwealth Mycological Institute, Kew

Ainsworth GC, Bisby GR (1954) A dictionary of the fungi, 4th edn. Commonwealth Mycological Institute, Kew

Anonymous (2002a) Index of fungi, 7 (3). CAB International, Wallingford

Anonymous (2002b) Index of fungi, 7 (4). CAB International, Wallingford

Anonymous (2003a) Index of fungi, 7 (5). CAB International, Wallingford

Anonymous (2003b) Index of fungi, 7 (6). CAB International, Wallingford

Anonymous (2004a) Index of fungi, 7 (7). CAB International, Wallingford

Anonymous (2004b) Index of fungi, 7 (8). CAB International, Wallingford

Anonymous (2005a) Index of fungi, 7 (9). CAB International, Wallingford

Anonymous (2005b) Index of fungi, 7 (10). CAB International, Wallingford

Anonymous (2006a) Index of fungi, 7 (11). CAB International, Wallingford

Anonymous (2006b) Index of fungi, 7 (12). CAB International, Wallingford

Anonymous (2007a) Index of fungi, 7 (13). CAB International, Wallingford

Anonymous (2007b) Index of fungi, 7 (14). CAB International, Wallingford

Anonymous (2008a) Index of fungi, 7 (15). CAB International, Wallingford

Anonymous (2008b) Index of fungi, 7 (16). CAB International, Wallingford

Anonymous (2009a) Index of fungi, 7 (17). CAB International, Wallingford

Anonymous (2009b) Index of fungi, 7 (18). CAB International, Wallingford

Anonymous (2010a) Index of fungi, 7 (19). CAB International, Wallingford

Anonymous (2010b) Index of fungi, 7 (20). CAB International, Wallingford

Anonymous (2011a) Index of fungi, 8 (1). CAB International, Wallingford

Anonymous (2011b) Index of fungi, 8 (2). CAB International, Wallingford

Anonymous (2012a) Index of fungi, 8 (3). CAB International, Wallingford

Anonymous (2012b) Index of fungi, 8 (4). CAB International, Wallingford

Anonymous (2013a) Index of fungi, 8 (5). CAB International, Wallingford

Anonymous (2013b) Index of fungi, 8 (6). CAB International, Wallingford

Anonymous (2014) Index of fungi, 8 (7). CAB International, Wallingford

Bai JK (2003a) Flora fungorum sinicorum Vol 15. *Phoma, Phyllosticta*. Science Press, Beijing

Bai JK (2003b) Flora fungorum sinicorum Vol 17. *Ascochyta, Septoria*. Science Press, Beijing

Blackwell M (2011) The fungi: 1, 2, 3. 5.1 million species? Am J Bot 98: 426–438

Cai Q, Tulloss RE, Tang LP, Tolgor B, Zhang P, Chen ZH, Yang ZL (2014) Multi-locus phylogeny of lethal amanitas: Implications for species diversity and historical biogeography. BMC Evol Biol 14: 143

Cao Y, Wu SH, Dai YC (2012) Species clarification of the prize medicinal *Ganoderma* mushroom "Lingzhi". Fungal Divers 56:49–62

Chen H, Feng Y, Zhang WF, Hyde KD, Liu JK (2010) HKU (M) moves to IFRDC Kunming. Mycotaxon 113:137–145

Chen ZH, Zhang P, Zhang ZG (2014) Investigation and analysis of 102 mushroom poisoning cases in Southern China from 1994 to 2012. Fungal Divers 64:123–131

Chen JJ, Cui BK, Zhou LW, Korhonen K, Dai YC (2015) Phylogeny, divergence time estimation, and biogeography of the genus *Heterobasidion* (Basidiomycota, Russulales). Fungal Divers 71: 185–200

Cui BK, Dai YC, He SH, Zhou LW, Yuan HS (2015) A novel *Phellinidium* sp. causes laminated root rot on Qilian juniper (*Sabina przewalskii*) in northwest China. Plant Dis 99:39–43

Dai YC, Xiong HX (2012) Flora fungorum sinicorum Vol 42. Cortiaceae s.l. (I). Science Press, Beijing

Dai YC, Zhuang JY (2010) Numbers of fungal species hitherto known in China. Mycosystema 29:625–628

Dai YC, Cui BK, Yuan HS, Li BD (2007) Pathogenic wood-decaying fungi in China. For Pathol 37:105–120

Dai YC, Yang ZL, Cui BK, Yu CJ, Zhou LW (2009) Species diversity and utilization of medicinal mushrooms and fungi in China (Review). Int J Med Mushrooms 11:287–302

Dai YC, Xue HJ, Vlasák J, Rajchenberg M, Wang B, Zhou LW (2014) Phylogeny and global diversity of *Polyporus* group Melanopus (Polyporales, Basidiomycota). Fungal Divers 64:133–144

Dissanayake AJ, Liu M, Zhang W, Chen Z, Udayanga D, Chukeatirote E, Li XH, Yan JY, Hyde KD (2015) Morphological and molecular characterization of *Diaporthe* species associated with grapevine trunk disease in China. Fungal Biol 119:283–294

Du XH, Zhao Q, O'Donnell K, Rooney AP, Yang ZL (2012a) Multigene molecular phylogenetics reveals true morels (*Morchella*) are especially species-rich in China. Fungal Genet Biol 49:455–469

Du XH, Zhao Q, Yang ZL, Hansen K, Taşkın H, Büyükalaca S, Dewsbury D, Moncalvo JM, Douhan GW, Robert Vincent ARG, Crous PW, Rehner SA, Rooney AP, Sink S, O'Donnell K (2012b) How well do ITS rDNA sequences differentiate species of true morels (*Morchella*)? Mycologia 104:1351–1368

Ge XQ, Chen YX, Xu T (2009) Flora fungorum sinicorum Vol 38. *Pestalotiopsis*. Science Press, Beijing

Guo L (2000) Flora fungorum sinicorum Vol 12. Ustilaginaceae. Science Press, Beijing

Guo L (2011) Flora fungorum sinicorum Vol 39. Tilietiales, Urocystidales, Entorrhizales, Doassansiales, Entylomatales, Georgefischeriales. Science Press, Beijing

Guo L (2015) Flora fungorum sinicorum Vol 50. Exobasidiales, Septobasidiales. Science Press, Beijing

Guo YL, Liu XJ (2003) Flora fungorum sinicorum Vol 20. *Mycoveillosielia*, *Passalora*, *Phaeoramularia*. Science Press, Beijing

Guo YL, Liu XJ (2005) Flora fungorum sinicorum Vol 24. *Cercospora*. Science Press, Beijing

Hawksworth DL (1991) The fungal dimension of biodiversity: magnitude, significance, and conservation. Mycol Res 95:641–655

Hawksworth DL (2001) The magnitude of fungal diversity: the 1–5 million species estimate revisited. Mycol Res 105:1422–1433

Hawksworth DL (2012) Global species numbers of fungi: are tropical studies and molecular approaches contributing to a more robust estimate? Biodivers Conserv 21:2425–2433

Hawksworth DL, Sutton BC, Ainsworth GC (1983) Ainsworth & Bisby's dictionary of the fungi, 7th edn. Commonwealth Mycological Institute, Kew

Hawksworth DL, Kirk PM, Sutton BC, Pegler DN (1995) Ainsworth & Bisby's dictionary of the fungi, 8th edn. CAB International, Wallingford

Hu YX (1996) Flora fungorum sinicorum Vol 4. Meliolales (I). Science Press, Beijing

Hu YX (1999) Flora fungorum sinicorum Vol 11. Meliolales (II). Science Press, Beijing

Hyde KD, Cai L, McKenzie EHC, Yang YL, Zhang JZ, Prihastuti H (2009) *Colletotrichum*: a catalogue of confusion. Fungal Divers 39:1–17

Hyde KD, Nilsson RH, Alias SA, Ariyawansa HA, Blair JE, Cai L, de Cock WAM, Dissanayake AJ, Glocking SL, Goonasekara ID, Gorczak M, Hahn M, Jayawardena RS, van Kan JAL, Evesque A, Li XH, Liu JK, Maharachchikumbura SSN, Manamgoda DS, Martin FN, McKenzie EHC, McTaggart AR, Mortimer PE, Nair PVR, Pawlowska J, Rintoul TL, Shivas RG, Spies ARCFJ, Summerell BA, Taylor PWJ, Terhem RB, Udayanga D, Vaghefi N, Walther G, Wilk M, Wrzosek M, Xu JC, Yan J, Zhou N (2014) One stop shop: backbones trees for important phytopathogenic genera: I (2014). Fungal Divers 67:21–125

Jayawardena RS, Zhang W, Liu M, Maharachchikumbura SN, Zhou Y, Huang JB, Nilthong S, Wang ZY, Li XH, Yan JY, Hyde KD (2015) Identification and characterization of *Pestalotiopsis* like fungi related to grapevine diseases in China. Fungal Biol 119:384–361

Kirk PM, Cannon PF, David JC, Stalpers JA (2001) Ainsworth & Bisby's dictionary of the fungi, 9th edn. CAB International, Wallingford

Kirk PM, Cannon PF, Minter DW, Stalpers JA (2008) Ainsworth & Bisby's dictionary of the fungi, 10th edn. CAB International, Wallingford

Kong HZ (2007) Flora fungorum sinicorum Vol 35. *Penicilium* et teleomorphi cognati. Science Press, Beijing

Li ZZ (2000) Flora fungorum sinicorum Vol 13. Entomophthorales. Science Press, Beijing

Li DM, de Hoog GS (2009) Cerebral phaeohyphomycosis—a cure at what lengths? Lancet Infect Dis 9:376–383

Li Y, Tolgor B (2014) Flora fungorum sinicorum Vol 45. Pleurotoid-lentinoid fungi. Science Press, Beijing

Li YC, Yang ZL, Tolgor B (2009) Phylogenetic and biogeographic relationships of *Chroogomphus* species as inferred from molecular and morphological data. Fungal Divers 38:85–104

Li DM, Shang PP, Zhu L, de Hoog GS (2014) Rhino-orbital-cerebral mycosis and cavernous thrombosis. Eur J Inflamm 12:1–10

Li Y, Li TH, Yang ZL, Torgor B, Dai YC (2015) Altas of Chinese macrofungal resources. Central Chinese Farmer Press, Zhengzhou

Liang ZQ (2007) Flora fungorum sinicorum Vol 32. *Cordyceps*. Science Press, Beijing

Liang ZQ (2013) Flora fungorum sinicorum Vol 43. *Paecilomyces*, *Isaria*, *Taifanglania*. Science Press, Beijing

Lin YR (2012) Flora fungorum sinicorum Vol 40. Rhytismatales. Science Press, Beijing

Lindahl BD, Nilsson RH, Tedersoo L, Abarenkov K, Carlsen T, Kjøller R, Kõljalg U, Pennanen T, Rosendahl S, Stenlid J, Kauserud H (2013) Fungal community analysis by high-throughput sequencing of amplified markers - a user's guide. New Phytol 199:288–299

Liu B (1992) Flora fungorum sinicorum Vol 2. Tremellales, Dacrymycetales. Science Press, Beijing

Liu B (1998) Flora fungorum sinicorum Vol 7. Hymenogastrales, Melanogastrales, Gautieriales. Science Press, Beijing

Liu B (2005) Flora fungorum sinicorum Vol 23. Sclerodermatales, Tulostomatales, Phallales, Podaxales. Science Press, Beijing

Liu XJ, Guo YL (1998) Flora fungorum sinicorum Vol 9. *Pseudocercospora*. Science Press, Beijing

Liu F, Cai L, Crous PW, Damm U (2014) The *Colletotrichum gigasporum* species complex. Persoonia 33:83–97

Maharachchikumbura SSN, Guo LD, Chukeatirote E, Bahkali AH, Hyde KD (2011) *Pestalotiopsis*–morphology, phylogeny, biochemistry and diversity. Fungal Divers 50:167–187

Maharachchikumbura SSN, Guo LD, Cai L, Chukeatirote E, Wu WP, Sun X, Crous PW, Bhat DJ, McKenzie EHC, Bahkali AH, Hyde KD (2012) A multi-locus backbone tree for *Pestalotiopsis*, with a polyphasic characterization of 14 new species. Fungal Divers 56: 95–129

O'Brien BL, Parrent JL, Jackson JA, Moncalvo JM, Vilgalys R (2005) Fungal community analysis by large-scale sequencing of environmental samples. Appl Environ Microbiol 71:5544–5550

Peršoh D (2015) Plant-associated fungal communities in the light of meta'omics. Fungal Divers. doi:10.1007/s13225-015-0334-9

Qi ZT (1997) Flora fungorum sinicorum Vol 5. *Aspergillus* et teleomorphi cognati. Science Press, Beijing

Qin PK, Jiang ZD, Xiang MM (2007) Flora fungorum sinicorum Vol 34. *Phomopsis*. Science Press, Beijing

Schmit JP, Mueller GM (2007) An estimate of the lower limit of fungal diversity. Biodivers Conserv 16:99–111

Shen YH, Ye DH (2006) Flroa fungorum sinicorum Vol 28. Laboulbeniales. Science Press, Beijing

Thawthong A, Karunarathna SC, Thongklang N, Chukeatirote E, Kakumyan P, Chamyuang S, Rizal LM, Mortimer PE, Xu J, Callac P, Hyde KD (2014) Discovering and domesticating wild tropical cultivable mushrooms. Chiang Mai J Sci 41:1–34

Tolgor B (2015) Flora fungorum sinicorum Vol 49. Strophariaceae (I). Science Press, Beijing

Wang YZ, Zhuang JY (1998) Flora fungorum sinicorum Vol 10. Uredinales (I). Science Press, Beijing

Wu WP (2009) Flora fungorum sinicorum Vol 37. *Sporidesmium* et genera cognata. Science Press, Beijing

Wu SH, Yu ZH, Dai YC, Chen CT, Su CH, Chen LC, Hsu WC, Hwang GY (2004) *Taiwanofungus*, a polypore new genus. Fungal Sci 19: 109–116

Wu G, Zhao K, Li YC, Zeng NK, Feng B, Halling RE, Yang ZL (2015) Four new genera of the fungal family Boletaceae. Fungal Divers. doi:10.1007/s13225-015-0322-0

Yan JY, Xie Y, Zhang W, Wang Y, Liu JK, Hyde KD, Seem RC, Zhang JZ, Wang ZY, Yao SW, Bai XJ, Dissanayake AJ, Peng YL, Li XH (2013) Species of Botryosphaeriaceae involved in grape-vine die-back in China. Fungal Divers 61:221–236

Yan JY, Jayawardena MMRS, Goonasekara ID, Wang Y, Zhang W, Liu M, Huang JB, Wang ZY, Shang JJ, Peng YL, Bahkali A, Hyde KD, Li XH (2015) Diverse species of *Colletotrichum* associated with grapevine anthracnose in China. Fungal Divers 71:233–246

Yang ZL (2005a) Diversity and biogeography of higher fungi in China. In: Xu J (ed) Evolutionary genetics of fungi. Horrizon Bioscience, Norfolk, pp 35–62

Yang ZL (2005b) Flora fungorum sinicorum Vol 27. Amanitaceae. Science Press, Beijing

Yang ZL (2011) Molecular techniques revolutionize knowledge of basidiomycetes evolution. Fungal Divers 50:47–58

Yang ZL (2013) Fungal taxonomy in the genomics era: opportunities and challenges. Mycosystema 32:931–946

Yu YN (1998) Flora fungorum sinicorum Vol 6. Peronosporales. Science Press, Beijing

Zang M (2006) Flora fungorum sinicorum Vol 22. Boletaceae (I). Science Press, Beijing

Zang M (2013) Flora fungorum sinicorum Vol 44. Boletaceae (II). Science Press, Beijing

Zhang TY (2003b) Flora fungorum sinicorum Vol 16. *Alternaria*. Science Press, Beijing

Zhang ZY (2003a) Flora fungorum sinicorum Vol 14. *Cladosporium*, *Fusicladium*, *Pyricularia*. Science Press, Beijing

Zhang TY (2006) Flroa Fungorum sinicorum Vol 26. *Botrytis*, *Ramularia*. Science Press, Beijing

Zhang TY (2009) Flora fungorum sinicorum Vol 31. 26 genera of dematiaceous, dictyosporous hyphomycetes excluding *Alternaria*. Science Press, Beijing

Zhang TY (2010) Flora fungorum sinicorum Vol 30. Helminthosporioid hyphomycetes. Science Press, Beijing

Zhang XQ, Dai YC (2005) Flora fungorum sinicorum Vol 29. Hymenochaetaceae. Science Press, Beijing

Zhang KQ, Mo MH (2006) Flora fungorum sinicorum Vol 33. *Arthrobotrys* et genera cetera cognata. Science Press, Beijing

Zhang ZY, Zhang T (2014) Flora fungorum sinicorum Vol 46. *Phyllachora*. Science Press, Beijing

Zhang S, Zhang YJ, Shrestha B, Xu JP, Wang CH, Liu XZ (2013) *Ophiocordyceps sinensis* and *Cordyceps militaris*: research advances, issues and perspectives. Mycosystema 32:577–597

Zhang JX, Chen Q, Huang CY, Cao W, Qu JB (2015) History, current situation and trend of edible mushroom industry development. Mycosystema 34 (in press)

Zhao JD (1998) Flora fungorum sinicorum Vol 3. Polyporaceae. Science Press, Beijing

Zhao JD, Zhang XQ (2000) Flora fungorum sinicorum Vol 18. Ganodermataceae. Science Press, Beijing

Zheng RY, Yu YN (1987) Flora fungorum sinicorum Vol 1. Erysiphales. Science Press, Beijing

Zhou TX (2007) Flora fungorum sinicorum Vol 36. Geastraceae, Nidulariaceae. Science Press, Beijing

Zhou LW, Vlasák J, Decock C, Assefa A, Stenlid J, Abate D, Wu SH, Dai YC (2015a) Global diversity and taxonomy of the *Inonotus linteus* complex (Hymenochaetales, Basidiomycota): *Sanghuangporus* gen. nov., *Tropicoporus excentrodendri* and *T. guanacastensis* gen. et spp. nov., and 17 new combinations. Fungal Divers. doi:10.1007/s13225-015-0335-8

Zhou LW, Cao Y, Wu SH, Vlasák J, Li DW, Li MJ, Dai YC (2015b) Global diversity of the *Ganoderma lucidum* complex (Ganodermataceae, Polyporales) inferred from morphology and multilocus phylogeny. Phytochemistry 114:7–15

Zhuang WY (1998) Flora fungorum sinicorum Vol 8. Sclerotiniaceae, Geoglossaceae. Science Press, Beijing

Zhuang JY (2003) Flora fungorum sinicorum Vol 19. Uredinales (II). Science Press, Beijing

Zhuang WY (2004) Flora fungorum sinicorum Vol 21. Hyaloscyphaceae, Sarcoscyphaceae et Sarcosomataceae. Science Press, Beijing

Zhuang JY (2005) Flora fungorum sinicorum Vol 25. Uredinales (III). Science Press, Beijing

Zhuang JY (2012) Flora fungorum sinicorum Vol 41. Uredinales (IV). Science Press, Beijing

Zhuang WY (2013) Flora fungorum sinicorum Vol 47. Nectriaceae et Bionectriaceae. Science Press, Beijing

Zhuang WY (2014) Flora fungorum sinicorum Vol 48. Pyronemataceae. Science Press, Beijing