

Fungi in Microbial Culture Collections and Their Metabolites

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Abstract: This study presents the results of a comparative analysis of the fungal diversity in the world system of microbial culture collections on one side with a variety of known fungal producers on the other side. The main VKM databases used are FungalDC and Metabolites of Fungi and the central point of analysis is the fungal ability to synthesize promising metabolites for applied use. It indicates that the option of obtaining new promising strains from the collection funds is still underestimated by the scientific community. In particular, it is shown that no more than 3% of the total fungal species fund contained in culture collections are used practically. It is possible that their use will considerably expand the range of studied strains and lead to the acquisition of new scientifically significant data.

Keywords: collections of microorganisms; databases; fungal diversity; metabolites

1. Introduction

Fungi belong to a kingdom of living organisms with extremely high diversity. According to expert estimates, the number of fungal species currently ranges from 2.2 to 3.8 million. In recent decades, the rate of description of new taxa has increased significantly due to the fast advances in molecular-biological diagnostics [1]. The Mycobank (www.mycobank.org), the premier reference platform for mycology, lists the names of over 440,000 legitimately described species (including synonyms), mostly held in culture collections worldwide, a large part of them in the leading CBS-KNAW Culture Collection (Westerdijk Fungal Biodiversity Institute; <https://wi.knaw.nl/page/Collection>). Obviously, ex situ conservation of microbial diversity for use in fundamental and applied scientific developments is of great importance. At the same time, culture collections play a decisive role in providing researchers with reliable biological material, which is the basis of any high-quality scientific work [2].

The large Microbial Culture Collections (mCCs) and MicroBiological Resource Center (mBRCs) maintain significant holdings of biological material and related information [3] to facilitate access to the biological resources conserved. They ensure the availability of microorganisms for the further use in sustainable scientific development. The mBRCs presents software for searching the data of required strains in their databases using various parameters. This helps to visualize and analyze the available information, and to make it accessible for the users of the online system.

The diversity of mCC and mBRC mycobiota in collections gets great attention, since fungi and their metabolites may represent an alternative to many currently used chemical compounds in the future [4]. Various new natural substances with promising potential for biological, medical, and industrial applications can be isolated and identified from fungi. The importance of fungal secondary metabolites for biotechnology cannot be overestimated. They can have antimicrobial activity, be enzyme inhibitors, be growth hormones, etc. [5,6].

A wide taxonomic diversity of various collections makes it possible to find strains capable of biosynthesis of specific organic substances. However, experience shows that



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the main fungal group studied by numerous researchers is very limited. Thus, in analysis of 245 patents related to the production of secondary metabolites and biotransformation processes using endophytic fungi [7], it was discovered that the most frequently mentioned fungi belong to the genera *Aspergillus*, *Fusarium*, *Trichoderma*, *Penicillium*, and *Phomopsis*. The representatives of these genera are also used in biomedicine, agriculture, and the food industry. Meanwhile, the biotechnological potential of other fungal groups can also be of high importance. They are, however, excluded from the scope of the research for a variety of reasons.

Therefore, for a global assessment of the biotechnological potential of fungal strains maintained in collections, it is necessary to collect all available and newly received information about their properties in specialized databases [8].

A recent analytical comparison of All-Russian Collection of Microorganisms (VKM) databases with the database ChEBI (Chemical Entities of Biological Interest; <https://www.ebi.ac.uk/chebi/>) and database ChEMBL (Chemical Database of European Molecular Biology Laboratory; <https://www.ebi.ac.uk/chembl/>) containing information on fungal metabolites showed that VKM have significant number of potentially interesting strains for a comprehensive study of their metabolome [9].

Due to the constant interest in the search for new producers of biotechnologically promising fungal metabolites, the specialized databases on the diversity of fungi maintained in collections worldwide (FungalDC—Fungal Diversity in Culture Collections) and the ability of fungi to produce secondary metabolites (Metabolites of Fungi) were constructed in VKM.

The goal of this study was to compare on the basis of VKM databases, the diversity of the total fund of fungi in collections worldwide with the diversity of known fungi-producers that synthesize metabolites promising for applied use.

2. Materials and Methods

Materials contained in databases FungalDC and Metabolites of Fungi were used in this research. Each database was constructed with the appropriate structure of tables, forms, and queries in Access 2010.

The FungalDC database [10–12] is available online at the VKM website (www.vkm.ru). A hyperlink to this database is provided on the Mycobank portal in the section “External links—Specimens and strains links” for each taxon mentioned on its pages. It should be noted that this database includes only those collections that have available electronic or printed catalogs of their holdings.

The table of the fungal diversity in the culture collections presented in the FungalDC has the following fields:

- Code.
- Country.
- Collection Acronym.
- WDCM Number.
- Full Name of Culture Collection.
- Count of Species.
- Genus.
- Species.
- Variant/Subspecies.

The Metabolites of Fungi database [13] is also available on the VKM website, but only in test mode so far.

The table of the fungal metabolites’ diversity contains the following fields:

- Code.
- Name of database.
- Database ID.
- Name of Metabolite.
- Genus.

- Species.
- Strain Number.
- Reference.

The method used here is a comparison of the common data fields with the same values of Genus and Species in two databases. Additional information was obtained from the other fields: the distribution of taxa of the cumulative fungal fund in various collections of different countries; the diversity of unique chemical compounds—fungal metabolites; the number and diversity of the mentioned specific strains.

3. Results

The FungalDC database was analyzed to obtain information on the different types of fungi found in the world's culture collections (Table 1).

Table 1. Volume of information in FungalDC (on 2 June 2022).

Characteristics	Volume of Information
Number of records	84,276
Number of countries	53
Number of culture collections	279
Number of fungal genera	4799
Number of fungal species	32,495

Curation is an essential aspect of FungalDC that distinguishes it from WDCM (<http://ccinfo.wdcm.org/>). This indicates that virtually every taxon was validated against the Index Fungorum (<http://www.indexfungorum.org/>) and Mycobank databases. This makes it possible to achieve correspondence in the spelling of the mentioned taxa, and this simplifies the search of the desired taxon by users. In FungalDC, the numerous misspellings and errors of genera names and species epithets that could be found in catalogues of any level collection were corrected. Continued curation work will contribute to the compilation of the most correct list of species of the world fungal fund in FungalDC.

Most of the collections analyzed in FungalDC are WDCM-registered and belong to the World Federation of Culture Collections (WFCC). WFCC maintain information on collections of microorganisms from various countries and accumulate information about the species presented in them, and promote and support the establishment of new culture collections and related services (https://wfcc.info/about_view). The remaining collections included in the database were created at scientific institutions and do not have WDCM registration numbers; however, they publish catalogs of fungal cultures stored in them.

The FungalDC query system allows to see the abbreviations of culture collections, their names, the country where the collection is located, and the number of fungal species in each.

Table 2 presents the number of culture collections per country. The biggest numbers of them are in Asia (such as Thailand, Japan, and India). A complete list of collections that make their catalogues available to users is provided in Appendix A.

Table 2. Location of the collections by country (on 2 June 2022).

Countries	Number of Culture Collections
Argentina	3
Armenia	1
Australia	19
Belarus	1
Belgium	6
Brazil	32
Bulgaria	2
Canada	18
Chile	1
China	5
Czech Republic	11
Denmark	2
Finland	2
France	4
Germany	4
Greece	3
Hong Kong	1
Hungary	2
India	13
Indonesia	4
Iran	2
Ireland	1
Italy	3
Japan	15
Malaysia	2
Mexico	9
The Netherlands	1
New Zealand	5
Pakistan	1
Philippines	3
Poland	4
Portugal	1
Republic of Korea	1
Romania	1
Russian Federation	10
Senegal	1
Serbia	1
Singapore	2
Slovak Republic	3
Slovenia	2
Spain	2
Sri Lanka	1
Sweden	3
Switzerland	1
Taiwan	1
Thailand	36
Turkey	2
UK	9
Ukraine	2
USA	17
Uzbekistan	1
Vietnam	1
Zimbabwe	1

The information on the fungal species in the collection catalogues indicates that the total collection fund is more than 4700 genera and 32,000 unique species, including synonyms. Most fungal species are represented in European collections (Figure 1). This is

largely due to the capability of the world’s leading mycological collection—CBS—in The Netherlands, which contains over 18,000 fungal species.

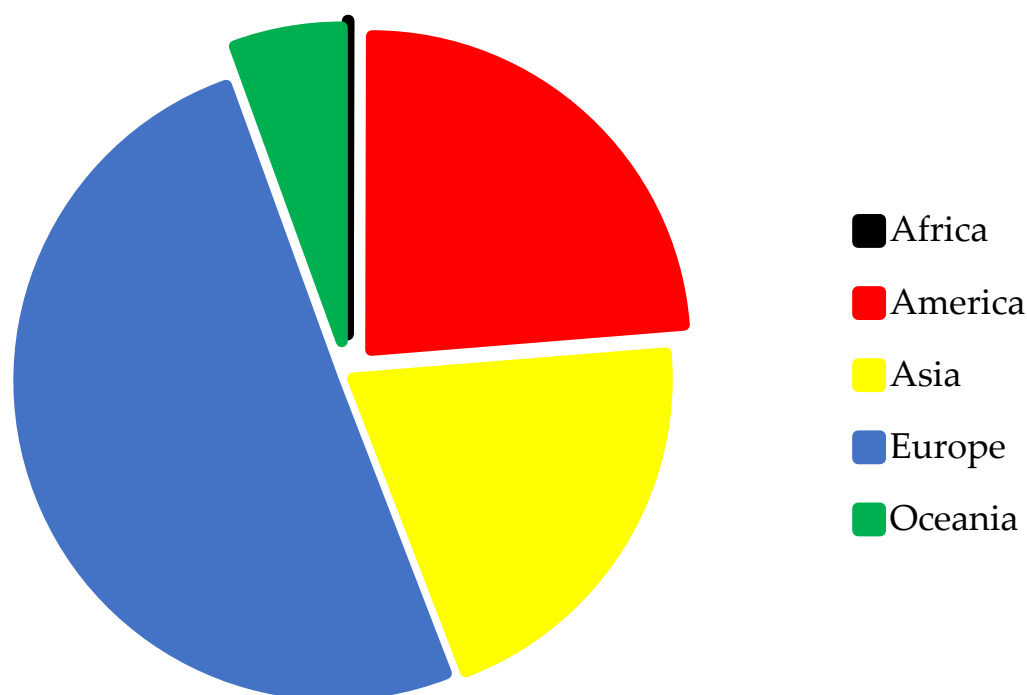


Figure 1. Distribution of fungal species in culture collections on different continents.

The genera whose strains are the most frequently isolated from different habitats and are widely studied in connection with their beneficial or harmful properties are the most numerous in the culture collections: *Penicillium*, *Candida*, *Aspergillus*, *Fusarium*, *Alternaria*, *Chaetomium*, *Colletotrichum*, *Phoma*, *Diaporthe*, and *Cladosporium*.

It should be noted that representatives of some fungal genera are preserved in the majority of the collections, or at least in a significant part of them (Table 3). These are, first of all, fungi whose metabolome is actively studied (*Penicillium*, *Fusarium*), yeasts actively used in the food industry (*Saccharomyces*), and opportunistic yeasts such as *Candida* and *Cryptococcus*. It is these fungi that are most in demand by users for scientific and practical research.

Table 3. Fungal genera preserved in the maximum number of collections (on 2 June 2022).

Fungal Genera	Number of Culture Collections
<i>Penicillium</i>	159
<i>Saccharomyces</i>	151
<i>Fusarium</i>	150
<i>Candida</i>	141
<i>Trichoderma</i>	135
<i>Rhizopus</i>	131
<i>Mucor</i>	127
<i>Cryptococcus</i>	124
<i>Cladosporium</i>	119
<i>Chaetomium</i>	110
<i>Rhodotorula</i>	109
<i>Paecilomyces</i>	105

However, there are collections, one of the tasks of which is to support fungi of rare taxa and to preserve biological diversity in general. They keep species that are poorly studied or new to science. This group also includes fungi isolated from extreme habitats.

These may be micromycetes with a high adaptive potential capable of active metabolism under unfavorable environmental conditions [14]. Such fungi are stored mainly in large bioresource centers such as CBS, MUCL, DAOMC, VKM, and others (Appendix A). It is in these poorly studied organisms that the potential of the kingdom of Fungi is concentrated, which has yet to be revealed.

The Metabolites of Fungi database was constructed on ChEBI (Chemical Entities of Biological Interest, (<https://www.ebi.ac.uk/chebi/>) and FungalMet (<http://www.fungalmet.org/it/>) databases.

The acronym ChEBI literally means “chemicals of biological interest database”. It provides all researchers with open access to information on low-molecular-weight chemical compounds produced by fungi and reflects the relationships between individual chemicals, their families, and classes [15]. All this database information is of public access (Creative Commons license, CC BY 4.0). All the data presented have links to their sources. The main data sources for the ChEBI database are the databases: IntEnz, ChEMBL, KEGG COMPOUND, PDBChem. Among the Life Sciences databases interacting with ChEBI, we found the following: ArrayExpress, EAWAG-BBD, BioModels, BRENDA, ChEMBL, ChemIDplus, COMe, DDBJ, DrugBank, EMBL, ENA, Enzyme Portal, Expression Atlas, GenBank, GMD, IEDB, IntAct, IntEnz, IUBMB, KEGG, KEGG DRUG, KEGG GLYCAN, LIPID MAPS, LMPD, LMSD, nmrshiftdb, NURSA, PDBe, PIR, PubChem, Reactome, RESID, Rhea, SABIO-RK, wwPDB, and UniProtKB.

The manual and default keyword search for fungal organisms in ChEBI provides comprehensive information on diverse fungal taxa and their metabolites.

FungalMet stores information on secondary metabolites of fungi that were addressed and correlated with fungal sources in scientific publications. Metabolites can be found using the search with various parameters, such as the microorganism-producer and the name of the compound or the chemical formula. Currently, the database contains more than 3000 metabolite names. When the new information comes, the database is updated with the new substances of the fungal origin. Information on all of its fungal taxa and on all the metabolite names was extracted from FungalMet. Interestingly, in the process of analyzing the data obtained, it turned out that these two bases largely complement each other, with very little overlap (Table 4).

Table 4. Data from different sources in the Metabolites of Fungi database (on 26 April 2022).

Characteristics	Total	ChEBI	FungalMet
Number of records	7437	4022	3226
Number of unique metabolite records	6397	3672	2725

Table 4 shows that these two databases together contain the information on more than 7400 metabolites. At the same time, 6397 of them are unique, that is, they are found only in one of them.

These metabolites are produced by 304 fungal genera, of which approximately 10% generate 20 or more metabolites and 35% produce a single metabolite. Several fungal taxa, however, as shown in Table 5, produce hundreds of beneficial compounds.

The yeast *Saccharomyces cerevisiae*, which has played an important role in food and beverage fermentation for centuries and has been extensively studied (Table 6), maintains a special place on the fungal list.

Table 5. Genera of fungi with high production of metabolites (on 26 April 2022).

Fungal Genera	Number of Metabolites Produced by Members of the Genus
<i>Saccharomyces</i>	1886
<i>Aspergillus</i>	1107
<i>Penicillium</i>	754
<i>Ganoderma</i>	434
<i>Fusarium</i>	293
<i>Chaetomium</i>	235
<i>Alternaria</i>	164
<i>Trichoderma</i>	128
<i>Phoma</i>	97
<i>Acremonium</i>	91

Table 6. Species of fungi with high production of metabolites (on 26 April 2022).

Fungal Species	Number of Metabolites Produced by Members of the Species
<i>Saccharomyces cerevisiae</i>	1881
<i>Ganoderma lucidum</i>	306
<i>Aspergillus fumigatus</i>	143
<i>Aspergillus niger</i>	128
<i>Chaetomium globosum</i>	108
<i>Aspergillus terreus</i>	85
<i>Aspergillus flavus</i>	53
<i>Gibberella fujikuroi</i>	53
<i>Cordyceps sinensis</i>	52
<i>Aspergillus ochraceus</i>	48
<i>Claviceps purpurea</i>	47
<i>Penicillium citrinum</i>	46
<i>Aspergillus nidulans</i>	42

As not all strains of the same species are equally active in the production of a particular metabolite, the substrate from which the strain was isolated, the duration and methods of its conservation in the collection, etc., are of high importance in research. In this regard, many scientific journals in their rules for authors indicate as compulsory the information on the number (designation) of the strain used in the study. For example, Journal of Microbiology in Instructions to Authors “strongly encourages authors to deposit important strains in publicly accessible culture collections and to refer to these collections and strain numbers in the manuscript”.

Nevertheless, not all the Metabolites of Fungi database records with metabolites produced by micromycetes are accompanied by specific strain numbers. Additionally, only a very small part of them keep the records with the strain numbers of the known culture collections. As a result, only 1176 database records present the strains, the rest do not indicate it at all. Of these, there are 325 records with numbers of known collections (Table 7), they make 129 unique collection strains only. Some collections are excluded from the database because neither their catalogues nor their WDCM numbers are available.

The results of the comparative analysis on the diversity of the world collection fungal strains on one side with the diversity of fungi with the metabolites studied and presented in the most famous Life Sciences databases on the other side, are presented in Table 8.

Table 7. Strains in Metabolites of Fungi database (on 26 April 2022).

Acronym of Culture Collection	Country	Website	Number in WDCM/Name of Collection	Records with the Strain Number	Number of Unique Strains
ATCC	USA	http://www.atcc.org/	WDCM1	115	34
BCC	Thailand	http://www.biotec.or.th/bcc/	WDCM783	54	16
CBMAI	Brazil	https://cbmai.cpqba.unicamp.br/?lang=en	WDCM823	1	1
CBS	The Netherlands	http://www.westerdijkinstituut.nl/	WDCM133	14	7
CCTCC	China	http://www.cctcc.org/	WDCM611	3	1
DSMZ	Germany	http://www.dsmz.de/	WDCM274	11	3
IBT	Denmark	http://www.bioengineering.dtu.dk/english	WDCM758	4	2
IFM	Japan	http://www.pf.chiba-u.ac.jp/	WDCM60	8	2
IFO (NRBC)	Japan	https://www.nite.go.jp/nbrc/catalogue/?lang=en	WDCM191	11	8
IMI	UK	http://www.cabi.org/	WDCM214	26	13
KMM	Russia	http://www.piboc.dvo.ru/	WDCM644	10	2
NRRL	USA	https://nrml.ncaur.usda.gov/	WDCM97	54	30
AJ	Japan	https://www.ajinomoto.com/	Central Research Laboratories, Ajinomoto Co. Inc., Kawasaki, Japan	5	3
FERM	Japan	https://www.aist.go.jp/index_en.html	Patent and Bio-Resource Center, National Institute of Advanced Industrial Science and Technology (AIST), Tsukuba, Ibaraki, Japan	3	3
MRC	South Africa	www.samrc.ac.za	National Research Institute for Nutritional Diseases, Tygerberg, South Africa	2	1
NRCC	Canada	https://nrc.canada.ca/en	Division of Biological Sciences, National Research Council of Canada, Ottawa, Canada	1	1
TUF	Estonia	https://www.natmuseum.ut.ee/en/content/mycological-collection	The mycological collection of the University of Tartu, Estonia	3	2

Table 8. Diversity of fungi in culture collections and metabolite database (on 2 June 2022).

Name of Database	Number of Genera	Number of Species
FungalDC	4799	32,495
Metabolites of Fungi	304	899
Share (%)	6.3	2.8

4. Discussion

The analysis of the integrated data made it possible to assess the extent to which fungi from different taxa have been studied in relation to their ability to produce metabolites and to understand in which collections of the world one or another known producer of certain chemical compounds should be sought.

The main interest in fungal metabolites is associated with the discovery of new drugs, since among the substances produced by fungi, most exhibit antibacterial, antifungal, or antitumor activity [16]. According to the literature data, these biologically active substances are found in certain taxa of fungi, mainly in the representatives of the *Pezizomycotina* subphylum and in several classes of basidiomycetes (for example, *Agaricomycetes* and *Exobasidiomycetes*) [17]. Our analysis of the database showed that, among the fungal genera whose representatives produce the maximum number of metabolites (more than 20), the greatest number actually belongs to the four classes of *Pezizomycotina* and *Agaricomycetes* of *Agaricomycotina* (Figure 2).

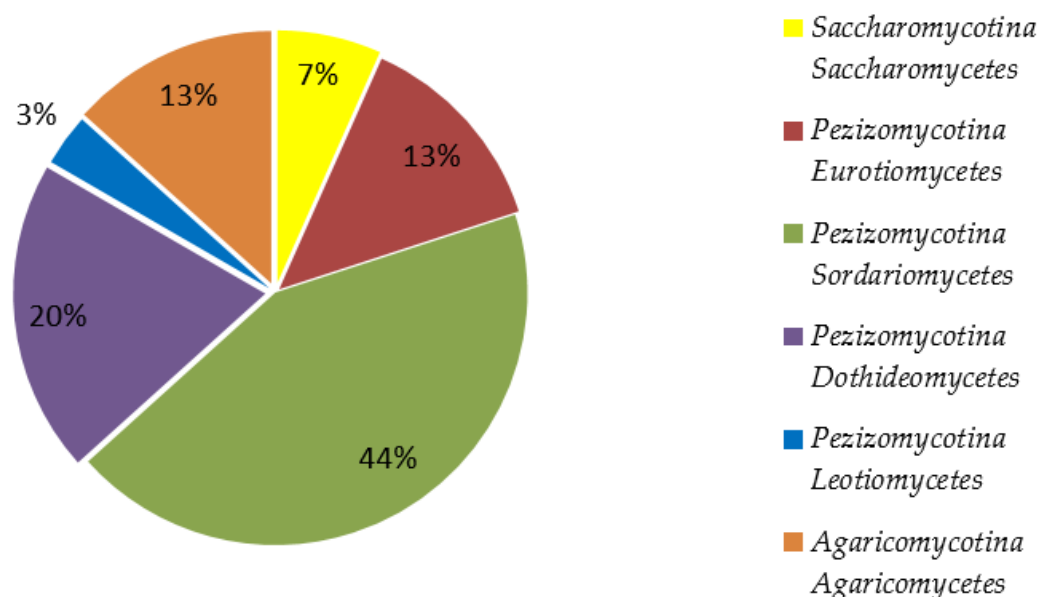


Figure 2. A variety of fungi with the greatest number of produced substances (more than 20).

The most inspected fungi belong to the order *Eurotiales* (*Eurotiomycetes*), including the genera *Aspergillus*, *Penicillium*, *Paecilomyces*, and *Paecilom*. Several dozen taxa are utilized in biotechnological research but are not supported in collections for *yces*, as well as certain fungal genera from the order *Hypocreales* (*Sordariomycetes*).

The last group has representatives of the genera *Fusarium*, *Trichoderma*, *Acremonium*, and others that have been constantly researched and studied over the years. Among the producers, there are also representatives of other phyla—*Mucoromycotina*, *Taphrinomycotina*, *Pucciniomycotina*, etc., but their number is disproportionately small. This is largely due to the insufficient use of the collection fund available for researchers.

Taxonomic diversity comparison in FungalDC and Fungal Metabolite database revealed only 70 fungal species known to be producers but not present in the culture collections.

Most of them are fungi whose metabolites were studied directly in the investigation of natural objects—a total of 50 species. These are difficultly cultivated basidiomycetes of the class *Pucciniomycetes* (*Glomospora* and *Uromyces*), pathogens of rust on cereal plants, lichenized ascomycetous fungi *Ramalina capitata* and *Pertusaria* sp., as well as representatives of the genera *Cytonaema* and *Smardaea* that form stromas on woody plants. This also includes the fungus *Plasmodiophora brassicae*, the causative agent of diseases of cruciferous plants, currently a representative of the Protozoa kingdom (*Plasmodiophoromycota*, *Plasmodiophoromycetes*). Most of the taxa of this group belong to the class *Agaricomycetes*

(23 genera, 41 species), a characteristic feature of which is the presence of rather large fruiting bodies, in the study of which metabolites were detected. Examples: the genera *Agaricus*, *Amanita*, *Boletus*, *Chlorophyllum*, *Clitocybe*, *Conocybe*, *Favolaschia*, *Ganoderma*, *Inocybe*, *Polyporus*, *Psilocybe*, *Tylopilus*, and others. Among ascomycetes, truffles *Tuber liyuanum* and *Tuber magnatum*, morel *Morchella importuna* can be included into this group.

The remaining 20 species are represented by cultivated micromycetes that are not maintained in collections according to the FungalDC database. Among them, the species with type strains not currently available and the species descriptions in the literature not sufficient to confirm the uniqueness of the taxon (for example, *Alternaria oryzae* [18], *Microascus tardifaciens* [19]), as well as taxa not represented in collections with available catalogs, such as *Pestalotiopsis fici*, *Pestalotiopsis oenotherae*, *Phomopsis paspali*, *Guanomyces polythrix*, *Cercospora coffeicola*, and *Sordaria araneosa*.

Several dozen taxa are utilized in biotechnological research but are not supported in collections for multiple reasons, as confirmed by the data obtained. On the other hand, the number of fungal taxa with the strains maintained in collections and with the known metabolites production is less than 3% of the total diversity of the total repository list of collections (Table 8).

On the one side, the diversity of the entire world fungal collection fund was compared to the diversity of the list of species traditionally utilized in scientific research. On the other side, it was demonstrated that the scientific community continues to underestimate the possibility of obtaining new promising strains from collection repositories.

The database FungalDC developed in VKM is available to users on various portals—www.vkm.ru and www.mycobank.org in online mode could possibly help with this issue. Perhaps its use will considerably expand the range of strains studied and lead to new scientifically significant data.

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Appendix A. List of Culture Collections (on 2 June 2022)

	Country	Acronym	WDCM Number	Culture Collection Name	Number of Species
1	Argentina	BGIV	WDCM962	Banco de Glomeromycota In Vitro (Bank of Glomeromycota In Vitro)	8
2		CCM	WDCM29	Coleccion de Cultivos Microbianos	28
3		CEP	WDCM973	Entomopathogenic Fungal Culture Collection of Argentina	30
4	Armenia	MDC	WDCM803	Microbial Depository Center (National Microbial Culture Collection of the Republic of Armenia)	305

	Country	Acronym	WDCM Number	Culture Collection Name	Number of Species
5		AMMRL	WDCM42	Australian National Reference Laboratory in Medical Mycology	326
6		AWRI MCC	WDCM22	AWRI Microorganism Culture Collection	55
7		CC	WDCM61	CSIRO Canberra Rhizobium Collection	1
8		CS	WDCM532	CSIRO Collection of Living Micro-algae	1
9		DE-CSIRO	WDCM70	CSIRO Insect Pathogen Culture Collection	14
10		DMPMC	WDCM454	Department of Microbiology	20
11		DFP	WDCM102	DFP Culture Collection	447
12		FRR	WDCM18	Food Science Australia, Ryde	451
13	Australia	WAITE	WDCM35	Insect Pathology Pathogen Collection	19
14		JCT	WDCM387	James Cook Townsville	161
15		KEMH	WDCM11	KEMH/PMH Culture collection	33
16		ACH	WDCM47	Mycology Culture Collection	123
17		WAC	WDCM77	Plant Pathology Culture Collection	347
18		SBSFU	WDCM78	School of Biological Sciences	3
19		SMTWA	WDCM90	School of Medical Technology Western Australia	1
20		SAITP	WDCM569	School of Pharmacy and Medical Sciences, University of South Australia	1
21		WACC	WDCM452	Western Australian Culture Collection	13
22		WM	WDCM1205	Westmead Medical Mycology Collection	366
23		DWT	WDCM36	Wood Technology and Forest Research Division	80
24	Belarus	BIM	WDCM909	Belarusian Collection of non-pathogenic microorganisms	164
25		MUCL	WDCM308	Agro-food and Environmental Fungal Collection	4601
26		BCCM/IHEM	WDCM642	BCCM/IHEM—Fungi Collection: Human and Animal Health	1855
27	Belgium	CRA-W	-	Fungi collection, Walloon Agricultural Research Centre	11
28		GINCO	-	Glomeromycota in vitro collection	7
29		LUC	-	Limburgs Universitair Centrum	11
30		CLO-Gent	-	<i>Verticillium chlamydosporium</i> (Fungi) strain collection	1
31		IPT	WDCM721	Agrupamento de Biotecnologia, Culture Collection of Microorganisms	4
32		ITAL	WDCM143	Banco de Fermentos Lacticos	2
33		CBMAI	WDCM823	Brazilian Collection of Microorganisms from the Environment and Industry	111
34		BCCCp	WDCM921	Brazilian Culture collection of <i>Crinipellis perniciosa</i>	1
35		CRM-UNESP	WDCM1043	Central de Recursos Microbianos do Instituto de Biociencias da UNESP	60
36	Brazil	FTI	WDCM716	Centro de Biotecnologia e Quimica-CEBIQ	14
37		CCB	WDCM713	Colecao de Culturas de Basidiomicetos	16
38		CFAF	-	Colecao de Culturas de Fitopatogenos e Agentes de Controle Biologico de Fitopatogenos	13
39		Fiocruz/CCFF	WDCM720	Colecao de Culturas de Fungos Filamentosos	359
40		CCT	WDCM885	Colecao de Culturas Tropical	692
41		Fiocruz/CFAM	WDCM957	Colecao de Fungos da Amazonia	71
42		CFEUioeste	-	Colecao de Fungos Entomopatogenicos do Laboratorio de Biotecnologia Agricola	5
43		CFEOCA	-	Colecao de Fungos Entomopatogenicos Oldemar Cardim Abre	19
44		Fiocruz/CFP	WDCM951	Colecao de Fungos Patogenicos	20
45	UFPEDA	WDCM114	Colecao de Microrganismos UFPEDA	127	

	Country	Acronym	WDCM Number	Culture Collection Name	Number of Species
46		CICG	-	Colecao Internacional de Cultura de Glomeromycota	24
47		CCMA-UFLA	WDCM1083	Culture Collection of Agricultural Microbiology	59
48		CCDCA	WDCM1081	Culture Collection of Microorganisms from the Department of Food Science	58
49		UFRJIM	WDCM725	Departamento de Microbiologia Medica	2
50		DPUA	WDCM715	Departamento de Patologia/ICB	81
51		IZ	WDCM724	Departamento de Tecnologia Rural	344
52		CG	WDCM712	Embrapa Genetic Resources and Biotechnology Collection of Fungi of Interest to Biological Control	42
53		CCOC	WDCM575	Fundacao Oswaldo Cruz-FIOCRUZ	45
54		CCT	WDCM711	Fundacao Tropical de Pesquisas e Tecnologia "Andre Tosello"	97
55		INPA	WDCM719	Laboratorio de Micologia Medica Divisao de Microbiologia e Nutricao	93
56		IALMIC	WDCM717	Micoteca do Insituto Adolfo Lutz	90
57		IMT	WDCM718	Micoteca do Instituto de Medicina Tropical de Sao Paulo	254
58		MGSS	-	Micoteca Prof. Gilson Soares da Silva	61
59		CMRP	WDCM1240	Microbiological Collections of Parana Network	344
60		IAL	WDCM282	Nucleo de Colecao de Micro-organismos	3
61		ITALSM	WDCM723	Secao de Microbiologia	19
62		URM	WDCM604	Universidade Federal de Pernambuco	1144
63	Bulgaria	BTCC	WDCM66	Bulgarian Type Culture Collection	77
64		NBIMCC	WDCM135	National Bank for Industrial Microorganisms and Cell Cultures	213
65	Canada	DAOMC	WDCM150	Canadian Collection of Fungal Cultures	2716
66		CSCC	-	Cereal Smuts Cultures Collection, Winnipeg Research Centre Agriculture and Agri-Food Department of Crop Sciences and Plant Ecology University of Saskatchewan	6
67		LSRRW	-	Department of Microbiology MUL-B 250	2
68		MUL	WDCM250	Department of Plant Sciences	6
69		UWO	WDCM91	Felix d'Herelle Reference Center for Bacterial Viruses	294
70		HER	WDCM6	Forest Pathology Culture Collection, Pacific Forest Research Centre	1
71		DFF	WDCM50	Fredericton Stock Culture Collection	164
72		FSC	WDCM237	Lallemand Yeast Culture Collection	128
73		LYCC	WDCM634	Oat crown rust Collection, Winnipeg Research Centre Agriculture and Agri-Food	1
74		OCRC	-	Oat Stem Rust Collection, Winnipeg Research Centre Agriculture and Agri-Food	1
75		OSRC	-	PFC Wood Decay Culture Collection, Pacific Forestry Centre	1
76		PFCWDCC	-	Research Centre Culture Collection of Agriculture and Agri-Food	8
77		CCRCAF	-	Salmonella Genetic Stock Centre	2
78		SGSC	WDCM338	Sporometrics Culture Collection of Microorganisms	21
79		SCCM	WDCM920	UAMH Center for Global Microfungal Biodiversity	30
80	UAMH	WDCM73	Wheat Leaf Rust Collection, Winnipeg Research Centre Agriculture and Agri-Food	1721	
81	WLRC	-		1	

	Country	Acronym	WDCM Number	Culture Collection Name	Number of Species
82		WSRC	-	Wheat Stem Rust Collection	1
83	Chile	CChRGM	WDCM1067	Chilean Collection of Microbial Genetic Resources	21
84		CCTCC	WDCM611	China Center for Type Culture Collection	822
85		ACCC	WDCM572	Agricultural Culture Collection of China	300
86	China	CGMCC	WDCM550	China General Microbiological Culture Collection Center	1118
87		CCDM	WDCM117	Culture Collection of Department of Microbiology	41
88		CMCC(B)	WDCM123	National Center for Medical Culture Collections	34
89		RIBM	WDCM655	Collection of Brewing Yeasts, Research Institute for Brewing and Malting	28
90		CMF ISB	-	Collection of Microscopic Fungi ISB (CMF ISB)	280
91		DBM	WDCM654	Collection of Yeasts and Industrial Microorganisms, Institute of Chemical Technology, Department of Biochemistry and Microbiology	103
92	Czech Republic	DMUP	WDCM658	Collection of Yeasts, Department of Genetics and Microbiology, Faculty of Science, Charles University	71
93		CCBAS	WDCM558	Culture Collection of Basidiomycetes	288
94		CCDM	-	Culture Collection of Dairy Microorganisms	16
95		CCF	WDCM182	Culture Collection of Fungi	615
96		RIFIS	-	Culture Collection of Microorganisms with Application in the Fodder Industry, Food Research Institute	30
97		CCC	-	Czech Collection Clavicipitales	31
98		CCM	WDCM65	Czech Collection of Microorganisms	513
99		CNCTC	WDCM130	Czech National Collection of Type Cultures	78
100		IBT	WDCM758	IBT Culture Collection of Fungi	103
101	Denmark	SSI	WDCM158	The International Escherichia and Klebsiella Centre (WHO)	1
102		HAMBI	WDCM779	HAMBI Culture Collection	36
103	Finland	VTTCC	WDCM139	VTT Culture Collection	139
104		UMIP	WDCM344	Collection de Champignons et Actinomycetes Pathogenes	229
105	France	CNCM	WDCM174	Collection Nationale de Cultures de Microorganismes	54
106		LCP	WDCM659	Fungal Strain Collection, Laboratory of Cryptogamy	588
107		UCLAF	WDCM552	HMR/Romainville	34
108		BLWG	WDCM264	Bayerische Landesanstalt fur Weinbau und Gartenbau	41
109	Germany	DSMZ	WDCM274	DSMZ-Deutsche Sammlung von Mikroorganismen und Zellkulturen GmbH	1603
110		IFAM	WDCM145	Institut fur Allgemeine Mikrobiologie	2
111		BBLF	WDCM204	Institut fur Pflanzenschutz im Forst	112
112		ATHUM	WDCM650	ATHens University Mycology	203
113	Greece	BPIC	WDCM610	Benaki Phytopathological Institute Collection	127
114		NUA	WDCM281	Department of Microbiology, National University of Athens	1

	Country	Acronym	WDCM Number	Culture Collection Name	Number of Species
115	Hong Kong	CUHK	WDCM68	Biology Department, Chinese University of Hong Kong	30
116	Hungary	DACT	WDCM496	Dept. Agricult. Chem. Technol.	256
117		NCAIM	WDCM485	National Collection of Agricultural and Industrial Microorganisms	127
118	India	MPKV	WDCM448	Biological Nitrogen Fixation Project College of Agriculture	13
119		CCDMBI	WDCM119	Culture Collection, Department of Microbiology	78
120		NTCCI	WDCM107	Culture Collection, Microbiology and Cell Biology Laboratory	48
121		DUM	WDCM40	Delhi University Mycological Herbarium	1273
122		DBV	WDCM173	Division of Standardisation	1
123		DMSRDE	WDCM166	DMSRDE Culture Collection	150
124		UMFFTD	WDCM562	Food and Fermentation Technology Division, University of Mumbai	5
125		VPCI	WDCM497	Fungal Culture Collection	60
126		GPCK	-	Germplasm Centre for Keratinophilic Fungi	22
127		ITCC	WDCM430	Indian Type Culture Collection	746
128		MCM	WDCM561	MACS Collection of Microorganisms	8
129		MTCC	WDCM773	Microbial Type Culture Collection and Gene Bank	1004
130		NCIM	WDCM3	National Collection of Industrial Microorganisms	288
131	Indonesia	FNCC	WDCM755	Food and Nutrition Culture Collection	92
132		ICBB	WDCM842	ICBB Culture Collection for Microorganisms and Cell Culture	27
133		ITBCC	WDCM44	Institute of Technology Bandung Culture Collection	57
134		InaCC	WDCM769	Lembaga Ilmu Pengetahuan Indonesia, Indonesian Institute for Sciences	150
135	Iran	IBRC	WDCM950	Iranian Biological Resource Center	288
136		PTCC	WDCM124	Persian Type Culture Collection	50
137	Ireland	IMD	WDCM227	Industrial Microbiology Dublin	104
138	Italy	ITEM	-	Agro-Food Microbial Culture Collection	92
139		CSMA	WDCM147	Centro di Studio dei Microorganismi Autotrofi—CNR	1
140		DBVPG	WDCM180	Industrial Yeasts Collection	288
141	Japan	AHU	WDCM635	AHU Culture Collection	339
142		OUT	WDCM748	Department of Biotechnology	220
143		ATU	WDCM636	Dept. of Biotechnology University of Tokyo	4
144		HUT	WDCM195	HUT Culture Collection	241
145		IAM	WDCM190	IAM Culture Collection	509
146		IFO	WDCM191	Institute for Fermentation, Osaka	3024
147		RIFY	WDCM749	Institute of Enology and Viticulture	15
148		TIMM	WDCM750	Institute of Medical Mycology	148
149		JCM	WDCM567	Japan Collection of Microorganisms	1984
150		TSY	WDCM67	Laboratory of Mycology, Division of Microbiology	5
151		MAFF	WDCM637	NARO Genebank, Microorganism Section	777
152		NIBH	WDCM746	National Institute of Bioscience and Human-Technology	15
153		RIB	WDCM640	National Research Institute of Brewing	14
154		NRIC	WDCM747	Nodai Research Institute Culture Collection	161

	Country	Acronym	WDCM Number	Culture Collection Name	Number of Species
155		IFM	WDCM60	Research Center for Pathogenic Fungi and Microbial Toxicoses, Chiba University	394
156	Malaysia	SKUK	WDCM565	Simpanan Kultur Universiti Kebangsaan	40
157		UKKP	WDCM430	Universiti Kebangsaan Kultur Perubatan	21
158		CENACUMI	WDCM757	Centro Nacional de Cultivos Microbianos (National Center For Microbial Cultures)	277
159		CFQ	WDCM100	Cepario de la Facultad de Quimica	65
160		ITD	WDCM99	Coleccion de Cepas Microbianas	10
161		ENCB-IPN	WDCM449	Coleccion de Cultivos de la Escuela Nacional de Ciencias Biologicas	97
162	Mexico	INIF	WDCM104	Coleccion de Microhongos	83
163		LIH-UNAM	WDCM817	CultureCollection of Histoplasma capsulatum Strains from the Fungal Immunology Laboratory of the Department of Microbiology and Parasitology, Faculty of Medicine, UNAM	1
164		IIBM-UNAM	WDCM48	Industrial Culture Collection	40
165		CDBB	WDCM500	Unidad de Servicios de la Coleccion Nacional de Cepas Microbianas y Cultivos Celulares	123
166		CISM	WDCM95	<i>Verticillium dahliae</i> from cotton	3
167	The Netherlands	CBS	WDCM133	Centraalbureau voor Schimmelcultures, Fungal and Yeast Collection	18,346
168		NZFS	WDCM62	Forest Research Culture Collection	100
169		ICMP	WDCM589	International Collection of Microorganisms from Plants	969
170	New Zealand	WARC	WDCM376	New Zealand Reference Culture Collection	1
171		NZRD	WDCM318	New Zealand Reference Culture Collection of Microorganisms, Dairy Section	2
172		NZRM	WDCM457	New Zealand Reference Culture Collection, Medical Section	5
173	Pakistan	FCBP	WDCM859	First fungal culture bank of Pakistan	119
174		ITDI	WDCM503	Industrial Technology Development Institute	49
175	Philippines	UPCC	WDCM310	Natural Sciences Research Institute Culture Collection	214
176		PNCM-BIOTECH	WDCM620	Philippine National Collection of Microorganisms	144
177		LOCK	WDCM105	Centre of Industrial Microorganisms Collection	38
178		IAFB	WDCM212	Collection of Industrial Microorganisms	159
179	Poland	IAW	-	Research and Development Centre for Biotechnology Culture Collection	17
180		LCC	WDCM231	University of Warmia and Mazury in Olsztyn	34
181	Portugal	MUM	WDCM816	Micoteca da Universidade do Minho	125
182	Republic of Korea	EFCC	-	Entomopatogenic Fungal Culture Collection	58
183	Romania	ICCF	WDCM232	Collection of Industrial Microorganisms	21
184		VKM	WDCM342	All-Russian Collection of Microorganisms	2100
185	Russian Federation	VIZR	WDCM760	Collection for plant protection, All-Russian Institute of Plant Protection	14
186		KMM	WDCM644	Collection of Marine Microorganisms of the Pacific Institute of Biorganic Chemistry of the Far-Eastern Branch of the RAS	48

	Country	Acronym	WDCM Number	Culture Collection Name	Number of Species
187		IPP	-	Collection of Monoxenic Cultures of Arbuscular Mycorrhizal Fungi of the Institute of Plant Physiology RAS	4
188		VNIISC	-	Culture Collection of the Institute of Agricultural Microbiology, Russian Academy of Agricultural Sciences	143
189		IBC	-	Institute of Cell Biology RAS	13
190		LE(BIN)	WDCM1015	Komarov Botanical Institute Basidiomycetes Culture Collection	672
191		VKPM	WDCM588	Russian National Collection of Industrial Microorganisms	733
192		DSB MSU	-	The Department of Soil Sciences Moscow State University	35
193		RIA	WDCM337	The Russia Research Institute for Antibiotics Culture Collection	43
194	Senegal	MAO	WDCM53	Mircen Afrique Ouest	1
195	Serbia	ISS	WDCM375	Collection of Bacteria	1
196	Singapore	DBS	WDCM510	Department of Biological Culture Collection	98
197		NUSDM	WDCM568	Department of Microbiology	24
198	Slovak Republic	CCWDF	-	Culture Collection of Wood-destroying Fungi	52
199		CCY	WDCM333	Culture Collection of Yeasts	394
200		RIVE	WDCM28	Research Institute for Viticulture and Enology	96
201	Slovenia	MZKI	WDCM599	Microbial Culture Collection of National Institute of Chemistry	174
202		ZIM	WDCM810	ZIM Collection of Industrial Microorganisms	112
203	Spain	CECT	WDCM412	Coleccion Espanola de Cultivos Tipo	394
204		CCMCU	WDCM599	Culture Collection of Microorganisms	182
205	Sri Lanka	DMBUK	WDCM564	Department of Microbiology	44
206	Sweden	CCUG	WDCM32	Culture Collection University of Goteborg	92
207		FCUG	WDCM651	Fungal Cultures University of Goteborg	507
208		UPSC	WDCM603	Uppsala University Culture Collection of Fungi	800
209	Switzerland	CCTM	WDCM475	Centre de Collection de Type Microbien	19
210	Taiwan	BCRC	WDCM59	Bioresource Collection and Research Center	1545
211	Thailand	BSMB	WDCM491	Bacteriology and Soil Microbiology Branch	20
212		BCC	WDCM783	BIOTEC Culture Collection	399
213		NRPSU	WDCM679	Department of Agro-industry, Faculty of Natural Resources	36
214		ABKMI	WDCM698	Department of Applied Biology, Faculty of Science	12
215		DBKKU1	WDCM687	Department of Biology, Faculty of Science	27
216		SWU2	WDCM697	Department of Biology, Faculty of Science	4
217		DBMU2	WDCM667	Department of Biotechnology, Faculty of Science	62
218		FTCMU	WDCM690	Department of Food Science and Technology, Faculty of Agriculture	10
219		DMST	WDCM707	Department of Medical Sciences Culture Collection	204
220		MPSU	WDCM492	Department of Microbiology	2
221		DMKKU1	WDCM680	Department of Microbiology, Faculty of Medicine	2
222		DMMU3	WDCM668	Department of Microbiology, Faculty of Medicine Siriraj Hospital	66

	Country	Acronym	WDCM Number	Culture Collection Name	Number of Species
223		DMKU	WDCM669	Department of Microbiology, Faculty of Science	57
224		NU	WDCM696	Department of Microbiology, Faculty of Science	2
225		PPKU1	WDCM670	Department of Plant Pathology, Faculty of Agriculture	5
226		PPKU3	WDCM672	Department of Plant Pathology, Faculty of Agriculture	19
227		PPKU4	WDCM673	Department of Plant Pathology, Faculty of Agriculture	18
228		PPKU5	WDCM674	Department of Plant Pathology, Faculty of Agriculture	10
229		MLMJI	WDCM701	Department of Plant Protection, Faculty of Agricultural Production	7
230		CMKKU	WDCM684	Diagnostic Microbiology Unit Division of Clinical Laboratory Srinagarind Hospital, Faculty of Medicine	9
231		IFRPD	WDCM676	Institute of Food Research and Product Development, Kasetsart University	35
232		KUFC	WDCM677	Kasetsart University Fungus Collection, Department of Plant Pathology, Faculty of Agriculture	18
233		KKU	WDCM23	MICKKU Culture Collection	18
234		MLLD	WDCM702	Microbiological Research Laboratory, Soil and Water Section, Department of Land Development	3
235		CHULA	WDCM511	Department of Microbiology, Faculty of Science	34
236		DMCU	WDCM663	Microbiology Department, Faculty of Science	24
237		MLRU	WDCM695	Microbiology Laboratory, Department of Biology, Faculty of Science	7
238		MSDS	WDCM494	Microbiology Section, Biological Science Division, Department of Science Services	9
239		MSCMU	WDCM692	Microbiology Section, Chiang Mai University (MSCMU)	50
240		MSPP	WDCM704	Mycology Section, Plant Pathology and Microbiology Division, Department of Agricultural Science	4
241		NCSC	WDCM664	National Center of Streptococcus Collection, Department of Microbiology, Faculty of Medical Science	16
242		PCU	WDCM662	Pharmaceutical Sciences Chulalongkorn University Culture Collection	10
243		PPKM	WDCM699	Plant Production Technology Department, Faculty of Agricultural Technology	5
244		ERAEP	WDCM706	Radiation Ecology Section, Biological Science Division, Office of Atomic Energy for Peace	5
245		SSMJI	WDCM700	Science Section, Department of General Education, Faculty of Agricultural Business	9
246		TISTR	WDCM383	TISTR Culture Collection, Bangkok MIRCEN	235
247	Turkey	KUKENS	WDCM101	Centre for Research and Application of Culture Collections of Microorganisms	83
248		RSKK	WDCM828	Refik Saydam National Type Culture Collection-RSKK	22
249	UK	IMI	WDCM214	CABI Bioscience Genetic Resource Collection	3716
250		BEG	WDCM777	La Banque European des Glomales	30
251		NCPF	WDCM184	National Collection of Pathogenic Fungi	151
252		NCTC	WDCM154	National Collection of Type Cultures	1

	Country	Acronym	WDCM Number	Culture Collection Name	Number of Species
253		NCWRF	WDCM134	National Collection of Wood Rotting Fungi	296
254		NCYC	WDCM169	National Collection of Yeast Cultures	449
255		PHBL	WDCM508	Philip Harris Biological Ltd.	27
256		DMCCUS	WDCM478	School of Biological Sciences Culture Collection	17
257		CCMF	WDCM766	University of Portsmouth	207
258	Ukraine	IBK	WDCM1152	Culture Collection of Mushrooms	195
259		UCM	WDCM1203	Ukrainian Collection of Microorganisms	195
260		NRRL	WDCM97	Agricultural Research Service Culture Collection	742
261		ATCC	WDCM1	American Type Culture Collection	5585
262		ARSEF	WDCM112	ARS Collection of Entomopathogenic Fungi	366
263		LMS	WDCM530	Carolina Biological Supply Company	67
264		FGSC	WDCM115	Fungal Genetics Stock Center	21
265		INVAM	-	International Culture Collection of VA Mycorrhizal Fungi	76
266	USA	MCC	-	Mushroom Culture Collection Department of Plant Pathology, The Pennsylvania State University, USA	198
267		DM	-	National Center for Agricultural Utilization Research	54
268		NCMA	WDCM2	Provasoli-Guillard National Center for Marine Algae and Microbiota	4
269		BMP	-	Pryor Lab Culture Collection, The University of Arizona, USA	119
270		RMF	-	Rocky Mountain Fungus, Wyoming	374
271		DSC	WDCM849	The Dicty Stock Center	16
272		UA	-	The University of Alabama	4
273		UBC	-	University of California at Berkeley	1
274		UM	-	University of Maine, Orono, Maine, USA	14
275		WVDH	WDCM411	West Virginia Hygienic Laboratory	13
276		WSF	-	Wisconsin Soil Fungus	183
277	Uzbekistan	NCAM	WDCM808	National Collection of Agricultural Microorganisms	146
278	Vietnam	CNTP	-	The Industrial Microorganisms Culture Collection	39
279	Zimbabwe	BDUZ	WDCM17	Biological Sciences	17

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