Culturable mycobiota from Karst caves in China II, with descriptions of 33 new species

Zhi-Feng Zhang1,2,3 · Shi-Yue Zhou1,3 · Lily Eurwilaichitr4 · Supawadee Ingsriswang4 · Mubashar Raza1,3 · Qian Chen1 · Peng Zhao1 · Fang Liu1 · Lei Cai1,3

Received: 1 March 2020 / Accepted: 29 June 2020 / Published online: 26 July 2020
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Abstract
Karst caves are characterized by darkness, low temperature, high humidity, and oligotrophic organisms due to its relatively closed and strongly zonal environments. Up to now, 1626 species in 644 genera of fungi have been reported from caves and mines worldwide. In this study, we investigated the culturable mycobiota in karst caves in southwest China. In total, 251 samples from thirteen caves were collected and 2344 fungal strains were isolated using dilution plate method. Preliminary ITS analyses showed that these strains belonged to 610 species in 253 genera. Among these species, 88.0% belonged to Ascomycota, 8.0% Basidiomycota, 1.9% Mortierellomycota, 1.9% Mucoromycota, and 0.2% Glomeromycota. The majority of these species have been previously known from other environments, and some of them are known as mycorrhizal or pathogenic fungi. About 52.8% of these species were discovered for the first time in karst caves. Based on morphological and phylogenetic distinctions, 33 new species were identified and described in this paper. Meanwhile, one new genus of Cordycipitaceae, Gamszarea, and five new combinations are established. This work further demonstrated that Karst caves encompass a high fungal diversity, including a number of previously unknown species. Taxonomic novelties: New genus: Gamszarea Z.F. Zhang & L. Cai; Novel species: Amphichorda cavernicola, Aspergillus limoniformis, Aspergillus phialiformis, Aspergillus phialosimplex, Auxarthron chinense, Auxarthron guangxiense, Auxarthronopsis globiasca, Auxarthronopsis pedicellaris, Auxarthronopsis pulverea, Auxarthronopsis stericola, Chrysosporium flavus, Chrysosporium globicum, Chrysosporium laticomatum, Chrysosporium pulvatum, C. testudinea, C. wallacei, Gamszarea indonesiaca (Kurihara & Sukarno) Z.F. Zhang & L. Cai, Gamszarea kalimantanensis (Kurihara & Sukarno) Z.F. Zhang & L. Cai, Gamszarea restricta (Kubátová, Nonaka, Čmoková & Řehulka) Z.F. Zhang & L. Cai, and Gamszarea testudinea (Kubátová, Nonaka, Čmoková & Řehulka) Z.F. Zhang & L. Cai.

Keywords Fungal diversity · Karst cave · Morphology · Phylogeny · Troglobitic fungi · 39 new taxa

Electronic supplementary material The online version of this article (https://doi.org/10.1007/s13225-020-00453-7) contains supplementary material, which is available to authorized users.

Lei Cai cail@im.ac.cn
1 State Key Laboratory of Mycology, Institute of Microbiology, Chinese Academy of Sciences, Beijing 100101, China
2 Institute for Advanced Study, Shenzhen University, Shenzhen 518060, China
3 University of Chinese Academy of Sciences, Beijing 100049, China
4 Thailand Bioresource Research Center, National Center for Genetic Engineering and Biotechnology, Bangkok, Thailand
Introduction

Caves are strongly zonal environment with unique characteristics determined by the karst morphology, subterranean water and surrounding rocks (Kuzmina et al. 2012; Gabriel and Northup 2013). Caves thus have distinctly characteristics, such as darkness, constantly low temperature, high humidity, and oligotrophy (Gabriel and Northup 2013; Zhang et al. 2017, 2018). As a relatively closed space, caves usually have one or several entrances and the environments may be affected by various factors, such as the air currents, chemolithoautotrophy, visitors, and water movements (streams or water seeps; Hose et al. 2000; Barton and Jurado 2007; Gabriel and Northup 2013; Ortiz et al. 2014). Meanwhile, caves are totally dark and lack photosynthesis thus believed to be generally oligotrophic in nature (Hose et al. 2000; Barton and Jurado 2007; Gabriel and Northup 2013; Ortiz et al. 2014; Jiang et al. 2017a). The microbial flora in caves might be shaped by these above affecting factors and oligotrophic environment (Ogórek et al. 2013; Ortiz et al. 2014).

Fungi play important roles in cave ecosystem, such as bio-mineralization or serving as food of cave fauna (Northup and Lavoie 2001; Barton and Northup 2007; Nováková 2009; Li et al. 2015). While, most of the previous studies were focused on cave fauna and fungal diversity has rarely been documented (Zhang et al. 2017). The studies on culturable fungi in caves can be divided into three periods, namely, early stage, developing stage, and explosive stage.

Early stage: before 1980s. The earliest description of fungi in caves was published as early as 1794 by Humboldt, as described in Dobat (1967), and the first ecological literature of caves was that by Megušar (1914). In 1913, Lagarde investigated the fungal diversity in several caves in Europe and described a new species, Ombrophila speluncarum Lagarde. During 1950s–1980s, studies on cave fungi were mostly about animal pathogens, e.g., Histoplasm capsulatum Darling (Ajello et al. 1960a, b; Al-Doory and Rhoades 1968; Di Salvo et al. 1969; Zamora 1977), Trichophyton mentagrophytes (C.P. Robin) Sabour and other dermatophytes (Lurie and Borok 1955; Lurie and Way 1957; Kajihiro 1965).

Developing stage: During 1980s to early 2010s, a number of studies on fungal diversity in caves were reported. Cunningham et al. (1995) investigated the microorganisms in Lechuguilla Cave in New Mexico and obtained nine fungal genera, of which, Aspergillus P. Micheli ex Haller and Penicillium Link were most common. Koilraj et al. (1999) isolated 35 sporulating fungi, belonging to 18 genera and seven sterile fungi from six different caves in India. In the investigation on mycobiota in caves in Slovakia, 195 species belonging to 73 genera, including 92 species were obtained from bat droppings and guano (Novákova 2009).

Explosive stage: since bat White Nose Syndrome (WNS) outbreak in America in 2006. WNS was caused by pathogenic fungus Pseudogymnoascus destructans (Blehert & Gargas) Minnis & D.L. Lindner (Syn: Geomyces destructans Blehert & Gargas), a species isolated from many caves in Europe and North America (Blehert et al. 2009; Martínková et al. 2010; Kubátová et al. 2011; Minnis and Lindner 2013), and resulted in 6 million deaths of bat and ca. 3.7 billion dollars loss in America in 2011 (Boyles et al. 2011). Studies on P. destructans signigicantly improved our knowledge on mycobiota in caves. According to our statistics, about 110 research papers on fungi in caves have been published since 2006 worldwide, indicating a high fungal diversity in caves. In total, about 1000 species of fungi in 550 genera have been documented from caves and mines worldwide by 2012 (Vanderwolf et al. 2013). Common genera are mostly cosmopolitans, i.e. Aspergillus, Penicillium, Mucor Fresen, Fusarium Link, Trichoderma Pers., etc. The most common species are also widespread, i.e. Aspergillus versicolor (Vuill.) Tirab., A. niger Tiegh., Penicillium chrysogenum Thom, Cladosporium cladosporioides (Fresen.) G.A. de Vries, A. fumigatus Fresen., etc. (Vanderwolf et al. 2013).

The Karst landform covers more than 1/3 of the total land area of China and there are more than half million karst caves scattered in China (Ran and Chen 1998; Chen 2006; Zhang and Zhu 2012). However, most studies on cave microorganisms in China were focus on bacteria, and the investigation on fungal diversity was rare, with only several documentations (Hsu and Agoramoorthy 2001; Man et al. 2015; Jiang et al. 2017a; Zhang et al. 2017). In Zhang et al. (2017), 563 fungal strains belonging to 246 species in 116 genera were reported from two unnamed karst cave in Guizhou, China, including 20 new species. Using oligotrophic carbon free silica gel medium, Jiang et al. (2017a, b) studied the oligotrophic fungi from a carbonate cave in China. 169 oligotrophic strains belonging to at least 84 taxa were isolated and four new species were described. With the development of tourism, more and more caves have been heavily affected by human activities. The fungal diversity and resources in caves are thus urgent to be investigated. The objective of this study was to systematically investigate the culturable fungal resources from karst caves in China. In response to this, 13 caves in five provinces were visited and sample of organic litter, rock, soil and water were collected for isolation. Novel species were identified and described based on morphological characters and phylogenetic affinities.
Material and methods

Sampling collection

Southwest China, including Yunnan-Guizhou Plateau, the center of East Asia developing Karst area, is the largest and most complex developing karst area in the world (Zhou et al. 2007). Thirteen accessible caves in Southwest China were selected for this study (Figs. 1 and 2, Table 1).

Samples of rock, soil and water were collected along these thirteen caves and preserved at 4 °C before isolation. From the entrance of the caves, the distance of each two adjacent sampling sites was same and depend on the length of caves (Table 1).

Seeping, stream and pool water was collected for 10 mL, respectively, and kept in 15 mL sterile centrifuge tubes. Ten grams of soil samples were collected at shallow depth (0.5–5.0 cm) after removing surface layer (ca. 0.5 cm) from three sites of each location. Rock samples were collected and packed in zip-locked plastic bags following Ruibal et al. (2005). At each sample site, 5 pieces of rock in different orientations were collected. Rocks that were apparently being colonized by fungi were also chipped off and collected along the caves. Organic litter, when discovered, were collected, including bat droppings, guano, animal dung, animal carcass, and plant debris (Zhang et al. 2017).

![Fig. 1](https://example.com/fig1.png) Locations of the 13 visited caves in southwest China. Cave names are abbreviated and full names are in Table 1.
**Isolation**

Fungi were isolated following the dilution plate method (Zhang et al. 2015). One gram of each collected sample was suspended in 9 mL sterile water in a 15 mL sterile centrifuge tube. The tubes were shaken with Vortex vibration meter thoroughly. The suspension was then diluted to a series of concentrations, i.e. $10^{-1}$, $10^{-2}$, $10^{-3}$, $10^{-4}$, $10^{-5}$ and $10^{-6}$. Diluted concentration of $10^{-3}$ and $10^{-4}$ appeared to be most convenient for colony pickup in the isolating process from organic litters, while that for water and soil samples were $10^{-1}$ and $10^{-2}$ respectively. Two hundred microliters suspensions from each concentration were spread onto 1/4 PDA containing ampicillin (50 µg/mL) and streptomycin (50 µg/mL) with three replicates.

Rock samples were processed following the protocol of Ruibal et al. (2005) with some modifications. Firstly, the rock surface was washed with 95% ethanol to eliminate the contamination from dust and airborne spores, and washed once with sterile water containing 0.1% of Tween 20. The small pieces of rocks were then ground into powder using a sterilized mortar and pestle. Suspensions were made by adding sterilized water to the concentration of $10^{-1}$. Three different volumes of the rock powder suspension, i.e. 300, 500, and 1000 µL, were respectively placed onto three 1/4 PDA plates supplemented with ampicillin (50 µg/mL) and streptomycin (50 µg/mL) (Ruibal et al. 2005; Selbmann et al. 2007b; Collado et al. 2007; Zhang et al. 2017).

All the plates were incubated at room temperature ($25 \pm 2 ^\circ C$) for 3–4 weeks, and from which the single colonies were picked up and inoculated onto new PDA plates every two days. All fungal strains were stored at 4 °C for further studies.

**Molecular analyses**

Total fungal genomic DNAs were extracted following a modified CTAB method of Doyle (1987). The internal transcribed spacer regions and intervening 5.8S nrRNA gene (ITS), the large subunit (LSU) rDNA, the small subunit (SSU) rDNA, the translation elongation factor 1-alpha (EF-1α), RNA polymerase II subunit (RPB2), Twenty S rRNA accumulation (Tsr1), and β-tubulin (TUB) regions were amplified using primer pairs ITS1/ITS4 (White et al. 1990), LR0R/LR5 (Vilgalys and Hester 1990), NS1/NS4 (White et al. 1990), 983F/2218R (Rehner and Buckley 2005), RPB2-5F2/IRPB2-7cR (Liu et al. 1999; Sung et al. 2007b) F1526Pc/R2434 (Houbraken and Samson 2011) and Bt2a/Bt2b (Glass and Donaldson 1995), respectively. Amplification reactions were performed in a 25 µL reaction volume including 2.5 µL 10 × PCR Buffer (Dingguo, Beijing, China), 2 mM MgCl2, 50 µM dNTPs, 0.1 µM of each forward and reverse primer, 0.5 U Taq DNA polymerase and 1–10 ng genomic DNA in amplifier (Dongsheng, EDC-810, China). PCR parameters were as follows: 94 °C for 10 min, followed by 35 cycles of 94 °C for 30 s, 54 °C for 30 s, 72 °C for 30 s and a final elongation step at 72 °C for 10 min. Annealing temperature for each gene were 50 °C for LSU and Tsr1, 54 °C for ITS, RPB2 and SSU, and 57 °C for EF-1α and TUB. Sequencing reactions were performed by OmegaGenetics Company Limited, Beijing, China.

All obtained strains were BLASTn searched in NCBI and assigned to potential genera and species. The strains whose ITS sequences had closest similarities below 97% were recognized as potential new species and further identified through morphological characterization and phylogenetic analyses.

To reveal the order placements of new species described in this paper, a LSU tree was constructed. To reveal the phylogenetic relationships and taxonomic distinctions of novel species, analyses were performed based on ITS, LSU and genetic markers recommended in recent publications, such as EF1-α, Tsr1 and TUB. All sequences of different loci were aligned using MAFFT (http://www.ebi.ac.uk/Tools/msa/mafft/) (Katoh and Toh 2010) and edited manually using MEGA v. 7 (Kumar et al. 2016) separately. Individual alignments were then concatenated and used for phylogenetic analysis next step. Ambiguously aligned regions were excluded from all analyses.

Maximum Likelihood (ML) and Bayesian inference (BI) methods were used to construct the phylogenetic trees. The ML analyses were implemented using RAxML-HPC v. 8.2.7 (Stamatakis 2014) with 1000 replicates under the GTR-GAMMA model. The robustness of branches was assessed by bootstrap analysis with 1000 replicates. For Bayesian analysis, the best model of evolution was estimated using jModelTest v. 2.1.7 (Guindon and Gascuel 2003; Darriba et al. 2012). Posterior probabilities (PP) (Rannala and Yang 1996; Zhaxybayeva and Gogarten 2002) were calculated by Markov Chain Monte Carlo sampling (MCMC) in MrBayes v. 3.2.1 (Huelsenbeck and Ronquist 2001), using the estimated evolutionary models. Six simultaneous Markov chains were run for 1,000,000 generations, and trees were sampled every 1000th generations (resulting 10,000 trees totally). The first 2000 trees, representing the burn-in phase of the analyses, were discarded and the remaining 8000 trees were used to calculate posterior probabilities (PP) in the majority rule consensus tree. The final trees were visualized in TreeView (Page 1996). All the sequences generated were deposited in GenBank (Table 2), typifications in Index
Fungi (http://www.indexfungorum.org), novel taxonomic descriptions in Faces of Fungi (Jayasiri et al. 2015), and the multi-locus alignments and trees in TreeBASE (submission number: 26362).

Morphological studies

Strains of potentially new species were transferred to new plates of PDA, OA and synthetic nutrient-poor agar (SNA; Nirenberg 1976) and were incubated at room temperature (25 ± 2 °C). Growth rates were measured after 7 days, while slow growing strains were measured after 10 days or even 8 weeks. Colony morphologies were determined after 10 days and colony colors on the surface and reverse of inoculated petri dishes were assessed according to the Methuen handbook of colour (Kornerup and Wanscher 1978). Cultures were examined periodically for the development of reproductive structures. Photomicrographs were taken using a Nikon 80i microscope with differential interference contrast. Measurements for each structure were made according to methods described by Liu et al. (2012). The dry cultures were deposited in the Herbarium of Microbiology, Academia Sinica (HMAS), while living cultures were deposited in the China General Microbiological Culture Collection Center (CGMCC) and LC Culture Collection (personal culture collection held in the lab of Dr Lei Cai).

Results

In this study, 251 samples from these thirteen caves were collected and 2344 fungal strains were isolated. These strains belong to 253 genera, 610 species by employing a BLASTn search in GenBank using the ITS sequences (Table S1). Among these species, 88.0 % (i.e., 536 species, 2115 strains) belong to 213 genera of Ascomycota; 8.0 % (i.e., 49 species, 133 strains) belong to 33 genera of Basidiomycota; 1.9 % (i.e., 12 species, 22 strains) belong to five genera of Mucoromycota, 1.9 % (i.e., 12 species, 73 strains) belong to one genera of Mortierellomycota; 0.2 % (i.e., 1 species, 1 strains) belong to one genera of Glomeromycota (Fig. 3a, Table S1). The most common genera included: Penicillium (12.0 %), Aspergillus (5.7 %), Trichoderma (3.4 %), Arthrinium Kunze (2.3 %), Fusarium (2.1 %), Microascus Zukal (2.1 %), Mortierella Coem. (2.0 %), Cephalotrichum Link (1.3 %), Clonostachys Corda (1.1 %), and Simplicillium Zare & W. Gams (1 %) (Fig. 3c, Table 3). The most common species included Purpureocillium lilacinum (Thom) Luangsa-ard (59 strains), Mortierella alpine Peyronel (56 strains), Penicillium (Pe.) citrinum Thom (55 strains), Pe. simplicissimum (Oudem.) Thom (53 strains), Acremonium sp. 6 (51 strains), Cladosporium cladosporioides (Fresen.) G.A. de Vries (45 strains), Amphichorda cavernicola Z.F.
| Species name            | Strain No\(^T\) | Cave   | Substrate        | Genbank accession number |
|------------------------|-----------------|--------|------------------|--------------------------|
|                        |                 |        |                  |                          |
|                        |                 |        |                  | ITS | LSU | TUB | TEF | SSU | RPB2 | Tsr |
| **Amphichorda cavernicola** | CGMCC3.19571\(^T\) | Feng cave | Bird faeces      | MK329056 | MK328961 | MK336083 | MK335997 | –     | –     | –     |
|                        | LC12481         | Sanwang cave | Soil             | MK329057 | MK328962 | MK336084 | MK335998 | –     | –     | –     |
|                        | LC12485         | Yuguang cave | Soil             | MK329058 | MK328963 | MK336085 | MK335999 | –     | –     | –     |
|                        | LC12553         | Tianliang cave | Animal faeces   | MK329059 | MK328964 | MK336086 | MK336000 | –     | –     | –     |
|                        | LC12554         | Feng cave | Bird faeces      | MK329060 | MK328965 | MK336087 | MK336001 | –     | –     | –     |
|                        | LC12560         | Bijia cave | Animal faeces    | MK329061 | MK328966 | MK336088 | MK336002 | –     | –     | –     |
|                        | LC12577         | Feng cave | Bird faeces      | MK329062 | MK328967 | MK336089 | MK336003 | –     | –     | –     |
|                        | LC12593         | Liujiang cave | Bird faeces    | MK329063 | MK328968 | MK336090 | MK336004 | –     | –     | –     |
|                        | LC12638         | Liujiang cave | Bat guano       | MK329064 | MK328969 | MK336091 | MK336005 | –     | –     | –     |
|                        | LC12674         | E’gu cave | Plant debris     | MK329065 | MK328970 | MK336092 | MK336006 | –     | –     | –     |
| **Aspergillus limoniformis** | CGMCC3.19323\(^T\) | Mingjiu cave | Bat guano       | MK329066 | MK328971 | MK336093 | MK336007 | –     | –     | –     |
|                        | LC12610         | Mingjiu cave | Bat guano       | MK329067 | MK328972 | MK336094 | MK336008 | –     | –     | –     |
| **Aspergillus phialiformis** | CGMCC3.19314\(^T\) | Sanjiao cave | Rock             | MK329068 | MK328973 | MK336095 | MK336009 | –     | –     | –     |
|                        | LC12537         | Sanjiao cave | Rock             | MK329069 | MK328974 | MK336096 | MK336010 | –     | –     | –     |
| **Aspergillus phialosimplex** | CGMCC3.19637\(^T\) | Liujiang cave | Plant debris   | MK329070 | MK328975 | MK336097 | MK336011 | –     | –     | –     |
|                        | LC12625         | Nuomo cave | Plant root       | MK329071 | MK328976 | MK336098 | MK336012 | –     | –     | –     |
|                        | LC12658         | E’gu cave | Animal faeces    | MK329072 | MK328977 | MK336099 | MK336013 | –     | –     | –     |
| **Auxarthron chinense** | CGMCC3.19572\(^T\) | Luotian cave | Soil             | MK329076 | MK328981 | MK336102 | MK336017 | –     | –     | –     |
|                        | LC12463         | Mingjiu cave | Soil             | MK329073 | MK328978 | –     | MK336014 | –     | –     | –     |
|                        | LC12473         | E’gu cave | Soil             | MK329074 | MK328979 | MK336100 | MK336015 | –     | –     | –     |
|                        | LC12474         | E’gu cave | Soil             | MK329075 | MK328980 | MK336101 | MK336016 | –     | –     | –     |
|                        | LC12477         | Luotian cave | Soil             | MK329077 | MK328982 | MK336103 | MK336018 | –     | –     | –     |
|                        | LC12550         | Luotian cave | Soil             | MK329078 | MK328983 | MK336104 | MK336019 | –     | –     | –     |
|                        | LC12580         | Luotian cave | Animal faeces    | MK329079 | MK328984 | MK336105 | MK336020 | –     | –     | –     |
| **Auxarthron guangxiense** | CGMCC3.19634\(^T\) | E’gu cave | Soil             | MK329080 | MK328985 | MK336106 | MK336021 | –     | –     | –     |
|                        | LC12465         | E’gu cave | Soil             | MK329081 | MK328986 | MK336107 | MK336022 | –     | –     | –     |
| **Auxarthronopsis globiasca** | CGMCC3.19305\(^T\) | Luotian cave | Soil             | MK329082 | MK328987 | MK336108 | –     | –     | –     |
|                        | LC12667         | E’gu cave | Soil             | MK329083 | MK328988 | MK336109 | –     | –     | –     |
| **Auxarthronopsis pedicellaris** | CGMCC3.19318\(^T\) | Erwang cave | Rock             | MK329084 | MK328989 | MK336110 | –     | –     | –     |
|                        | LC12576         | Erwang cave | Rock             | MK329085 | MK328990 | MK336111 | –     | –     | –     |
| **Auxarthronopsis pulvereae** | CGMCC3.19312\(^T\) | Liujiang cave | Plant debris   | MK329086 | MK328991 | MK336112 | –     | –     | –     |
|                        | LC12522         | Liujiang cave | Plant debris   | MK329087 | MK328992 | MK336113 | –     | –     | –     |
| **Auxarthronopsis stercicola** | CGMCC3.19639\(^T\) | Mingjiu cave | Animal faeces   | MK329088 | MK328993 | MK336114 | MK336023 | –     | –     | –     |
|                        | LC12611         | Mingjiu cave | Animal faeces   | MK329089 | MK328994 | MK336115 | MK336024 | –     | –     | –     |
| **Chrysosporium pallidum** | CGMCC3.19575\(^T\) | E’gu cave | Animal faeces   | MK329090 | MK328995 | –     | MK336025 | –     | –     | –     |
|                        | LC12670         | E’gu cave | Animal faeces   | MK329091 | MK328996 | –     | MK336026 | –     | –     | –     |
| Species name                  | Strain No$^a$ | Cave         | Substrate     | Genbank accession number | ITS       | LSU       | TUB | TEF       | SSU     | RPB2     | Tsrb |
|-----------------------------|--------------|--------------|---------------|--------------------------|-----------|-----------|-----|-----------|---------|----------|------|
| Gamszarea humicola          | CGMCC3.19303$^T$ | E’gu cave    | Soil          | MK329092 MK328997 – MK336027 MK311230 MK335979 – | | | | | | | | |
|                             | LC12462      | E’gu cave    | Soil          | MK329093 MK328998 – MK336028 MK311231 MK335980 – | | | | | | | | |
| Gamszarea lunata            | CGMCC3.19315$^T$ | E’gu cave    | Rock          | MK329094 MK328999 – MK336029 MK311232 MK335981 – | | | | | | | | |
|                             | LC12546      | E’gu cave    | Rock          | MK329095 MK329000 – MK336030 MK311233 MK335982 – | | | | | | | | |
| Gamszarea microspora        | CGMCC3.19313$^T$ | Tianliang cave | Rock         | MK329096 MK329001 – MK336031 MK311234 MK335983 – | | | | | | | | |
|                             | LC12531      | Tianliang cave | Rock         | MK329097 MK329002 – MK336032 MK311235 MK335984 – | | | | | | | | |
| Gymnoascus flavus           | CGMCC3.19574$^T$ | Feng cave    | Soil          | MK329098 MK329003 MK336116 MK336033 – | | | | | | | | |
|                             | LC12511      | Tianliang cave | Soil          | MK329099 MK329004 MK336117 MK336034 – | | | | | | | | |
| Jattaea reniformis          | CGMCC3.19311$^T$ | Luotian cave | Water         | MK329100 MK329005 MK336118 MK336035 – | | | | | | | | |
|                             | LC12510      | Luotian cave | Water         | MK329101 MK329006 MK336119 MK336036 – | | | | | | | | |
| Lecanicillium magnisporum   | CGMCC3.19304$^T$ | Erwang cave  | Soil          | MK329102 MK329007 – MK336037 MK311236 MK335985 – | | | | | | | | |
|                             | LC12469      | Erwang cave  | Soil          | MK329103 MK329008 – MK336038 MK311237 MK335986 – | | | | | | | | |
|                             | LC12470      | Erwang cave  | Soil          | MK329104 MK329009 – MK336039 MK311238 MK335987 – | | | | | | | | |
|                             | LC12647      | Sanwang cave | Soil          | MK329105 MK329010 – MK336040 MK311239 MK335988 – | | | | | | | | |
|                             | LC12663      | Sanwang cave | Soil          | MK329106 MK329011 – MK336041 MK311240 MK335989 – | | | | | | | | |
| Microascus collaris         | CGMCC3.19321$^T$ | Sanshan cave | Plant debris  | MK329109 MK329012 MK336120 MK336042 – | | | | | | | | |
|                             | LC12599      | Sanshan cave | Plant debris  | MK329110 MK329013 MK336121 MK336043 – | | | | | | | | |
| Microascus levis            | CGMCC3.19308$^T$ | Luotian cave | Soil          | MK329108 MK329015 MK336123 MK336045 – | | | | | | | | |
|                             | LC12447      | Luotian cave | Soil          | MK329107 MK329014 MK336122 MK336044 – | | | | | | | | |
| Microascus sparsimycelialis | CGMCC3.19307$^T$ | Sanshan cave | Soil          | MK329111 MK329016 MK336124 MK336046 – | | | | | | | | |
|                             | LC12680      | Sanshan cave | Soil          | MK329112 MK329017 MK336125 MK336047 – | | | | | | | | |
| Microascus superficialis    | CGMCC3.19638$^T$ | Sanshan cave | Animal faeces | MK329113 MK329018 MK336126 MK336048 – | | | | | | | | |
|                             | LC12600      | Sanshan cave | Animal faeces | MK329114 MK329019 MK336127 MK336049 – | | | | | | | | |
|                             | LC12601      | Sanshan cave | Animal faeces | MK329115 MK329020 MK336128 MK336050 – | | | | | | | | |
| Microascus trigonus         | CGMCC3.19636$^T$ | Luotian cave | Soil          | MK329117 MK329022 MK336130 MK336052 – | | | | | | | | |
|                             | LC12513      | Luotian cave | Soil          | MK329116 MK329021 MK336129 MK336051 – | | | | | | | | |
|                             | LC12559      | E’gu cave    | Animal faeces | MK329118 MK329023 MK336131 MK336053 – | | | | | | | | |
|                             | LC12586      | E’gu cave    | Animal faeces | MK329119 MK329024 MK336132 MK336054 – | | | | | | | | |
|                             | LC12631      | E’gu cave    | Animal faeces | MK329120 MK329025 MK336133 MK336055 – | | | | | | | | |
| Nigrospora globosa          | CGMCC3.19633$^T$ | Luotian cave | Soil          | MK329121 MK329026 MK336134 MK336056 – | | | | | | | | |
|                             | LC12441      | Luotian cave | Soil          | MK329122 MK329027 MK336135 MK336057 – | | | | | | | | |
| Paracremoneum apiculatum    | CGMCC3.19309$^T$ | Sanjiao cave | Soil          | MK329123 MK329028 MK336136 MK336058 – | | | | | | | | |
|                             | LC12502      | Sanjiao cave | Soil          | MK329124 MK329029 MK336137 MK336059 – | | | | | | | | |

$^a$ Strain No: CGMCC, China General Microbiological Culture Collection; Tsr, Tolcamicilin.
| Species name                      | Strain No\(^a\) | Cave       | Substrate      | Genbank accession number |
|----------------------------------|-----------------|------------|----------------|--------------------------|
|                                  |                 |            |                | ITS | LSU | TUB | TEF | SSU | RPB2 | Tsr |
| Paracrenonium ellipsoideum       | CGMCC3.19316\(^T\) | Sanjiao cave | Sewage         | MK329125 | MK329030 | MK336138 | MK336060 | –   | –   | –   |
|                                  | LC12552         | Sanjiao cave | Sewage         | MK329126 | MK329031 | MK336139 | MK336061 | –   | –   | –   |
| Paraphaeosphaeria hydei          | CGMCC3.19317\(^T\) | Sanjiao cave | Plant debris   | MK329127 | MK329032 | MK336140 | MK336062 | –   | –   | –   |
|                                  | LC12565         | Sanjiao cave | Plant debris   | MK329128 | MK329033 | MK336141 | MK336063 | –   | –   | –   |
| Pseudoscopulariopsis asperispora | CGMCC3.19302\(^T\) | Luotian cave | Soil           | MK329129 | MK329034 | MK336142 | MK336064 | –   | –   | –   |
|                                  | LC12446         | Luotian cave | Soil           | MK329130 | MK329035 | MK336143 | MK336065 | –   | –   | –   |
| Setophaeosphaeria microspora     | CGMCC3.19301\(^T\) | Sanshan cave | Soil           | MK329131 | MK329036 | MK336144 | MK336066 | –   | –   | –   |
|                                  | LC10444         | Sanshan cave | Soil           | MK329132 | MK329037 | MK336145 | MK336067 | –   | –   | –   |
| Simplicillium album              | CGMCC3.19635\(^T\) | Sanshan cave | Soil           | MK329133 | MK329038 | –         | MK336068 | –   | –   | –   |
|                                  | LC12543         | E’gu cave   | Animal faeces  | MK329134 | MK329039 | –         | MK336069 | –   | –   | –   |
|                                  | LC12557         | E’gu cave   | Animal faeces  | MK329135 | MK329040 | –         | MK336070 | –   | –   | –   |
| Simplicillium humicola           | CGMCC3.19573\(^T\) | E’gu cave   | Soil           | MK329136 | MK329041 | –         | MK336071 | –   | –   | –   |
|                                  | LC12494         | E’gu cave   | Soil           | MK329137 | MK329042 | –         | MK336072 | –   | –   | –   |
| Wardomyces dolichi               | CGMCC3.19310\(^T\) | E’gu cave   | Soil           | MK329138 | MK329043 | –         | MK336073 | –   | –   | –   |
|                                  | LC12504         | E’gu cave   | Soil           | MK329139 | MK329044 | –         | MK336074 | –   | –   | –   |
| Wardomyces ellipsoconidiophora    | CGMCC3.19322\(^T\) | Sanshan cave | Animal faeces  | MK329141 | MK329046 | MK336147 | MK336076 | –   | –   | –   |
|                                  | LC12588         | Sanshan cave | Animal faeces  | MK329140 | MK329045 | MK336146 | MK336075 | –   | –   | –   |
| Wardomyces fusca                 | CGMCC3.19306\(^T\) | Luotian cave | Soil           | MK329142 | MK329047 | MK336148 | MK336077 | –   | –   | –   |
|                                  | LC12526         | Luotian cave | Soil           | MK329143 | MK329048 | MK336149 | MK336078 | –   | –   | –   |
|                                  | LC12607         | Mingjiu cave | Animal faeces  | MK329144 | MK329049 | MK336150 | MK336079 | –   | –   | –   |
|                                  | LC12636         | E’gu cave   | Animal faeces  | MK329145 | MK329050 | MK336151 | MK336080 | –   | –   | –   |
|                                  | LC12643         | Sanjiao cave | Soil           | MK329146 | MK329051 | MK336152 | MK336081 | –   | –   | –   |
|                                  | LC12661         | Mingjiu cave | Animal faeces  | MK329147 | MK329052 | MK336153 | MK336082 | –   | –   | –   |

\(^a\)Ex-type strains are indicated with \(^T\)
Fig. 3 Statistics of fungi in caves in this study (a–d) and worldwide (e–f). a The number of fungal genera, species and strains in different phyla obtained in this study; b the number of fungal genera, species and strains isolated from different substrates in this study; c most abundant fungal genera observed in this study; d venn diagram of fungal genera obtained from different substrates in this study. e the number of fungal genera and species reported in caves worldwide; f fungal genera with highest diversity reported in caves worldwide.

Table 3 Most common genera (≥ 5 species) obtained from Karst caves in this study

| Genus           | Species | Strains | Genus          | Species | Strains |
|-----------------|---------|---------|----------------|---------|---------|
| Penicillium     | 73      | 456     | Simplicillium  | 6       | 14      |
| Aspergillus     | 35      | 206     | Arthroderma    | 5       | 10      |
| Trichoderma     | 21      | 90      | Aasarthon      | 5       | 26      |
| Acremonium      | 14      | 103     | Chaetomium     | 5       | 21      |
| Fusarium        | 13      | 49      | Phoma          | 5       | 15      |
| Microascus      | 13      | 48      | Talaromyces    | 5       | 8       |
| Mortierella     | 12      | 73      | Tolyposcadium  | 5       | 6       |
| Cephalotrichum  | 8       | 105     | Coprinellus    | 5       | 7       |
| Clonostachys    | 7       | 25      | Mucor          | 5       | 13      |

Zhang & L. Cai (42 strains), Trichoderma harzianum Rifai (40 strains), Cephalotrichum asperulum (J.E. Wright & S. Marchand) Sand.-Den., Guarro & Gené (36 strains), Aspergillus versicolor (Vuill.) Tirab. (32 strains), Parenzyodonium album (Limber) C.C. Tsang, et al. (30 strains), and Plectosphaerella cucumerina (Lindf.) W. Gams (30 strains).

For the isolations of substrate, 1137 strains from soil samples belong to 377 species in 170 genera; 803 strains from organic litters belong to 270 species in 129 genera; 300 strains from rock samples belong to 133 species in 74 genera; 104 strains from water samples belong to 60 species in 46 genera (Fig. 3b). Seventeen genera were found in these four types of substrate, i.e., Acremonium Link, Arthrinium Kunze, Aspergillus, Beauveria Vuill., Cephalotrichum, Chaetomium Kunze, Cladosporium Link, Cutaneotrichosporon Xin Zhan Liu, F.Y. Bai, M. Groenew. & Boekhout, Didymella Sacc, Fusarium, Leptosphaeria Ces. & De Not., Mortierella, Mucor, Penicillium, Plectosphaerella Kleb, Purpureocillium Luangsard, Hywel-Jones, Houbaken & Samson, Trichoderma (Fig. 3d).

Meanwhile, we summarized data on the fungi of caves from 56 papers published in the peer-reviewed literatures (Table 4) since 2013 in English based on Vanderwolf et al. (2013). Following the newest records in Index Fungorum (http://www.indexfungorum.org/Names/Names.asp), we revised the fungal names documented in caves. By February 2020, 1626 species in 644 genera of fungi have been reported from caves and mines worldwide. In our study, 76 of the 253 genera and 247 of the 468 identified species (52.8 %) were reported for the first time from caves. With our data, totally, 1923 fungal species in 720 genera were documented from caves and mines (Table 4). Of the fungal taxa reported from caves and mines, nine phyla were observed (Fig. 3e), Ascomycota (1474 species in 502 genera), Basidiomycota (339 species in 189 genera), Mucoromycota (64 species in 17 genera), Mortierellomycota (33 species in 1 genus), Entomophthoromycota (4 species in 3 genera), Chytridiomycota (3 species in 3 genera), Zoopagomycota (3 species in 3 genera), Kickxellomycota (2 species in 1 genus) and Glomeromycota (1 species in 1 genus). Twenty-two genera have more than 10 species reported in caves worldwide, most of which belong to Ascomycota (Fig. 3f).

Thirty-three new species were described and illustrated in this paper, based on the morphological characteristics and phylogenetic analyses. The LSU phylogenetic tree (Fig. 4) showed that these 33 new species (marked with bold font) scattered in seven different orders, i.e., Calosphaeriales, Eurotiales, Hypocreales, Microascales, Onygenales, Pleosporales, and Xylariales. Significant ML bootstrap values (≥ 70 %) and Bayesian posterior probabilities (≥ 90 %) are shown in the phylogenetic tree.

**Taxonomy**

**Phylum Ascomycota** Cav..-Sm.
We follow the latest treatment of Ascomycota (Wijayawardene et al. 2018, 2020), with classes, subclasses, orders, families, genera and species listed below in alphabetical order.

**Class Dothideomycetes** O.E. Erikss. & Winka
Based on molecular dating evidence, Liu et al. (2017) updated the multi-locus phylogeny of Dothideomycetes and unraveled the evolutionary relationships. In this paper, the classification of families in Dothideomycetes follow Liu et al. (2017) and Wijayawardene et al. (2018, 2020).

**Subclass Pleosporomycetidae** C.L. Schoch, Spatafora, Crous & Shoemaker

**Pleosporales** Lutr. ex M.E. Barr
The order Pleosporales was introduced by Luttrell (1955) to accommodate a highly diverse fungal group of Dothideomycetes having perithecioid ascomata and asci with pseudoparaphyses (Zhang et al. 2009). More details see Zhang et al. (2012) and Hyde et al. (2013).

**Didymosphaeriaceae** Munk
We follow the treatment of Ariyawansa et al. (2014), Hyde et al. (2017) and Wijayawardene et al. (2020) in the study.
Table 4  Fungi documented from caves and mines worldwide with references. New species described in this study are in bold

| Genus         | Species                  | Chinaa | This studyb | References                                                                 |
|---------------|--------------------------|--------|-------------|---------------------------------------------------------------------------|
| **Ascomycota**|                          |        |             |                                                                           |
| Acidea        | Acidea extrema           |        |             | Burow et al. (2019)                                                       |
| Acaulium      | Acaulium caviariforme    |        |             | Vanderwolf et al. (2013, 2015, 2019)                                       |
| Acidomyces    | Acidomyces acidothermus  |        |             | Brad et al. (2018)                                                        |
| Acremoniella  | Acremoniella atra        |        |             | Pusz et al. (2018a)                                                       |
| Acremonium    | Acremonium alternatum    | Y      | Y           | Vanderwolf et al. (2013)                                                  |
|               | A. antarcticum           | Y      |             | Vanderwolf et al. (2013)                                                  |
|               | A. atrogriseum           |        |             | Vanderwolf et al. (2013)                                                  |
|               | A. biseptum              |        |             | Vanderwolf et al. (2013)                                                  |
|               | A. cereale               |        |             | Vanderwolf et al. (2013)                                                  |
|               | A. charticola            | Y      |             | Vanderwolf et al. (2013, 2015), Popkova and Mazina (2019), Zhang (2019)  |
|               | A. furcatum              | Y      | Y           | Vanderwolf et al. (2013), Jiang et al. (2017a, b)                         |
|               | A. hennebertii           | Y      |             | Zhang (2019)                                                              |
|               | A. longisporum           | Y      | Y           | Vanderwolf et al. (2013)                                                  |
|               | A. marorum              | Y      | Y           | Vanderwolf et al. (2013), Martin-Sanchez et al. (2014), Zhang et al. (2017), Pusz et al. (2018a) |
|               | A. persicinum            | Y      | Y           | Vanderwolf et al. (2013), Zhang et al. (2017)                             |
|               | A. polychromum           |        |             | Vanderwolf et al. (2013)                                                  |
|               | A. roseolatum            |        |             | Vanderwolf et al. (2013)                                                  |
|               | A. rutulatum             |        |             | Vanderwolf et al. (2013, 2019)                                            |
|               | A. verruculosum          |        |             | Vanderwolf et al. (2013)                                                  |
|               | A. vitis                |        |             | Vanderwolf et al. (2013)                                                  |
|               | Acremonium sp.           | Y      | Y           | Connell and Staudigel (2013), Vanderwolf et al. (2013, 2015, 2019), Man et al. (2015), Jiang et al. (2017a, b), Zhang et al. (2017), Leplat et al. (2018), Popkova and Mazina (2019) |
| Acrocalymma   | Acrocalymma vagum       | Y      |             | Vanderwolf et al. (2013)                                                  |
| Acrocylindrium| Acrocylindrium sp.       |        |             | Vanderwolf et al. (2013)                                                  |
| Acrodontium   | Acrodontium crateriforme| Y      |             | Vanderwolf et al. (2013, 2017)                                            |
| Acrodontium sp.|                      |        |             | Vanderwolf et al. (2013, 2019)                                            |
| Acrophialophora| Acrophialophora fiaspora |        |             | Vanderwolf et al. (2013)                                                  |
| Acrostalagmus | Acrostalagmus luteolbus  | Y      | Y           | Vanderwolf et al. (2013, 2015), Zhang et al. (2017)                       |
| Adelphella    | Adelphella babingtonii   |        |             | Vanderwolf et al. (2013)                                                  |
| Ajellomyces   | Ajellomyces capsulatus   |        |             | Vanderwolf et al. (2013)                                                  |
| Ajellomyces sp.|                      | Y      | Y           | Vanderwolf et al. (2013)                                                  |
| Akanthomyces  | Akanthomyces lecanii     | Y      | Y           | Vanderwolf et al. (2013)                                                  |
| Allibifmbria  | Allibifmbria verrucaria  | Y      | Y           | Connell and Staudigel (2013), Vanderwolf et al. (2013), Nováková et al. (2018) |
| Allantophomopsisella| Allantophomopsisella pseudosugae| |        | Leplat et al. (2018)                                                      |
| Allantophomopsisella|                   |        |             | Pusz et al. (2017)                                                        |
| Allophoma     | Allophoma sp.            | Y      |             | Jiang et al. (2017a, b)                                                   |
| Alternaria    | Alternaria abundans      |        |             | Pusz et al. (2015), Ogórek et al. (2017, 2018), Ogórek (2018a)            |
|               | Al. alternata            | Y      | Y           | Connell and Staudigel (2013), Vanderwolf et al. (2013), Ogórek et al. (2014a, b, c, 2016b, c, d), Man et al. (2015), Pusz et al. (2015, 2017, 2018a, b), Kokurewicz et al. (2016), Jiang et al. (2017a, b), Zhang et al. (2017), Nováková et al. (2018), Pusz et al. (2018a), Popkova and Mazina (2019) |
|               | Al. alternariae          |        |             | Ogórek et al. (2013)                                                      |
|               | Al. atra                |        |             | Vanderwolf et al. (2013)                                                  |
|               | Al. botrytis             |        |             | Vanderwolf et al. (2013), Kokurewicz et al. (2016), Pusz et al. (2018a, b) |
|               | Al. brevicola            |        |             | Vanderwolf et al. (2013)                                                  |
|               | Al. chartarum            |        |             | Vanderwolf et al. (2013)                                                  |
|               | Al. humicola             |        |             | Vanderwolf et al. (2013)                                                  |
|               | Al. infectoria           |        |             | Connell and Staudigel (2013)                                              |
|               | Al. longipes             |        |             | Nováková et al. (2018)                                                    |
|               | Al. mali                 | Y      |             | Zhang (2019)                                                              |
|               | Al. mouchaccaes          |        |             | Vanderwolf et al. (2013)                                                  |
|               | Al. oudemansi           |        |             | Vanderwolf et al. (2013)                                                  |
| Genus          | Species                  | China$^a$ | This study$^b$ | References                                                                 |
|---------------|--------------------------|-----------|----------------|-----------------------------------------------------------------------------|
| Al. radicina  |                          |           |                | Vanderwolf et al. (2013)                                                  |
| Al. solani    |                          | Y         | Y              | Vanderwolf et al. (2013), Zhang et al. (2017)                              |
| Al. tamaricis |                          | Y         |                | Vanderwolf et al. (2013, 2015), Popović et al. (2015), Pusz et al. (2015), Zhang et al. (2017), Nováková et al. (2018) |
| Al. tenuissima|                          | Y         | Y              | Vanderwolf et al. (2013), Popović et al. (2015), Pusz et al. (2015), Zhang et al. (2017), Nováková et al. (2018) |
| Alternaria sp.|                          |           |                | Vanderwolf et al. (2013), Martin-Sanchez et al. (2014), Popović et al. (2015), Belyagoubi et al. (2018), Bercea et al. (2018), Nováková et al. (2018), Leplat et al. (2018), Zhang (2019) |
| Amauroascus   | Amauroascus albicans     |           |                | Vanderwolf et al. (2013)                                                  |
| Amauroascus   |                          |           |                | Vanderwolf et al. (2013)                                                  |
| Amauroascus sp.|                          | Y         |                | Vanderwolf et al. (2013), Zhang (2019)                                   |
| Amblyosporium | Amblyosporium botrytis   |           |                | Vanderwolf et al. (2013)                                                  |
| Amesia        | Amesia nigricolor        | Y         | Y              | Zhang et al. (2017)                                                       |
| Ampelomyces   | Ampelomyces hamuli       | Y         | Y              | Vanderwolf et al. (2013)                                                  |
| Amphicorda    | Amp. cavernicola         | Y         |                | Vanderwolf et al. (2013), Zhang et al. (2017), Belyagoubi et al. (2018)  |
| Amphicorda felina |                   | Y         | Y              | Zhang et al. (2017)                                                       |
| Annulohypoxylon| Annulohypoxylon sp.      | Y         | Y              | Vanderwolf et al. (2013)                                                  |
| Aphanocladium | Aphanocladium album      |           |                | Vanderwolf et al. (2013, 2019) Nováková et al. (2018)                     |
| Arachniotus   | Arachniotus dankaudiensis|           |                | Vanderwolf et al. (2013)                                                  |
| Ar. ruber     |                          |           |                | Vanderwolf et al. (2013)                                                  |
| Ar. verruculosus |                   | Y         | Y              | Vanderwolf et al. (2013)                                                  |
| Arachniotus sp.|                          |           |                | Vanderwolf et al. (2013)                                                  |
| Arachnomyces  | Arachnomyces glareosus   |           |                | Vanderwolf et al. (2013)                                                  |
| Arachnomyces sp.|                        | Y         |                | Vanderwolf et al. (2013), Zhang (2019)                                   |
| Arachnotheca  | Arachnotheca albicans    |           |                | Vanderwolf et al. (2013)                                                  |
| Arcopilus     | Arcopilus aureus         |           |                | Vanderwolf et al. (2013)                                                  |
| Arthopyrenia  | Arthopyrenia salicis     | Y         | Y              | Vanderwolf et al. (2013), Man et al. (2015), Jiang et al. (2017a, b), Mitova et al. (2017), Zhang et al. (2017) |
| Art. kogelbergense |                   |           |                | Ogérek et al. (2017), Ogérek et al. (2018)                                |
| Art. malaysianum |                       | Y         |                | Zhang et al. (2017)                                                       |
| Art. marii    |                          | Y         |                | Zhang et al. (2017)                                                       |
| Art. phoeospermum |                    | Y         | Y              | Vanderwolf et al. (2013), Popović et al. (2015), Zhang et al. (2017)     |
| Art. sacchari |                          |           |                | Zhang et al. (2017)                                                       |
| Art. sphaeospermum |                   |           |                | Vanderwolf et al. (2013)                                                  |
| Arthrinium    | Arthrinium arundinis     | Y         | Y              | Vanderwolf et al. (2013), Man et al. (2015), Jiang et al. (2017a, b), Mitova et al. (2017), Zhang et al. (2017) |
| Art. kogelbergense |                   |           |                | Ogérek et al. (2017), Ogérek et al. (2018)                                |
| Arthr. curreyi |                          | Y         | Y              | Vanderwolf et al. (2013), Zhang et al. (2017)                              |
| Arthr. melis  |                          |           |                | Vanderwolf et al. (2013)                                                  |
| Arthr. quadrifidum |                  | Y         | Y              | Vanderwolf et al. (2013), Zhang et al. (2017)                              |
| Arthr. silverae |                         |           |                | Vanderwolf et al. (2013, 2015, 2019)                                      |
| Arthr. tuberculatum |                   | Y         | Y              | Vanderwolf et al. (2013)                                                  |
| Arthr. uncinatum |                         |           |                | Vanderwolf et al. (2013)                                                  |
| Arthr. curreyi |                          | Y         | Y              | Vanderwolf et al. (2013, 2015, 2019)                                      |
| Arthr. hispanica |                        |           |                | Zhang et al. (2017)                                                       |
| Arthr. nycteribiae |                        |           |                | Vanderwolf et al. (2013)                                                  |
| Arxiella    | Arxiella sp.             | Y         | Y              | Vanderwolf et al. (2013)                                                  |
| Asaphomyces  | Asaphomyces tubanticus   |           |                | Vanderwolf et al. (2013)                                                  |
Table 4 (continued)

| Genus          | Species          | China<sup>a</sup> | This study<sup>b</sup> | References                                                                 |
|----------------|------------------|-------------------|------------------------|-----------------------------------------------------------------------------|
| Ascobolus      | Ascobolus sp.    |                   |                        | Vanderwolf et al. (2013)                                                    |
| Aspergillus    | Aspergillus aculeatus |              |                        | Nováková et al. (2018)                                                     |
| As. affinis    |                  |                   |                        | Nováková et al. (2018)                                                     |
| As. alliaceus  |                  |                   |                        | Taylor et al. (2013), Vanderwolf et al. (2013)                             |
| As. amstelodami|                  |                   |                        | Vanderwolf et al. (2013)                                                    |
| As. amylivorus |                  |                   |                        | Vanderwolf et al. (2013)                                                    |
| As. asperescens|                  |                   |                        | Vanderwolf et al. (2013)                                                    |
| As. aureolatus | Y                | Y                 |                        | Vanderwolf et al. (2013), Ogórek et al. (2017), Tavares et al. (2018)       |
| As. aurorus    | Y                | Y                 |                        | Vanderwolf et al. (2013)                                                    |
| As. awamori    |                  |                   |                        | Vanderwolf et al. (2013), Nováková et al. (2018)                          |
| As. baeticus   |                  |                   |                        | Vanderwolf et al. (2013)                                                    |
| As. brunneoviolaceus |            | Y                 |                        | Taylor et al. (2013), Vanderwolf et al. (2013)                             |
| As. caespitosus| Y                |                   |                        | Jiang et al. (2017a, b), Nováková et al. (2018)                            |
| As. cavernicola| Y                | Y                 |                        | Vanderwolf et al. (2013), Zhang et al. (2017)                              |
| As. candidus   | Y                | Y                 |                        | Vanderwolf et al. (2013), Vanderwolf et al. (2013), Zhang et al. (2017)     |
| As. carneo     | Y                |                   |                        | Vanderwolf et al. (2013)                                                    |
| As. chevalieri |                  |                   |                        | Vanderwolf et al. (2013)                                                    |
| As. claftus    | Y                |                  |                        | Vanderwolf et al. (2013), Vanderwolf et al. (2013), Popović et al. (2015)  |
| As. conjunctus |                  |                   |                        | Vanderwolf et al. (2013)                                                    |
| As. creber     | Y                |                   |                        | Zhang et al. (2017), Nováková et al. (2018)                                |
| As. cremeus    |                  |                   |                        | Vanderwolf et al. (2013)                                                    |
| As. crustossas |                  |                   |                        | Vanderwolf et al. (2013)                                                    |
| As. deflectus  | Y                | Y                 |                        | Vanderwolf et al. (2013)                                                    |
| As. elegans    |                  |                   |                        | Ogórek (2018a, b)                                                           |
| As. europaeus  |                  |                   |                        | Nováková et al. (2018)                                                     |
| As. fijensis   | Y                | Y                 |                        | Vanderwolf et al. (2013)                                                    |
| As. fischni    |                  |                   |                        | Vanderwolf et al. (2013)                                                    |
| As. flavipes   |                  |                   |                        | Vanderwolf et al. (2013), Popkova and Mazina (2019)                        |
| As. flavus     |                  |                   |                        | Vanderwolf et al. (2013)                                                    |
| As. flavifurcatus |              |                   |                        | Taylor et al. (2013), Vanderwolf et al. (2013), Pusz et al. (2014), Man et al. (2015), Yoder et al. (2015), Jiang et al. (2017a, b), Zhang et al. (2017), Nováková et al. (2018), Ogórek (2018a) |
| As. foetidus   |                  |                   |                        | Vanderwolf et al. (2013), Ogórek et al. (2016b)                            |
| As. fumagatus  | Y                | Y                 |                        | Vanderwolf et al. (2013), Pusz et al. (2015), Yoder et al. (2015), Ogórek et al. (2016b, c, d), Zhang et al. (2017), Dylag et al. (2019), Popkova and Mazina (2019) |
| As. giganteus  |                  |                   |                        | Vanderwolf et al. (2013)                                                    |
| As. glaucus    |                  |                   |                        | Vanderwolf et al. (2013)                                                    |
| As. granulosus |                  |                   |                        | Vanderwolf et al. (2013)                                                    |
| As. hongkongensis |              | Y                 |                        | Vanderwolf et al. (2013)                                                    |
| As. humicola   |                  |                   |                        | Vanderwolf et al. (2013)                                                    |
| As. icukae     |                  |                   |                        | Nováková et al. (2018)                                                     |
| As. inflatus   | Y                | Y                 |                        | Vanderwolf et al. (2013)                                                    |
| As. insuenus   |                  |                   |                        | Vanderwolf et al. (2013)                                                    |
| As. jonas      |                  |                   |                        | Vanderwolf et al. (2013)                                                    |
| As. japonicus  | Y                | Y                 |                        | Taylor et al. (2013), Vanderwolf et al. (2013)                             |
| As. jensennii  |                  |                   |                        | Nováková et al. (2018)                                                     |
| As. kanagavaensis|               |                   |                        | Vanderwolf et al. (2013)                                                    |
| As. keveii     |                  |                   |                        | Tavares et al. (2018)                                                       |
| As. limoniformis |             | Y                 |                        | Nováková et al. (2018)                                                     |
| As. movilensis |                  |                   |                        | Vanderwolf et al. (2013)                                                    |
| As. neolivaceus|                  |                   |                        | Taylor et al. (2013), Vanderwolf et al. (2013)                             |
| As. nidulans   |                  |                   |                        | Vanderwolf et al. (2013)                                                    |
| As. niger      | Y                | Y                 |                        | Ogórek et al. (2013, 2014a, b, c, 2016c, d, 2017, 2018), Taylor et al. (2013), Vanderwolf et al. (2013), Pusz et al. (2014, 2015, 2017), Popović et al. (2015), Yoder et al. (2015), Jiang et al. (2017a, b), Zhang et al. (2017), Ogórek (2018a, b), Pusz et al. (2018a), Popkova and Mazina (2019) |
Table 4 (continued)

| Genus          | Species                        | Chinaa | This studyb | References                                                                 |
|----------------|--------------------------------|--------|-------------|-----------------------------------------------------------------------------|
| As. niveoglaucus | Y                              |        |             | Zhang et al. (2017)                                                        |
| As. nomius      | Y                              | Y      |             |                                              |
| As. ochraceus   | Taylor et al. (2013), Vanderwolf et al. (2013), Popović et al. (2015), Jacobs et al. (2017), Popkova and Mazina (2019) |        |             |                                              |
| As. parasiticus | Vanderwolf et al. (2013)       |        |             |                                              |
| As. penicilioides| Connell and Staudigel (2013), Vanderwolf et al. (2013) |        |             |                                              |
| As. persii      | Y                              | Y      |             |                                              |
| As. phialiformis| Y                              | Y      |             |                                              |
| As. phialosimplex|                              | Y      |             |                                              |
| As. phoenicis   | Vanderwolf et al. (2013)       |        |             |                                              |
| As. polyphorica | Y                              | Y      |             |                                              |
| As. pragensis   | Y                              | Y      |             | Zhang et al. (2017)                                                        |
| As. prolifera   | Vanderwolf et al. (2013)       |        |             |                                              |
| As. protuberus  | Novákova et al. (2018)        |        |             |                                              |
| As. pseudodeflectus|                            |        |             |                                              |
| As. pseudoglaucus|                            |        |             |                                              |
| As. puniceus    | Vanderwolf et al. (2013)       |        |             |                                              |
| As. puulaauensis| Novákova et al. (2018)        |        |             |                                              |
| As. reptans     | Y                              |        |             | Vanderwolf et al. (2013), Zhang (2019)                                     |
| As. repens      | Y                              |        |             | Jiang et al. (2017a, b), Zhang et al. (2017)                               |
| As. restrictus  | Y                              |        |             | Taylor et al. (2013), Vanderwolf et al. (2013), Zhang (2019), Popkova and Mazina (2019) |
| As. ruber       | Y                              |        |             | Zhang et al. (2017)                                                        |
| As. rugulosus   | Taylor et al. (2013), Vanderwolf et al. (2013) |        |             |                                              |
| As. sclerotiorum| Taylor et al. (2013), Vanderwolf et al. (2013) |        |             |                                              |
| As. silvicatus  | Vanderwolf et al. (2013)       |        |             |                                              |
| As. speluncicus | Y                              | Y      |             | Vanderwolf et al. (2013), Zhang et al. (2017)                               |
| As. stellatus   | Y                              |        |             |                                              |
| As. sulphureus  | Vanderwolf et al. (2013)       |        |             |                                              |
| As. sydowii     | Y                              | Y      |             | Taylor et al. (2013), Vanderwolf et al. (2013), Jiang et al. (2017a, b), Novákova et al. (2018), Tavares et al. (2018) |
| As. tabacinus    | Y                              | Y      |             | Novákova et al. (2018)                                                     |
| As. tamarisci   | Vanderwolf et al. (2013)       |        |             |                                              |
| As. templicola  | Novákova et al. (2018)        |        |             |                                              |
| As. tennesseensis| Y                              | Y      |             | Zhang et al. (2017), Novákova et al. (2018)                                 |
| As. terreus     | Y                              | Y      |             | Vanderwolf et al. (2013), Popkova and Mazina (2019)                         |
| As. thesausicus | Y                              | Y      |             | Vanderwolf et al. (2013), Zhang et al. (2017), Novákova et al. (2018)      |
| As. tubingenensis| Y                              | Y      |             | Zhang et al. (2017)                                                        |
| As. unguis      | Vanderwolf et al. (2013)       |        |             |                                              |
| As. ustus       | Y                              | Y      |             | Taylor et al. (2013), Vanderwolf et al. (2013), Zhang et al. (2017), Novákova et al. (2018), Paula et al. (2019), Popkova and Mazina (2019) |
| As. versicolor  | Y                              |        |             | Taylor et al. (2013), Vanderwolf et al. (2013), Martin-Sanchez et al. (2014), Man et al. (2015), Jacobs et al. (2017), Jiang et al. (2017a, b), Mitova et al. (2017), Zhang et al. (2017), Popkova and Mazina (2019) |
| As. wentii      | Y                              |        |             | Taylor et al. (2013), Vanderwolf et al. (2013), Zhang et al. (2017), Belyagoubi et al. (2018) |
| As. westerdijkiae| Jacobs et al. (2017), Novákova et al. (2018) |        |             |                                              |
| Aspergillus sp. | Y                              | Y      |             | Connell and Staudigel (2013), Taylor et al. (2013), Vanderwolf et al. (2013), Busquets et al. (2014), Popović et al. (2015), Yoder et al. (2015), Kookancz et al. (2016), Jiang et al. (2017a, b), Zhang et al. (2017), Belyagoubi et al. (2018), Berceanu et al. (2018), Novákova et al. (2018), Leplat et al. (2018), Paula et al. (2019) |
| Asperisporium   | Vanderwolf et al. (2013)       |        |             |                                              |
| Athelia         | Pusz et al. (2018b)            |        |             |                                              |
| Aureobasidium   | Connell and Staudigel (2013), Vanderwolf et al. (2013), Popović et al. (2015), Brad et al. (2018), Pusz et al. (2018a), Popkova and Mazina (2019) |        |             |                                              |
| Aureobasidium sp.| Connell and Staudigel (2013), Vanderwolf et al. (2013), Leplat et al. (2018) |        |             |                                              |
| Auxarthron      | Man et al. (2015)              |        |             |                                              |
| Au. californiense| Vanderwolf et al. (2015), Novákova et al. (2018) |        |             |                                              |
Table 4 (continued)

| Genus            | Species                        | Chinaa | This studyb | References                        |
|------------------|--------------------------------|--------|-------------|-----------------------------------|
| Au. chinense     | Y                               | Y      |             | Vanderwolf et al. (2013)          |
| Au. guangxiense  | Y                               | Y      |             |                                   |
| Au. thaxteri     |                                 |        |             | Vanderwolf et al. (2013)          |
| Au. umbraunum    | Y                               |        |             | Zhang et al. (2017)               |
| Auxarthron sp.   | Y                               | Y      |             | Vanderwolf et al. (2013), Zhang et al. (2014) |
| Auxarthronopsis  | Auxarthronopsis globiasticas    | Y      |             |                                   |
| Aux. guizhouensis| Y                               |        |             | Zhang et al. (2017)               |
| Aux. pedicellaris| Y                               | Y      |             | Vanderwolf et al. (2013)          |
| Aux. pulveira    | Y                               | Y      |             | Vanderwolf et al. (2013)          |
| Aux. stercicola  | Y                               | Y      |             | Vanderwolf et al. (2013)          |
| Barnettozyma     | Barnettozyma californica        | Y      | Y           | Vanderwolf et al. (2013)          |
| Bartalinia       | Bartalinia robillardoides       | Y      | Y           |                                   |
| Basipetospora    | Basipetospora sp.               |        |             | Vanderwolf et al. (2013)          |
| Beauveria        | Beauveria bassiana              | Y      | Y           | Ogórek et al. (2013, 2014a), Vanderwolf et al. (2013), Zhang et al. (2014), Yoder et al. (2015), Pusz et al. (2018a) |
| B. bronniartii   | Y                               | Y      |             | Vanderwolf et al. (2013)          |
| B. caledonica    | Y                               | Y      |             | Yoder et al. (2015)               |
| Beauveria sp.    |                                 |        |             | Vanderwolf et al. (2013, 2019), Leplat et al. (2018) |
| Beltrania        | Beltrania sp.                   |        |             | Vanderwolf et al. (2013)          |
| Bieneccaria      | Bieneccaria ochroleuca           | Y      | Y           | Vanderwolf et al. (2013), Zhang et al. (2014), Jacobs et al. (2017), Zhang et al. (2017) |
| Bl. rosmaniae    | Y                               | Y      |             | Mitova et al. (2017)              |
| Bl. solani       | Y                               |        |             | Nováková et al. (2018)            |
| Bieneccaria sp.  |                                 |        |             | Zhang (2019)                      |
| Bipolaris        | Bipolaris sorokiniana           |        |             | Vanderwolf et al. (2013)          |
| Bipolaris sp.    |                                 |        |             | Vanderwolf et al. (2013)          |
| Biscogniauxia    | Biscogniauxia petrensis          | Y      | Y           | Zhang et al. (2017)               |
| Biscogniauxia sp.| Y                               | Y      |             | Zhang et al. (2017)               |
| Bisfusarium      | Bisfusarium delphinoidea         | Y      | Y           | Vanderwolf et al. (2013)          |
| Bispora          | Bispora antennata               |        |             | Vanderwolf et al. (2013)          |
| Bis. bendicina   |                                 |        |             | Vanderwolf et al. (2013)          |
| Bis. effusa      |                                 |        |             | Vanderwolf et al. (2013)          |
| Bispora sp.      |                                 |        |             | Vanderwolf et al. (2013)          |
| Bisporella       | Bisporella citrina              |        |             | Vanderwolf et al. (2013)          |
| Blastobotrys     | Blastobotrys chiropertorum      |        |             | Vanderwolf et al. (2013)          |
| Bl. malaysiensis |                                 |        |             | Vanderwolf et al. (2013)          |
| Bl. persicus     |                                 |        |             | Vanderwolf et al. (2013)          |
| Blastobotrys sp. |                                 |        |             | Vanderwolf et al. (2013)          |
| Blastoischichium | Blastoischichium sp.            |        |             | Vanderwolf et al. (2013)          |
| Boeremia         | Boeremia exigua                 | Y      |             | Vanderwolf et al. (2013), Zhang (2019) |
| Boeremia sp.     |                                 |        |             | Jiang et al. (2017a, b)           |
| Botryosporium    | Botryosporium longibrachiatum    |        |             | Vanderwolf et al. (2013)          |
| Botryotinia      | Botryotinia fuckeliaena         | Y      |             | Vanderwolf et al. (2013), Zhang et al. (2014), Zhang (2019) |
| Botryotrichium   | Botryotrichium murorum          | Y      | Y           | Vanderwolf et al. (2013)          |
| Botrytis         | Botrytis cinerea                | Y      |             | Vanderwolf et al. (2013), Ogórek et al. (2014a, b, c, 2016b, d, 2017), Man et al. (2015), Pusz et al. (2017, 2018a, b), Nováková et al. (2018), Ogórek (2018a, b), Ogórek et al. (2018), Pusz et al. (2018a), Popkova and Marina (2019) |
| Boeadiera        | Boudiera sp.                    |        |             | Vanderwolf et al. (2013)          |
| Brachiosphaera   | Brachiosphaera jamaicensis       |        |             | Vanderwolf et al. (2013)          |
| Brachyconidiella | Brachyconidiella monitspora      |        |             | Brad et al. (2018)                |
| Brachysporium    | Brachysporium echinoides        |        |             | Vanderwolf et al. (2013)          |
| Brunnemycyes     | Brunnemycyes brunnescens        | Y      |             | Zhang (2019)                      |
| Bulgaria         | Bulgaria inquinans              |        |             | Vanderwolf et al. (2013)          |
| Bysschlamys      | Bysschlamys fulva               |        |             | Vanderwolf et al. (2013)          |
| Bysschlamys sp.  |                                 |        |             | Vanderwolf et al. (2013)          |
| Cadophora        | Cadophora fastigia             |        |             | Out et al. (2016), Zhang (2019)   |
| C. malorum       |                                 |        |             | Nováková et al. (2018)            |
| Genus         | Species                          | Chinaa | This studyb | References                                                      |
|--------------|----------------------------------|--------|-------------|----------------------------------------------------------------|
| C. melinii   | Vanderwolf et al. (2013)         |        |             |                                                                 |
| Cadophora sp.| Zhang et al. (2014), Vanderwolf et al. (2019) |        |             |                                                                 |
| Calcarisporiella | Calcarisporiella sp.           | Vanderwolf et al. (2013) |        |                                                                 |
| Calcarisporum | Calcarisporum sp.               | Y      | Taylor et al. (2013), Zhang et al. (2017) |                                                                 |
| Camarosporium | Camarosporium aerovirulens     | Vanderwolf et al. (2013) |        |                                                                 |
| Candida      | Candida albicans                | Ogórek et al. (2013, 2016c, d), Vanderwolf et al. (2013), Kokurewicz et al. (2016) |        |                                                                 |
| Ca. deformans| Vanderwolf et al. (2013)        |        |             |                                                                 |
| Ca. fimitaria var. fimetaria | Vanderwolf et al. (2013) |        |             |                                                                 |
| Ca. glabrata  | Vanderwolf et al. (2013)        |        |             |                                                                 |
| Ca. guilliermondii | Vanderwolf et al. (2013) |        |             |                                                                 |
| Ca. laxianiae | Vanderwolf et al. (2013)        |        |             |                                                                 |
| Ca. norvegica | Vanderwolf et al. (2013)        |        |             |                                                                 |
| Ca. palmiolephila | Vanderwolf et al. (2013) |        |             |                                                                 |
| Ca. parapsilosis | Vanderwolf et al. (2013)      |        |             |                                                                 |
| Ca. pseudoglaebosa | Zhang et al. (2014) |        |             |                                                                 |
| Ca. saitoana  | Vanderwolf et al. (2013)        |        |             |                                                                 |
| Ca. tropicalis| Vanderwolf et al. (2013)        |        |             |                                                                 |
| Ca. viswanathi | Vanderwolf et al. (2013)        |        |             |                                                                 |
| Ca. zeylanoides | Connell and Staudigel (2013), Vanderwolf et al. (2013) |        |             |                                                                 |
| Candida sp.  | Vanderwolf et al. (2013), Jiang et al. (2017a, b), Burow et al. (2019) |        |             |                                                                 |
| Capnodium    | Capnodium sp.                   | Zhang et al. (2017) |        |                                                                 |
| Cenococcum   | Cenococcum sp.                  | Vanderwolf et al. (2013) |        |                                                                 |
| Cephalosporium | Cephalosporium atrum           | Vanderwolf et al. (2013) |        |                                                                 |
| Ce. lanoosiovum | Vanderwolf et al. (2013)      |        |             |                                                                 |
| Cephalotrichum sp. | Vanderwolf et al. (2013)  |        |             |                                                                 |
| Cephalotheca | Cephalotheca sp.                | Y      |             |                                                                 |
| Cephalotrichiella | Cephalotrichiella penicillata | Y      |             |                                                                 |
| Cephalotrichum asperulum | Vanderwolf et al. (2013) |        |             |                                                                 |
| Cep. castaneum | Vanderwolf et al. (2013)        | Y      |             |                                                                 |
| Cep. columnare | Vanderwolf et al. (2013)        | Y      |             |                                                                 |
| Cep. dendrocephaeum | Zhang (2019) |        |             |                                                                 |
| Cep. guizhouense | Jiang et al. (2017a, b)       | Y      |             |                                                                 |
| Cep. leve  | Jiang et al. (2017a, b)        | Y      |             |                                                                 |
| Cep. medium | Vanderwolf et al. (2013)        | Y      |             |                                                                 |
| Cep. microsorum | Vanderwolf et al. (2013)        | Y      |             |                                                                 |
| Cep. nanum  | Vanderwolf et al. (2013), Zhang et al. (2017) |        |             |                                                                 |
| Cep. oligotrichicum | Jiang et al. (2017a, b) |        |             |                                                                 |
| Cep. purpureofuscum | Vanderwolf et al. (2013) |        |             |                                                                 |
| Cep. stemonitis | Vanderwolf et al. (2013, 2015, 2019), Nováková et al. (2018) |        |             |                                                                 |
| Cep. verrucisporum | Vanderwolf et al. (2017) |        |             |                                                                 |
| Cephalotrichum sp. | Vanderwolf et al. (2019) |        |             |                                                                 |
| Ceratocystis  | Ceratocystis autographa         | Vanderwolf et al. (2013) |        |                                                                 |
| Ceratocystis sp. | Vanderwolf et al. (2013)       |        |             |                                                                 |
| Cercophora   | Cercophora solanis              | Y      |             |                                                                 |
| Cer. sparsa  | Vanderwolf et al. (2013)        | Y      |             |                                                                 |
| Cercophora sp. | Vanderwolf et al. (2013)       | Y      |             |                                                                 |
| Cercospora   | Cercospora sp.                  |        |             |                                                                 |
| Chaetomidium | Chaetomidium arxii              | Zhang et al. (2017) |        |                                                                 |
| Ch. fineti  | Vanderwolf et al. (2013)        |        |             |                                                                 |
| Chaetomidium sp. | Vanderwolf et al. (2019), Zhang (2019) |        |             |                                                                 |
| Chaetomium   | Chaetomium uncistrocioidum      | Zhang (2019) |        |                                                                 |
| Cha. crispatum | Vanderwolf et al. (2013), Zhang et al. (2014), Ogórek et al. (2017), Zhang et al. (2017) |        |             |                                                                 |
| Cha. elatum  | Vanderwolf et al. (2013)        | Y      |             |                                                                 |
| Cha. fineti  | Vanderwolf et al. (2013)        |        |             |                                                                 |
| Cha. globosum | Vanderwolf et al. (2013), Kokurewicz et al. (2016), Zhang et al. (2017), Nováková et al. (2018), Pusz et al. (2018a), Popkova and Mazina (2019) |        |             |                                                                 |
| Cha. heterothallicum | Vanderwolf et al. (2013) |        |             |                                                                 |
| Genus         | Species                      | China | This study | References                                                                 |
|--------------|------------------------------|-------|------------|-----------------------------------------------------------------------------|
| *Chaetomium* | sp.                          | Y     | Y          | Taylor et al. (2013), Vanderwolf et al. (2013), Mitova et al. (2017), Zhang et al. (2017), Leplat et al. (2018), Popkova and Mazina (2019) |
| *Chaetosphaeria* | *inaequalis*                |       |            | Vanderwolf et al. (2013)                                                    |
| *Cha. murorum* |                              | Y     |            | Y Zhang et al. (2017)                                                       |
| *Cha. piluliferum* |                            | Y     |            | Y Vanderwolf et al. (2013), Mitova et al. (2017)                            |
| *Cha. spinosum* |                              |       |            | Vanderwolf et al. (2013)                                                    |
| *Cha. succineum* |                             |       |            | Vanderwolf et al. (2013)                                                    |
| *Cha. thermophilum* |                           |       |            | Vanderwolf et al. (2013)                                                    |
| *Cha. trigomosporum* |                         | Y     |            | Zhang et al. (2017)                                                         |
| *Cha. udagawae* |                              | Y     |            | Zhang et al. (2017)                                                         |
| *Chloridium* | *minus*                      | Y     |            | Vanderwolf et al. (2013)                                                    |
| *Chloridium* | sp.                         | Y     |            | Vanderwolf et al. (2013, 2019)                                              |
| *Ch. holubovae* |                              | Y     |            | Vanderwolf et al. (2013)                                                    |
| *Ch. inaequalis* |                             |       |            | Vanderwolf et al. (2013)                                                    |
| *Ch. microspora* |                             |       |            | Vanderwolf et al. (2013)                                                    |
| *Ch. succineum* |                             |       |            | Vanderwolf et al. (2013)                                                    |
| *Ch. thermophilum* |                            |       |            | Vanderwolf et al. (2013)                                                    |
| *Ch. trigomosporum* |                          | Y     |            | Vanderwolf et al. (2013)                                                    |
| *Ch. udagawae* |                              | Y     |            | Vanderwolf et al. (2013)                                                    |
| *Ch. vermicularioides* |                        | Y     |            | Vanderwolf et al. (2013)                                                    |
| *Ch. carmichaelii* |                         | Y     |            | Vanderwolf et al. (2013)                                                    |
| *Ch. chiropterorum* |                        | Y     |            | Vanderwolf et al. (2013)                                                    |
| *Ch. lobatum* |                              |       |            | Vanderwolf et al. (2013)                                                    |
| *Ch. merdarium* |                              |       |            | Vanderwolf et al. (2013, 2019)                                              |
| *Ch. pallidum* |                             | Y     | Y          | Vanderwolf et al. (2013)                                                    |
| *Ch. pannicola* |                              |       |            | Vanderwolf et al. (2013)                                                    |
| *Ch. pseudomerdarium* |                       | Y     |            | Vanderwolf et al. (2013, Zhang et al. (2017)                                |
| *Ch. speluncarum* |                              |       |            | Vanderwolf et al. (2013)                                                    |
| *Ch. tropicum* |                              |       |            | Vanderwolf et al. (2013)                                                    |
| *Ch. tropicarum* |                             |       |            | Vanderwolf et al. (2013)                                                    |
| *Ch. undulatum* |                              |       |            | Vanderwolf et al. (2013)                                                    |
| *Cladosporium* | *allicinum*                 |       |            | Vanderwolf et al. (2013)                                                    |
| *Cl. angustisporum* |                        | Y     |            | Nováková et al. (2018)                                                      |
| *Cl. anthropophilum* |                        | Y     |            | Jiang et al. (2017a, b)                                                     |
| *Cl. asperulatum* |                            | Y     |            | Nováková et al. (2018)                                                      |
| *Cl. cladosporioides* |                        | Y     | Y          | Taylor et al. (2013), Vanderwolf et al. (2013), Ogórek et al. (2014b, c, 2016c, d, 2017, 2018), Zhang et al. (2014), Pusz et al. (2015, 2018a, b), Yoder et al. (2015), Kokurewicz et al. (2016), Jiang et al. (2017a, b), Zhang et al. (2017), Novákůvá et al. (2018), Ogórek (2018a, b), Popkova and Mazina (2019) |
| *Cl. colombiae* |                              | Y     |            | Zhang (2019)                                                                |
| *Cl. cucumerinum* |                             | Y     |            | Vanderwolf et al. (2013)                                                    |
| *Cl. grevilleae* |                              | Y     |            | Connell and Staudigel (2013)                                                |
| *Cl. halotolerans* |                           | Y     | Y          | Ogórek et al. (2013, 2014a, b, 2016b, c), Taylor et al. (2013), Vanderwolf et al. (2013), Ogórek et al. (2016), Jiang et al. (2017a, b), Ogórek et al. (2017, 2018), Novákůvá et al. (2018), Ogórek (2018a), Pusz et al. (2018a), Popkova and Mazina (2019) |
| *Cl. herbarum* |                              | Y     |            | Ogórek et al. (2013, 2014a, b, 2016b, c), Taylor et al. (2013), Vanderwolf et al. (2013), Ogórek et al. (2017, 2018), Novákůvá et al. (2018), Ogórek (2018a), Pusz et al. (2018a), Popkova and Mazina (2019) |
| *Cl. linicola* |                              |       |            | Vanderwolf et al. (2013)                                                    |
| *Cl. macrocarpum* |                            | Y     |            | Vanderwolf et al. (2013), Ogórek et al. (2017, 2018), Novákůvá et al. (2018), Ogórek (2018b) |
| *Cl. oxysporum* |                              | Y     |            | Vanderwolf et al. (2013), Popović et al. (2015), Novákůvá et al. (2018), Zhang (2019) |
| *Cl. paracladosporioides* |                       | Y     |            | Novákůvá et al. (2018)                                                      |
| *Cl. perungustum* |                              | Y     |            | Jiang et al. (2017a, b)                                                     |
| *Cl. pseudocladosporioides* |                    | Y     |            | Belyagoubi et al. (2018)                                                     |
| *Cl. rectoides* |                              | Y     |            | Jiang et al. (2017a, b)                                                     |
Table 4 (continued)

| Genus       | Species                     | Chinaa | This studyb | References                                                                 |
|-------------|-----------------------------|--------|-------------|-----------------------------------------------------------------------------|
| Cl. scabrellum |                             | Y      |             | Jiang et al. (2017a, b)                                                     |
| Cl. sphaerospermum |                        | Y      | Y           | Connell and Staudigel (2013), Vanderwolf et al. (2013), Popović et al. (2015), Zhang et al. (2017), Nováková et al. (2018), Popkova and Mazina (2019) |
| Cl. spongiosum |                             |        |             | Vanderwolf et al. (2013)                                                     |
| Cl. subaliforme |                             | Y      |             | Zhang (2019)                                                                |
| Cl. tenuissimum |                             | Y      | Y           | Vanderwolf et al. (2013), Jiang et al. (2017a, b)                           |
| Cl. uredinicola |                             | Y      |             | Man et al. (2015), Pusz et al. (2015)                                       |
| Cl. variabile |                             |        |             | Mitova et al. (2017), Nováková et al. (2018)                               |
| Cladosporium sp. |                             | Y      |             | Connell and Staudigel (2013), Vanderwolf et al. (2013, 2015, 2019), Martin-Sanchez et al. (2014), Popović et al. (2015), Oot et al. (2016), Jiang et al. (2017a, b), Bereza et al. (2018), Leplat et al. (2018) |
| Clavariopsis | Clavariopsis azlanii |        |             | Vanderwolf et al. (2013)                                                     |
| Claviceps | Claviceps purpurea |          |             | Vanderwolf et al. (2013)                                                     |
| Claviceps sp. |                             | Y      | Y           | Connell and Staudigel (2013)                                                |
| Clavispora | Clavispora lusitaniae |          |             | Vanderwolf et al. (2013)                                                     |
| Clonostachys | Clonostachys candelabrum | Y      |             | Vanderwolf et al. (2013)                                                     |
| Clo. intermedia |                             | Y      | Y           | Taylor et al. (2013), Vanderwolf et al. (2013), Kokurewicz et al. (2016), Ogórek et al. (2016b, d), Jiang et al. (2017a, b), Zhang et al. (2017), Nováková et al. (2018), Pusz et al. (2018a) |
| Clo. phyllophila |                             | Y      |             | Vanderwolf et al. (2013)                                                     |
| Clo. rhizophaga |                             | Y      | Y           | Zhang et al. (2017)                                                         |
| Clo. rogerstoniana |                             | Y      |             | Vanderwolf et al. (2013)                                                     |
| Clo. rosea |                             | Y      | Y           | Vanderwolf et al. (2013, 2015), Jiang et al. (2017a, b), Zhang et al. (2017) |
| Clonostachys sp. |                             | Y      | Y           | Vanderwolf et al. (2013, 2015), Jiang et al. (2017a, b), Zhang et al. (2017) |
| Cocidioides | Cocidioides immittis |          |             | Vanderwolf et al. (2013)                                                     |
| Cochliomyces | Cochliomyces trinitais |          |             | Vanderwolf et al. (2013)                                                     |
| Collariella | Collariella bostrychodes | Y      |             | Vanderwolf et al. (2013), Man et al. (2015), Zhang et al. (2017)             |
| Co. quadrum |                             | Y      |             | Zhang et al. (2017)                                                         |
| Colletotrichum | Colletotrichum acutatum | Y      |             | Vanderwolf et al. (2013)                                                     |
| Col. fioriniae |                             | Y      |             | Vanderwolf et al. (2013)                                                     |
| Col. gloeosporioides |                             | Y      | Y           | Zhang et al. (2017)                                                         |
| Col. karstii |                             | Y      |             | Zhang et al. (2017)                                                         |
| Col. pisi |                             | Y      | Y           | Vanderwolf et al. (2013)                                                     |
| Colletotrichum sp. |                             | Y      |             | Vanderwolf et al. (2013, 2015), Jiang et al. (2017a, b), Zhang et al. (2017) |
| Compsonymes | Compsonymes lestevi |          |             | Vanderwolf et al. (2013)                                                     |
| Coniochaeta | Coniochaeta hoffmannii | Y      | Y           | Vanderwolf et al. (2013)                                                     |
| Con. mutabilis |                             | Y      |             | Vanderwolf et al. (2013)                                                     |
| Coniochaeta sp. |                             | Y      |             | Vanderwolf et al. (2013)                                                     |
| Coniothyrium | Coniothyrium sp. |          |             | Martin-Sanchez et al. (2014)                                                |
| Conoideocrella | Conoideocrella lateorostrata | Y      |             | Vanderwolf et al. (2013)                                                     |
| Corallinopsis | Corallinopsis ptilulfera | Y      |             | Vanderwolf et al. (2013)                                                     |
| Cordyceps | Cordyceps cicadae | Y      | Y           | Vanderwolf et al. (2013)                                                     |
| Cor. militaris |                             | Y      | Y           | Vanderwolf et al. (2013)                                                     |
| Cor. odynieri |                             |        |             | Vanderwolf et al. (2013)                                                     |
| Cor. polyarthra |                             | Y      |             | Vanderwolf et al. (2013)                                                     |
| Cor. riverae |                             |        |             | Vanderwolf et al. (2013)                                                     |
| Cor. sphingum |                             |        |             | Vanderwolf et al. (2013)                                                     |
| Cor. tenupes |                             | Y      | Y           | Vanderwolf et al. (2013, 2015)                                               |
| Cordyceps sp. |                             | Y      |             | Vanderwolf et al. (2013, 2015)                                               |
| Corynespora | Corynespora sp. | Y      |             | Zhang et al. (2017)                                                         |
| Cosmopora | Cosmopora berkeleyana | Y      |             | Vanderwolf et al. (2013)                                                     |
| Cos. butyri |                             |        |             | Vanderwolf et al. (2013)                                                     |
| Cos. diminata |                             | Y      | Y           | Burrow et al. (2019)                                                         |
| Cos. viridescens |                             |        |             | Vanderwolf et al. (2013, 2015), Jiang et al. (2017a, b)                      |
| Cosmopora sp. |                             | Y      | Y           | Vanderwolf et al. (2013)                                                     |
| Creosphaeria | Creosphaeria asafoafra | Y      |             | Zhang (2019)                                                                |
| Cryomyces | Cryomyces sp. |                             | Y      |             | Vanderwolf et al. (2015)                                                     |
| Ctenomyces | Ctenomyces serratus |                             |        |             | Vanderwolf et al. (2015)                                                     |
| Genus            | Species                               | China | This study | References                                    |
|------------------|---------------------------------------|-------|------------|----------------------------------------------|
| Ct. vellereus    | Vanderwolf et al. (2013)              |       |            |                                              |
| Calcinomyces     | Calcinomyces sp.                      |       |            | Vanderwolf et al. (2019)                     |
| Cumuliphoma      | Cumuliphoma omnivirens                | Y     | Y          | Vanderwolf et al. (2013)                     |
| Curryea          | Curryea sp.                           | Y     | Y          | Vanderwolf et al. (2013)                     |
| Curvularia       | Curvularia brachyspora                |       |            | Vanderwolf et al. (2013)                     |
| Curvularia       | Cu. eragrostidis                      | Vanderwolf et al. (2013) |
| Curvularia       | Cu. hawaiiensis                       | Vanderwolf et al. (2013) |
| Cu. lunata       | Y                                     | Y     |            | Vanderwolf et al. (2013), Connell and Staudigel (2013) |
| Cu. senegalensis | Vanderwolf et al. (2013)              |       |            |                                              |
| Cu. trifolii     | Vanderwolf et al. (2013)              | Y     | Y          |                                              |
| Cu. sp.          | Taylor et al. (2013), Vanderwolf et al. (2013) |
| Cylindrocarpon   | Cylindrocarpon didymum                | Vanderwolf et al. (2013), Nováková et al. (2018) |
| Cylindrocarpon   | Cy. obtusisculum                      | Nováková et al. (2018) |
| Cylindrocarpon   | Cy. olidum                            | Jiang et al. (2017a, b), Zhang et al. (2017) |
| Cylindrocarpon   | Cy. sp.                               | Vanderwolf et al. (2013, 2019), Zhang et al. (2017) |
| Cylindrocephalum | Cylindrocephalum stellatum            | Vanderwolf et al. (2013) |
| Cylindrocladiella| Cylindrocladiella lanceolata          | Y     | Y          | Vanderwolf et al. (2013)                     |
| Cyl. stellenschenis | Vanderwolf et al. (2013)            | Y     | Y          |                                              |
| Cylindrocladium  | Cylindrocladium scoparium              | Vanderwolf et al. (2013) |
| Cylindrocladium  | Cylindrocladium sp.                   | Vanderwolf et al. (2013) |
| Cylindrodendrum  | Cylindrodendrum album                 | Vanderwolf et al. (2013) |
| Cyli. alicantinum | Vanderwolf et al. (2013)             | Y     | Y          |                                              |
| Cylindrocladium  | Cylindrocladium scoparium              | Vanderwolf et al. (2013) |
| Cylindrocladium  | Cylindrocladium sp.                   | Vanderwolf et al. (2013) |
| Cyphellophora    | Cyphellophora laciniata               | Connell and Staudigel (2013) |
| Dactylaria       | Dactylaria lanosa                     | Vanderwolf et al. (2013) |
| Dactylaria       | Dactylaria sp.                        | Y     | Y          | Vanderwolf et al. (2013)                     |
| Dactylella       | Dactylella sp.                        | Vanderwolf et al. (2013) |
| Dactylonecctria  | Dactylonecctria macrodidyma           | Vanderwolf et al. (2013) |
| Dactylorosporium | Dactylorosporium sp.                  | Vanderwolf et al. (2013) |
| Daldinia         | Daldinia concentrica                  | Vanderwolf et al. (2013) |
| Dasysscyphella   | Dasysscyphella sp.                    | Vanderwolf et al. (2013) |
| Debaromyces      | Debaromyces hansenii                  | Vanderwolf et al. (2013) |
| D. marmus        | Zhang et al. (2014)                   |       |            |                                              |
| D. napelensis    | Vanderwolf et al. (2013)              |       |            |                                              |
| D. prosopidis    | Vanderwolf et al. (2013)              |       |            |                                              |
| D. psychrophorus | Vanderwolf et al. (2013)              |       |            |                                              |
| D. s. r.         | Vanderwolf et al. (2013)              |       |            |                                              |
| D. sp.           | Vanderwolf et al. (2013)              |       |            |                                              |
| Delitschia       | Delitschia sp.                        | Vanderwolf et al. (2013) |
| Dematioscypha    | Dematioscypha catenata                | Vanderwolf et al. (2013) |
| Dendrosporium    | Dendrosporium lobatum                 | Vanderwolf et al. (2013) |
| Dendryphion      | Dendryphion sp.                      | Vanderwolf et al. (2013) |
| Didalonecctria   | Didalonecctria sp.                    | Y     | Y          | Vanderwolf et al. (2013)                     |
| Diaporthe        | Diaporthe eres                        | Zhang (2019) |
| Di. jukashii     | Zhang (2019)                          |       |            |                                              |
| Di. melosis      | Jiang et al. (2017a, b)               |       |            |                                              |
| Diaporthe nobilis | Zhang (2019)                         | Y     | Y          |                                              |
| Di. phaseolorum  | Zhang (2019)                          |       |            |                                              |
| Di. phoenicicola | Zhang et al. (2017)                   |       |            |                                              |
| Di. vaccini      | Zhang (2019)                          |       |            |                                              |
| Diaporthe sp.    | Y                                     | Y     |            |                                              |
| Di. vaccini      | Vanderwolf et al. (2013)              |       |            |                                              |
| Di. phoenicicola | Zhang et al. (2017)                   |       |            |                                              |
| Diaptyre         | Diarytype palmicola                   | Zhang (2019) |
| Dia. phoenicicola | Zhang (2019)                         | Y     | Y          |                                              |
| Dia. vaccini     | Zhang (2019)                          |       |            |                                              |
| Dia. phoenicicola | Zhang et al. (2017)                   |       |            |                                              |
| Dichomopilus     | Dichomopilus funicola                 | Vanderwolf et al. (2013) |
| Dic. indicus     | Vanderwolf et al. (2013)              |       |            |                                              |
| Genus            | Species                          | China<sup>a</sup> | This study<sup>b</sup> | References                                      |
|------------------|----------------------------------|-------------------|------------------------|-------------------------------------------------|
| Dictyosporium    | Dictyosporium elegans            |                   |                        | Vanderwolf et al. (2013)                         |
|                  | Dictyosporium sp.                |                   |                        | Vanderwolf et al. (2013)                         |
|                  | Dictyosporium toruloides         |                   |                        | Vanderwolf et al. (2013)                         |
| Didymella        | Didymella bellidis               | Y                 | Y                      | Vanderwolf et al. (2013)                         |
|                  | Did. glomerata                   |                   |                        | Vanderwolf et al. (2013)                         |
|                  | Did. macrostoma                  | Y                 |                        | Vanderwolf et al. (2013), Zhang et al. (2017)    |
|                  | Did. pinodella                   | Y                 | Y                      | Vanderwolf et al. (2013)                         |
|                  | Did. rhei                        | Y                 | Y                      | Vanderwolf et al. (2013), Jiang et al. (2017a, b) |
| Didymospheria    | Didymospheria variabilis         | Y                 | Y                      | Zhang (2019)                                     |
|                  | Didymospheria sp.                |                   |                        |                                                 |
| Diplococcium     | Diplococcium sp.                 |                   |                        | Vanderwolf et al. (2015)                         |
| Diplocodia       | Diplocodia sp.                   |                   |                        | Vanderwolf et al. (2013)                         |
| Diplosporidium   | Diplosporidium callipodos        |                   |                        | Vanderwolf et al. (2013)                         |
| Dipodascus       | Dipodascus fermentans            |                   |                        | Vanderwolf et al. (2013)                         |
|                  | Dip. geotrichum                  | Y                 | Y                      | Vanderwolf et al. (2013), Yoder et al. (2015), Zhang et al. (2017), Nováková et al. (2018) |
| Discosia         | Discosia pseudoartocreas         |                   |                        | Ogórek et al. (2017, 2018a), Ogórek (2018a, b)   |
|                  | Discosia sp.                     |                   |                        |                                                 |
| Discostroma      | Discostroma corticola            | Y                 | Y                      | Vanderwolf et al. (2013)                         |
| Diutina          | Diutina catenulata               |                   |                        | Vanderwolf et al. (2013)                         |
|                  | Diu. rugosa                      |                   |                        | Vanderwolf et al. (2013)                         |
| Doratomyces      | Doratomyces microsporus          |                   |                        | Mitova et al. 2017                               |
|                  | Doratomyces sp.                  | Y                 |                        | Vanderwolf et al. (2013), Martin-Sanchez et al. (2014), Zhang et al. (2014, 2017), Leplat et al. (2018) |
| Doffidella       | Doffidella ulmi                  | Y                 | Y                      |                                                 |
| Drechslera       | Drechslera avenueca              |                   |                        | Vanderwolf et al. (2013)                         |
|                  | Drechslera sp.                   |                   |                        | Vanderwolf et al. (2013), Leplat et al. (2018)   |
| Echinobryum      | Echinobryum parasitans           |                   |                        | Vanderwolf et al. (2013)                         |
|                  | E. subterraneum                  |                   |                        | Vanderwolf et al. (2013)                         |
|                  | Echinobryum sp.                  |                   |                        | Vanderwolf et al. (2013)                         |
| Emericella       | Emericella sp.                   |                   |                        | Vanderwolf et al. (2013)                         |
| Emericellopsis   | Emericellopsis minima            | Y                 | Y                      | Vanderwolf et al. (2013)                         |
|                  | Em. terricola                    |                   |                        |                                                 |
| Emmonsia         | Emmonsia sp.                     |                   | Y                      | Man et al. (2015)                                 |
| Endophoma        | Endophoma elongata               |                   |                        | Vanderwolf et al. (2013)                         |
| Endophagmiella   | Endophagmiella sp.               |                   |                        | Vanderwolf et al. (2013)                         |
| Engyodontium     | Engyodontium aranearum           |                   |                        | Vanderwolf et al. (2013)                         |
|                  | En. parvisporum                  |                   |                        | Vanderwolf et al. (2013)                         |
|                  | En. recidentatum                 |                   |                        | Vanderwolf et al. (2013)                         |
|                  | Engyodontium sp.                 |                   |                        | Vanderwolf et al. (2013), Leplat et al. (2018)   |
| Epicoccum        | Epicoccum draconis               | Y                 | Y                      | Connell and Staudigel (2013), Vanderwolf et al. (2013), Martin-Sanchez et al. (2014), Ogórek et al. (2014a, b, c, 2016b, e, d, 2017, 2018), Pusz et al. (2015), Zhang et al. (2017), Nováková et al. (2018), Pusz et al. (2018a), Tavares et al. (2018) |
|                  | Ep. nigrum                       | Y                 | Y                      |                                                 |
|                  | Ep. plurivorum                   |                   | Y                      | Vanderwolf et al. (2013), Leplat et al. (2018)   |
| Eremomyces       | Eremomyces sp.                   |                   |                        | Vanderwolf et al. (2013, 2015)                    |
| Erysiphe         | Erysiphe polygoni                |                   |                        | Connell and Staudigel (2013)                      |
| Eupenicillium    | Eupenicillium sp.                |                   |                        | Vanderwolf et al. (2013)                         |
| Eutypella        | Eutypella citricola              | Y                 | Y                      | Jiang et al. (2017a, b)                           |
|                  | Eu. scoparia                     |                   |                        |                                                 |
| Eurotium         | Eurotium sp.                     |                   | Y                      | Vanderwolf et al. (2013), Zhang (2019)            |
| Exophiala        | Exophiala castellani             |                   |                        | Vanderwolf et al. (2013)                         |
|                  | Ex. moniliae                     |                   |                        | Vanderwolf et al. (2013)                         |
|                  | Ex. pisciphila                   | Y                 | Y                      |                                                 |
Table 4 (continued)

| Genus         | Species                  | China | This study | References                                      |
|---------------|--------------------------|-------|------------|------------------------------------------------|
| Ex. salmonis  | Mitova et al. (2017)     |       |            |                                                 |
| Ex. xenobiotica | Ogórek (2018a, b)       |       |            |                                                 |
| Esophilus sp. | Vanderwolf et al. (2013) | Y     |            |                                                 |
| Farrowia      | Vanderwolf et al. (2013) |       |            |                                                 |
| Forlioniymces | Leplat et al. (2018)     |       |            |                                                 |
| Fusariella    | Vanderwolf et al. (2013) |       |            |                                                 |
| Fusarium      | Vanderwolf et al. (2013) |       |            |                                                 |
| F. avenaceum  | Vanderwolf et al. (2013) |       |            |                                                 |
| F. chlamydosporum | Vanderwolf et al. (2013) | Y     |            |                                                 |
| F. coerulescens | Vanderwolf et al. (2013) |       |            |                                                 |
| F. culmorum   | Vanderwolf et al. (2013) |       |            |                                                 |
| F. dimerum    | Vanderwolf et al. (2013) |       |            |                                                 |
| F. equiseti   | Vanderwolf et al. (2013) |       |            |                                                 |
| F. fujikuroi  | Vanderwolf et al. (2013) |       |            |                                                 |
| F. graminearum| Ogórek et al. (2013), Jiang et al. (2017a, b), Zhang et al. (2017) | Y     |            |                                                 |
| F. incarnatum | Vanderwolf et al. (2013) |       |            |                                                 |
| F. lateritium | Vanderwolf et al. (2013), Ogórek (2018b) | Y     |            |                                                 |
| F. merismoides| Zhang et al. (2017)      | Y     |            |                                                 |
| F. nematophilum | Jiang et al. (2017a, b) |       |            |                                                 |
| F. oxysporum  | Vanderwolf et al. (2013), Ogórek et al. (2013, 2014b, c), Taylor et al. (2013), Vanderwolf et al. (2013), Kokurewicz et al. (2016), Jiang et al. (2017a, b), Nováková et al. (2018), Pusz et al. (2018b), Popkova and Mazina (2019) | Y     |            |                                                 |
| F. poae       | Ogórek et al. (2014c)    |       |            |                                                 |
| F. proliferatum | Vanderwolf et al. (2013) | Y     |            |                                                 |
| F. roseum     | Vanderwolf et al. (2013) |       |            |                                                 |
| F. sacchari   | Vanderwolf et al. (2013) | Y     |            |                                                 |
| F. solani     | Taylor et al. (2013), Vanderwolf et al. (2013), Man et al. (2015), Jiang et al. (2017a, b), Zhang et al. (2017), Nováková et al. (2018), Pusz et al. (2018b), Popkova and Mazina (2019) | Y     |            |                                                 |
| F. sporotrichoides | Vanderwolf et al. (2013), Ogórek et al. (2014c), Popkova and Mazina (2019) | Y     |            |                                                 |
| F. subglutinans| Vanderwolf et al. (2013) |       |            |                                                 |
| F. thapsinum  | Jiang et al. (2017a, b)  | Y     |            |                                                 |
| F. tricinctum | Vanderwolf et al. (2013) |       |            |                                                 |
| Fusarium sp.  | Vanderwolf et al. (2013, 2015, 2019), Yoder et al. (2015), Zhang et al. (2017), Nováková et al. (2018), Leplat et al. (2018), Pusz et al. (2018a), Popkova and Mazina (2019) | Y     |            |                                                 |
| Fusicolla     | Vanderwolf et al. (2013) |       |            |                                                 |
| Fu. merismoides | Vanderwolf et al. (2013) | Y     |            |                                                 |
| Gabarnaudia   | Leplat et al. (2018)     |       |            |                                                 |
| Gamsia        | Gamsia aggregata         | Y     |            |                                                 |
|               | G. columbina             | Y     |            |                                                 |
|               | G. simplex               | Y     |            |                                                 |
| Gamszarea     | Ga. kalimantanensis      | Y     |            |                                                 |
|               | Ga. lunata               | Y     |            |                                                 |
|               | Ga. microspora           | Y     |            |                                                 |
| Geomyces      | Vanderwolf et al. (2013) |       |            |                                                 |
| Ge. vinaces   | Vanderwolf et al. (2013) | Y     |            |                                                 |
| Geomyces sp.  | Vanderwolf et al. (2013), Zhang et al. (2014), Man et al. (2015), Leplat et al. (2018), Burow et al. (2019), Pfendler et al. (2019) | Y     |            |                                                 |
| Geosmithia    | Vanderwolf et al. (2013) |       |            |                                                 |
| Geo. putterillii | Vanderwolf et al. (2013) |       |            |                                                 |
| Geo. namyslowski | Vanderwolf et al. (2013) |       |            |                                                 |
| Geotrichum    | Taylor et al. (2013), Vanderwolf et al. (2013) | Y     |            |                                                 |
| Glibella      | Vanderwolf et al. (2013) |       |            |                                                 |
| Gibellulopsis | Connell and Staudigel (2013), Vanderwolf et al. (2013), Zhang (2019) | Y     |            |                                                 |
| Gilmaniella  | Vanderwolf et al. (2013) |       |            |                                                 |
| Glicephalotrichum | Vanderwolf et al. (2013) |       |            |                                                 |
| Glicadlospis  | Zhang (2019)             | Y     |            |                                                 |
| Genus          | Species                        | Chinaa | This studyb | References                        |
|---------------|--------------------------------|--------|-------------|-----------------------------------|
| Gliocladium   | Gliocladium atrum              |        |             | Vanderwolf et al. (2013)          |
|               | Gl. cibitii                    |        |             | Vanderwolf et al. (2013)          |
|               | Gl. roseum                     | Y      |             | Jiang et al. (2017)               |
|               | Gliocladium sp.                |        |             | Vanderwolf et al. (2013)          |
| Gliomastix    | Gliomastix laezulae            | Y      | Y           | Vanderwolf et al. (2013)          |
|               | Gliomastix sp.                 | Y      | Y           | Vanderwolf et al. (2013)          |
|               | Gl. murorum                    | Y      |             | Jiang et al. (2017)               |
| Gnemonopis     | Gnomonopis sp.                 |        |             | Vanderwolf et al. (2013)          |
| Graphiophyllum| Graphiophyllum sp.             |        |             | Vanderwolf et al. (2013)          |
| Graphium      | Graphium penicillioides        | Y      | Y           | Vanderwolf et al. (2013)          |
| Gymnascella   | Gymnascella citrina            |        |             | Vanderwolf et al. (2013)          |
|               | Gy. hyalinospora               |        |             | Vanderwolf et al. (2013)          |
|               | Gymnascella sp.                |        |             | Vanderwolf et al. (2013)          |
| Gymnoascoides | Gymnoascus exasperatus         | Y      | Y           | Zhang et al. (2017)               |
|               | Gym. flavus                    | Y      |             | Vanderwolf et al. (2013)          |
|               | Gym. intermedius               |        |             | Vanderwolf et al. (2013)          |
|               | Gym. reessii                   | Y      | Y           | Vanderwolf et al. (2013, 2019)    |
|               | Gym. udagnueae                 | Y      |             | Mitova et al. (2017)              |
|               | Gymnoascus sp.                 |        |             | Zhang et al. (2017)               |
| Gymnostellatospora | Gymnostellatospora sp.     |        |             | Vanderwolf et al. (2013)          |
| Gyrothrix     | Gyrothrix sp.                  | Y      |             | Zhang et al. (2017)               |
| Halenospora   | Halenospora varia              |        |             | Vanderwolf et al. (2013)          |
| Hanseniaaspera| Hanseniaaspera ostophila       |        |             | Vanderwolf et al. (2013)          |
| Hanseniaspora | Hanseniaspora sp.             |        |             | Vanderwolf et al. (2013)          |
| Hansenfossia  | Hansenfossia sp.              |        |             | Connell and Staudigel (2013)      |
| Harzia        | Harzia acromenioides           |        |             | Vanderwolf et al. (2013)          |
| Helicogermilia| Helicogermilia sp.             |        |             | Vanderwolf et al. (2013)          |
| Helicoma      | Helicoma sp.                   |        |             | Vanderwolf et al. (2013)          |
| Helicomyces   | Helicomyces sp.                |        |             | Vanderwolf et al. (2013)          |
| Helminthosporium | Helminthosporium sp.     |        |             | Vanderwolf et al. (2013)          |
|               | H. trichellum                  |        |             | Vanderwolf et al. (2013)          |
| Heloium       | Helodium sp.                   |        |             | Vanderwolf et al. (2013)          |
| Herpomyces    | Herpomyces arietinus           |        |             | Vanderwolf et al. (2013)          |
| Herpotrichia  | Herpotrichia sp.               |        |             | Vanderwolf et al. (2013)          |
| Hirutella     | Hirutella dipterigena          |        |             | Vanderwolf et al. (2013)          |
|               | H. guignardi                   |        |             | Vanderwolf et al. (2013)          |
|               | Hirutella sp.                  |        |             | Vanderwolf et al. (2013)          |
|               |                               |        |             | Martin-Sanchez et al. (2014)      |
| Hormiactis    | Hormiactis candida            |        |             | Vanderwolf et al. (2013)          |
| Hormiascium   | Hormiascium sp.                |        |             | Vanderwolf et al. (2013)          |
| Hormodendrum  | Hormodendrum sp.               |        |             | Vanderwolf et al. (2013)          |
| Hormographiella| Hormographiella sp.           |        |             | Vanderwolf et al. (2015)          |
| Humaria       | Humaria jeannelii             |        |             | Vanderwolf et al. (2013)          |
| Humicola      | Humicola brunnea              | Y      | Y           | Vanderwolf et al. (2013)          |
|               | Hu. fuscosta                   |        |             | Vanderwolf et al. (2013)          |
|               | Hu. grisea                     |        |             | Vanderwolf et al. (2013)          |
|               | Hu. limonisporum              | Y      |             | Zhang et al. (2017)               |
|               | Hu. nigrescens                 |        |             | Vanderwolf et al. (2013)          |
|               | Humicola sp.                   | Y      | Y           | Vanderwolf et al. (2013)          |
| Hyalopus       | Hyalopus cartipes              |        |             | Vanderwolf et al. (2013)          |
| Hyaloseta     | Hyaloseta sp.                  | Y      | Y           | Vanderwolf et al. (2013)          |
| Hydropisphaera| Hydropisphaera sp.             |        |             | Vanderwolf et al. (2013)          |
| Hyphopichia   | Hyphopichia burtonii           |        |             | Vanderwolf et al. (2013)          |
| Hyphocyma     | Hyphocyma sp.                  |        |             | Vanderwolf et al. (2015, 2019)    |
| Hypocrea      | Hypocrea lactea               | Y      |             | Zhang (2019)                      |
Table 4 (continued)

| Genus         | Species                        | China | This study | References                                                                 |
|---------------|--------------------------------|-------|------------|----------------------------------------------------------------------------|
| *Hy. pachybasioides*  |                               | Y     |            | Zhang et al. (2014), Pusz et al. (2015), Zhang (2019)                      |
| *Hypocrea*     |                               |       |            | Vanderwolf et al. (2013)                                                  |
| *Hypomyces*   | *Hypomyces rosellus*           |       |            | Vanderwolf et al. (2013)                                                  |
|                | *Hypomyces sp.*                |       |            | Vanderwolf et al. (2013)                                                  |
| *Hypoxylon*   | *Hypoxylon fragiforme*         | Y     | Y          | Vanderwolf et al. (2013)                                                  |
|                | *Hy. monticulosum*             |       |            | Vanderwolf et al. (2013)                                                  |
|                | *Hy. perforatum*               | Y     |            | Zhang et al. (2017)                                                       |
|                | *Hypoxylon sp.*                |       |            | Vanderwolf et al. (2013)                                                  |
| *Idriella*    | *Idriella lunata*              | Y     | Y          | Vanderwolf et al. (2013)                                                  |
|                | *Idriella sp.*                 | Y     | Y          | Vanderwolf et al. (2013)                                                  |
| *Ilyonectria* | *Ilyonectria destructans*      | Y     | Y          | Vanderwolf et al. (2013)                                                  |
|                | *L. radicicola*                | Y     |            | Zhang et al. (2017)                                                       |
|                | *Ilyonectria sp.*              |       |            | Zhang et al. (2017)                                                       |
| *Inaequalispora* | *Inaequalispora prestonii*   | Y     |            | Zhang (2019)                                                              |
|                | *Inaequalispora sp.*           | Y     |            | Zhang (2019)                                                              |
| *Infundichalara* | *Infundichalara microchona* |       |            | Vanderwolf et al. (2013)                                                  |
| *Isaria*      | *Isaria amoene-rosea*          |       |            | Vanderwolf et al. (2013)                                                  |
|                | *Is. cataniamulata*            | Y     |            | Zhang (2019)                                                              |
|                | *Is. farinosa*                 | Y     |            | Vanderwolf et al. (2013, 2015), Zhang et al. (2017), Pusz et al. (2018a) |
|                | *Is. fumosorosea*              | Y     | Y          | Vanderwolf et al. (2013, 2015), Jiang et al. (2017a, b), Zhang et al. (2017) |
|                | *Isaria sp.*                   |       |            | Vanderwolf et al. (2013, 2019), Leplat et al. (2018)                      |
| *Isthmolongispora* | *Isthmolongispora quadricellularis* |       |            | Vanderwolf et al. (2013)                                                  |
| *Jackrogersella* | *Jackrogersella sp.*         | Y     | Y          | Vanderwolf et al. (2013)                                                  |
| *Jattaea*     | *Jattaea reniformis*           | Y     | Y          | Vanderwolf et al. (2013)                                                  |
| *Juxtiphoma*  | *Juxtiphoma eupyrena*          | Y     | Y          | Vanderwolf et al. (2013)                                                  |
| *Keissleriella* | *Keissleriella sp.*          |       |            | Vanderwolf et al. (2013)                                                  |
| *Kernia*      | *Kernia columnaris*            | Y     |            | Zhang (2019)                                                              |
|                | *Kernia sp.*                   | Y     |            | Vanderwolf et al. (2013, 2014, 2019)                                      |
| *Kretzschmaria* | *Kretzschmaria deusta*        |       |            | Vanderwolf et al. (2013)                                                  |
| *Lambertella* | *Laboulbenia arawaka*          | Y     |            | Zhang (2019)                                                              |
| *Laboulbenia* | *Laboulbenia arawaka*          |       |            | Vanderwolf et al. (2013)                                                  |
|                | *L. bolivarii*                 |       |            | Vanderwolf et al. (2013)                                                  |
|                | *L. bordoni*                   |       |            | Vanderwolf et al. (2013)                                                  |
|                | *L. cantabrica*                |       |            | Vanderwolf et al. (2013)                                                  |
|                | *L. coiffaitii*                |       |            | Vanderwolf et al. (2013)                                                  |
|                | *L. flagellata*                |       |            | Vanderwolf et al. (2013)                                                  |
|                | *L. leccoreri*                 |       |            | Vanderwolf et al. (2013)                                                  |
|                | *L. nebritae*                  |       |            | Vanderwolf et al. (2013)                                                  |
|                | *L. orghidanii*                |       |            | Vanderwolf et al. (2013)                                                  |
|                | *L. picardii*                  |       |            | Vanderwolf et al. (2013)                                                  |
|                | *L. polyphaga*                 |       |            | Vanderwolf et al. (2013)                                                  |
|                | *L. shordomii*                 |       |            | Vanderwolf et al. (2013)                                                  |
|                | *L. shanorii*                  |       |            | Vanderwolf et al. (2013)                                                  |
|                | *L. stilicicola*               |       |            | Vanderwolf et al. (2013)                                                  |
|                | *L. subterranea*               |       |            | Vanderwolf et al. (2013)                                                  |
|                | *L. vignae*                    |       |            | Vanderwolf et al. (2013)                                                  |
|                | *L. vulgaris*                  |       |            | Vanderwolf et al. (2013)                                                  |
|                | *Laboulbenia sp.*              |       |            | Vanderwolf et al. (2013)                                                  |
| *Lachancea*   | *Lachancea kluyveri*           |       |            | Vanderwolf et al. (2013)                                                  |
|                | *La. thermotolerans*           |       |            | Vanderwolf et al. (2013)                                                  |
| *Lachnea*     | *Lachnea spelaea*              |       |            | Vanderwolf et al. (2013)                                                  |
| *Lachnellula* | *Lachnellula resinaria*        |       |            | Vanderwolf et al. (2013)                                                  |
| *Lachnum*     | *Lachnum brevipilosum*         |       |            | Vanderwolf et al. (2013)                                                  |
| *Latorua*     | *Latorua caligans*             | Y     | Y          | Zhang et al. (2017)                                                       |
| *Leccanicillium* | *Leccanicillium antillanum*   |       |            | Vanderwolf et al. (2013)                                                  |
|                | *Le. aphanoecladii*            | Y     |            | Tavares et al. (2018), Cardoso et al. (2019), Zhang (2019)                |
|                | *Le. dimorphum*                |       |            | Nováková et al. (2018)                                                    |
Table 4 (continued)

| Genus              | Species                        | Chinaa | This studyb | References                                           |
|--------------------|--------------------------------|--------|-------------|-----------------------------------------------------|
| Le. fusisporum     | Y Y Vanderwolf et al. (2013), Zhang et al. (2017) |
| Le. magnisporum    | Y Y Vanderwolf et al. (2013)   |
| Le. muscarium      | Y Vanderwolf et al. (2013)     |
| Le. psiloiota      | Y Vanderwolf et al. (2013), Nováková et al. (2018) |
| Lecaniium sp.      | Y Vanderwolf et al. (2013), Man et al. (2015), Leplat et al. (2018) |
| Lectera            | Lectera colletotrichoides      | Connell and Staudigel (2013) |
| Lecithophora       | Lecithophora sp.               | Vanderwolf et al. (2019)    |
| Lepidosphaeria     | Lepidosphaeria sp.             | Vanderwolf et al. (2013)   |
| Leptobacillium     | Leptobacillium leptobactrum    | Vanderwolf et al. (2013), Martin-Sanchez et al. (2014), Zhang et al. (2014), Leplat et al. (2018), Burow et al. (2019) |
| Leptodontidium     | Leptodontidium trabilinum      | Vanderwolf et al. (2013)   |
| Leptosphaeria      | Leptosphaeria fuscella         | Y Vanderwolf et al. (2013) |
| L. maculans        | Y Vanderwolf et al. (2013)     |
| L. psalliota       | Y Vanderwolf et al. (2013), Jiang et al. (2017a, b), Zhang et al. (2017) |
| Leptosphaerulina   | Leptosphaerulina chartarum     | Y Jiang et al. (2017a, b)  |
| Leptosphaerulina   | Leptosphaerulina sp.           | Vanderwolf et al. (2013)   |
| Letendreae         | Letendreae helminthica         | Y Zhang (2019)             |
| Leuconospora       | Leuconospora capsici           | Y Vanderwolf et al. (2013, 2015, 2019), Malloch et al. (2016) |
| Leu. pulcherrima   | Leu. pulcherrima               | Vanderwolf et al. (2013)   |
| Leuconeurospora    | Leuconeurospora               | Y Vanderwolf et al. (2013) |
| Leucocentum        | Leucocentum emdenii            | Y Vanderwolf et al. (2013) |
| Linderina          | Linderina pennispora           | Vanderwolf et al. (2013)   |
| Lophiotrema        | Lophiotrema sp.               | Y Vanderwolf et al. (2013) |
| Malbranchea        | Malbranchea aurantiaca         | Vanderwolf et al. (2013)   |
| Malbranchea sp.    | Y Vanderwolf et al. (2013)     |
| Mammaria           | Mammaria echinobryoides        | Vanderwolf et al. (2013, 2019) |
| Mammaria sp.       | Y Vanderwolf et al. (2015)     |
| Mariannaea         | Mariannaea camptospora         | Vanderwolf et al. (2013)   |
| Ma. elegans        | Y Vanderwolf et al. (2013)     |
| Ma. nipponica      | Y Vanderwolf et al. (2013)     |
| Massarina          | Massarina igniaria             | Y Vanderwolf et al. (2013), Zhang et al. (2017) |
| Massarina sp.      | Y Y Vanderwolf et al. (2013), Zhang et al. (2017) |
| Melanconium        | Melanconium sp.               | Y Vanderwolf et al. (2013) |
| Melanocarpus       | Melanocarpus albomyces         | Vanderwolf et al. (2013)   |
| Melanospora        | Melanospora sp.                | Vanderwolf et al. (2013)   |
| Mel. zamiae        | Mel. zamiae                    | Vanderwolf et al. (2013)   |
| Memnoniella        | Memnoniella sp.               | Y Vanderwolf et al. (2013) |
| Metispora          | Metispora coealiina            | Vanderwolf et al. (2013)   |
| Metacordycopsis    | Metacordycopsis chlamydosporia | Y Vanderwolf et al. (2013), Man et al. (2015), Nováková et al. (2018) |
| Metapochonia       | Metapochonia bulbillosa        | Y Y Zhang et al. (2017)    |
| Met. rubescens     | Y Zhang et al. (2017)          |
| Met. subhispuria   | Y Vanderwolf et al. (2013), Martin-Sanchez et al. (2014) |
| Met. variabilis    | Y Y Zhang et al. (2017)        |
| Metapochonia sp.   | Metapochonia sp.               | Mitova et al. (2017)       |
| Metarhizium        | Metarhizium anisopliae         | Y Y Vanderwolf et al. (2013), Zhang et al. (2017), Nováková et al. (2018) |
| Met. marquandii    | Y Y Vanderwolf et al. (2013), Man et al. (2015), Jiang et al. (2017a, b), Nováková et al. (2018) |
| Met. rileyi        | Y Vanderwolf et al. (2013), Zhang (2019) |
| Met. robertsi     | Y Zhang (2019)                 |
| Metarhizium sp.    | Y Y Vanderwolf et al. (2013), Jiang et al. (2017a, b), Leplat et al. (2018), Bercea et al. (2018) |
| Metchnikowia       | Metchnikowia pulcherrima       | Vanderwolf et al. (2013)   |
| Meyerozyma         | Meyerozyma caribbica           | Jacobs et al. (2017)       |
| Microascus         | Microascus anfractus           | Y Y Zhang et al. (2017)    |
| M. boulangeri      | Yang et al. (2017)             |
| M. borealis        | Vanderwolf et al. (2013)       |
| Genus               | Species                     | Chinaa | This studyb | References                                                                 |
|---------------------|-----------------------------|--------|-------------|-----------------------------------------------------------------------------|
| Mi. brevicaulis     | Y                            | Y      | Y           | Vanderwolf et al. (2013), Yoder et al. (2015), Pusz et al. (2018a)          |
| Mi. chartarum       | Y                            | Y      | Y           | Vanderwolf et al. (2013), Zhang et al. (2017)                              |
| Mi. cirrosus        | Y                            | Y      | Y           | Vanderwolf et al. (2013)                                                   |
| Mi. collaris        | Y                            | Y      | Y           | Vanderwolf et al. (2013)                                                   |
| Mi. croci           | Y                            | Y      | Y           | Vanderwolf et al. (2013)                                                   |
| Mi. globulosus      | Y                            | Y      | Y           | Zhang et al. (2017)                                                        |
| Mi. levis           | Y                            | Y      | Y           | Vanderwolf et al. (2013)                                                   |
| Mi. longirostris    | Y                            | Y      | Y           | Vanderwolf et al. (2013)                                                   |
| Mi. murinus         | Y                            | Y      | Y           | Yoder et al. (2015)                                                        |
| Mi. paisii          | Y                            |        | Y           | Vanderwolf et al. (2013)                                                   |
| Mi. sparsimycelialis| Y                            | Y      | Y           | Vanderwolf et al. (2013)                                                   |
| Mi. superficialis   | Y                            | Y      | Y           | Vanderwolf et al. (2013)                                                   |
| Mi. trigonus        | Y                            | Y      | Y           | Vanderwolf et al. (2013)                                                   |
| Microascus sp.      | Vanderwolf et al. (2013, 2019)|       |             | Vanderwolf et al. (2013)                                                   |
| Microdiploidia      | Microdiploidia miyakei      | Y      | Y           | Zhang (2019)                                                               |
| Microdochium        | Microdochium bolleyi         | Y      | Y           | Vanderwolf et al. (2013)                                                   |
| Microdochium        | Y                            | Y      | Y           | Vanderwolf et al. (2013)                                                   |
| Mycosphaeropsis     | Mycosphaeropsis arundinis    | Y      | Y           | Zhang et al. (2017)                                                        |
| MycolCentrula       | MycolCentrula granulatum     |        | Y           | Vanderwolf et al. (2013)                                                   |
| Mycosporum          | Mycosporum canis             |        | Y           | Vanderwolf et al. (2013)                                                   |
| Mycosporum          | Y                            | Y      | Y           | Vanderwolf et al. (2013)                                                   |
| Monascus            | Monascus ruber               |        | Y           | Vanderwolf et al. (2013)                                                   |
| Mo. purpureus       | Y                            |        | Y           | Man et al. (2015)                                                          |
| Monocillium         | Monocillium grunatum         |        | Y           | Vanderwolf et al. (2013)                                                   |
| Monocillium         | Y                            | Y      | Y           | Vanderwolf et al. (2013)                                                   |
| Monographella       | Monographella sp.            |        | Y           | Zhang (2019)                                                               |
| Monosporium         | Monosporium sp.              |        | Y           | Vanderwolf et al. (2013)                                                   |
| Montagnula          | Montagnula sp.               | Y      | Y           | Vanderwolf et al. (2013)                                                   |
| Myceliophthora      | Myceliophthora sp.           |        | Y           | Vanderwolf et al. (2013, 2015), Nováková et al. (2018)                     |
| Mycoarthris         | Mycoarthris sp.              |        | Y           | Vanderwolf et al. (2013)                                                   |
| Mycogone            | Mycogone nigra               |        | Y           | Vanderwolf et al. (2013)                                                   |
| Mycogone            | Y                            | Y      | Y           | Vanderwolf et al. (2013)                                                   |
| Mycosphaerella      | Mycosphaerella polygoni-   |        |             | Zhang (2019)                                                               |
| Mycorhizaeae        | Mycosphaerella sp.           |        |             | Zhang (2019)                                                               |
| Myriodontium        | Myriodontium keratinophilum  | Y      | Y           | Man et al. (2015), Zhang et al. (2017), Nováková et al. (2018)              |
| Myriodontium        | Myriodontium sp.             | Y      | Y           | Leplat et al. (2018)                                                       |
| Myrmecridium        | Myrmecridium salutarii       | Y      | Y           | Vanderwolf et al. (2013)                                                   |
| Myrothecium         | Myrothecium sp.              | Y      | Y           | Vanderwolf et al. (2013)                                                   |
| Myxotrichum         | Myxotrichum chartarum        |        | Y           | Vanderwolf et al. (2013)                                                   |
| Myxotrichum         | Y                            | Y      | Y           | Vanderwolf et al. (2013)                                                   |
| Myxotrichum         | Y                            | Y      | Y           | Vanderwolf et al. (2013)                                                   |
| Myxotrichum         | Y                            | Y      | Y           | Vanderwolf et al. (2013)                                                   |
| Nannizzia           | Nannizzia fulva              |        |             | Vanderwolf et al. (2013)                                                   |
| Nectria             | Nectria ellisi              |        |             | Vanderwolf et al. (2013)                                                   |
| Nectria             | N. ramulareae               |        |             | Zhang et al. (2014)                                                        |
| Nectria             | Nectria sp.                 | Y      | Y           | Vanderwolf et al. (2013)                                                   |
| Nectria             | N. pseudotrachia             | Y      | Y           | Jiang et al. (2017a, b)                                                     |
| Nemanis             | Nemanis bipapillata          | Y      | Y           | Zhang et al. (2017)                                                        |
| Ne. diffusa         | Y                            | Y      | Y           | Zhang et al. (2017)                                                        |
| Ne. serpens         | Y                            |        | Y           | Zhang (2019)                                                               |
| Ne. sparsimycelialis| Y                            | Y      | Y           | Vanderwolf et al. (2013)                                                   |
| Neosociochyta       | Neosociochyta paspali        | Y      | Y           | Zhang (2019)                                                               |
| Neosociochyta       | Neosociochyta sp.            |        | Y           | Jiang et al. (2017a, b)                                                     |
Table 4 (continued)

| Genus                  | Species                        | China<sup>a</sup> | This study<sup>b</sup> | References                                      |
|------------------------|--------------------------------|-------------------|------------------------|------------------------------------------------|
| Neoconiothyrium        | Neoconiothyrium sp.            | Y                 | Y                      | Zhang et al. (2014)                             |
| Neoconiospora          | Neoconiospora ipomoeae         | Y                 |                         |                                                 |
| Neobulgaria            | Neobulgaria sp.                |                   |                        | Zhang et al. (2014)                             |
| Neogymnomyces          | Neogymnomyces sp.              | Y                 | Y                      | Vanderwolf et al. (2013)                        |
| Neogymnomyces          | Neo. virgineus                 |                   |                        | Vanderwolf et al. (2013)                        |
| Neomassarina           | Neomassarina thailandica       | Y                 | Y                      | Out et al. (2016)                               |
| Neomectria             | Neomectria obtusispora         |                   |                        | Vanderwolf et al. (2013)                        |
| Neophragonella         | Neophragonella inflorescentiae | Y                 | Y                      | Vanderwolf et al. (2013)                        |
| Neurospora             | Neurospora crassa              |                   |                        | Vanderwolf et al. (2013)                        |
| Neurospora             | Neu. intermedia                | Y                 |                        | Zhang et al. (2017)                             |
| Neurospora             | Neu. tetrasperma               |                   |                        | Pusz et al. (2015)                              |
| Neurospora             | Neurospora sp.                 |                   |                        | Vanderwolf et al. (2013)                        |
| Nigrograna             | Nigrograna cangshanensis       | Y                 |                         | Zhang (2019)                                    |
| Nigrograna             | Nigrograna mackinonii          | Y                 |                         | Vanderwolf et al. (2013)                        |
| Nigrograna             | Nigrograna sp.                 | Y                 |                         | Vanderwolf et al. (2013)                        |
| Nigrospora             | Nigrospora globosa             | Y                 | Y                      | Vanderwolf et al. (2013)                        |
| Nigrospora             | Ni. oryzae                     | Y                 | Y                      | Vanderwolf et al. (2013)                        |
| Nigrospora             | Ni. sphaericcia                |                   |                        | Vanderwolf et al. (2013)                        |
| Nigrospora             | Nigrospora sp.                 |                   |                        | VanderWolf et al. (2013), Bercea et al. (2018)  |
| Nomuraea               | Nomuraea rileyi                |                   |                        | VanderWolf et al. (2013)                        |
| Ochroconis             | Ochroconis sp.                 | Y                 | Y                      | VanderWolf et al. (2013)                        |
| Ochroconis             | O. tannicus                    |                   |                        | VanderWolf et al. (2013)                        |
| Oedoccephalum          | Oedoccephalum sp.              |                   |                        | VanderWolf et al. (2013)                        |
| Oidiocordyceps         | Oidiocordyceps entomorrhiza    |                   |                        | VanderWolf et al. (2013)                        |
| Oidiocordyceps         | Op. sinensis                   | Y                 |                         | VanderWolf et al. (2013)                        |
| Oidiocordyceps         | Op. solubilis                  | Y                 | Y                      | VanderWolf et al. (2013)                        |
| Ophiocordyceps         | Ophiocordyceps ischnostyla     | Y                 |                         | Zhang (2019)                                    |
| Ophiostoma             | Ophiostoma polyoporica         |                   |                        | VanderWolf et al. (2013)                        |
| Ophiostoma             | Oph. stenoceras                |                   |                        | VanderWolf et al. (2013)                        |
| Ovadendron             | Ovadendron sulphureocharaceum  |                   |                        | VanderWolf et al. (2013)                        |
| Paecilomyces           | Paecilomyces divaricatus       |                   |                        | VanderWolf et al. (2013)                        |
| Paecilomyces           | P. fumosoroseus                |                   |                        | Pusz et al. (2015), Kokurewicz et al. (2016)    |
| Paecilomyces           | P. hepiali                     | Y                 | Y                      | VanderWolf et al. (2013)                        |
| Paecilomyces           | P. lilacinus                   |                   |                        | VanderWolf et al. (2013)                        |
| Paecilomyces           | P. tenuis                      | Y                 | Y                      | Taylor et al. (2013), VanderWolf et al. (2013), Kokurewicz et al. (2016) |
| Paecilomyces           | P. varioti                    |                   |                        | VanderWolf et al. (2013), Man et al. (2015), Popović et al. (2015), Yoder et al. (2015), Zhang et al. (2017), Leplat et al. (2018) |
| Paecilomyces           | Paecilomyces sp.               | Y                 |                         | VanderWolf et al. (2013)                        |
| Pallidocercospora      | Pallidocercospora heimioides   | Y                 | Y                      | VanderWolf et al. (2013)                        |
| Papulaspora            | Papulaspora rubida             |                   |                        | VanderWolf et al. (2013)                        |
| Papulaspora            | Papulaspora sp.                |                   |                        | VanderWolf et al. (2013)                        |
| Parabotryospora        | Parabotryospora oligotrophica  | Y                 |                         | Jiang et al. (2017a, b)                         |
| Paracamarosporium      | Paracamarosporium hawaiense   | Y                 | Y                      | VanderWolf et al. (2013)                        |
Table 4 (continued)

| Genus            | Species                      | Chinaa | This studyb | References                                      |
|------------------|------------------------------|--------|-------------|------------------------------------------------|
| Paracoccidioides | Paracoccidioides brasiensis  |        |             | Vanderwolf et al. (2013)                        |
| Paraconiothyrium | Paraconiothyrum brasiense    | Y      | Y           |                                                 |
|                  | Ps. estuarium                | Y      | Y           |                                                 |
| Paraconiothyrum  | sp.                          | Y      |             | Zhang (2019)                                    |
| Paracremonium     | Paracremonium apiculatum     | Y      | Y           |                                                 |
|                   | Par. ellipsoideum            | Y      | Y           |                                                 |
|                   | Par. variiforme              | Y      |             | Zhang et al. (2017)                             |
| Paramicrothyrum   | Paramicrothyrum sp.          | Y      | Y           |                                                 |
| Paramyrothecium   | Paramyrothecium roridum      | Y      | Y           | Vanderwolf et al. (2013)                        |
| Paranomuraea      | Paranomuraea carneae         |        |             | Vanderwolf et al. (2013)                        |
| Paraphaeosphaeria | Paraphaeosphaeria hydei      | Y      | Y           |                                                 |
|                  | Para. michotii               | Y      | Y           |                                                 |
|                  | Para. neglecta               | Y      |             | Zhang (2019)                                    |
|                  | Para. sporulosa              | Y      | Y           | Vanderwolf et al. (2013), Man et al. (2015), Pusz et al. (2015) |
| Paraphaeosphaeria | sp.                         | Y      |             | Zhang (2019)                                    |
| Paraphoma         | Phytophoma chrysanthemicola  | Y      | Y           | Vanderwolf et al. (2013)                        |
|                  | Paraph. fimeti               |        |             | Ogórek et al. (2016b, c)                        |
| Paraphyton        | Paraphyton Cookei            |        |             | Ogórek et al. (2019)                            |
| Parastagonospora  | Parastagonospora nodorum     | Y      | Y           | Vanderwolf et al. (2013), Nováková et al. (2018) |
| Parengyodontium   | Parengyodontium album        | Y      | Y           | Vanderwolf et al. (2013), Nováková et al. (2018) |
|                  | Parengyodontium sp.          | Y      |             | Zhang (2019)                                    |
| Pectinotrichum    | Pectinotrichium chinesis     | Y      |             | Zhang et al. (2017)                             |
| Penicillium       | Penicillium dipartitectorus  | Y      | Y           |                                                 |
|                  | Penicillium ademetzioides    | Y      | Y           | Vanderwolf et al. (2013)                        |
| Pe. admetzii      |                               |        |             |                                                 |
| Pe. aeneum        |                               | Y      | Y           | Vanderwolf et al. (2013)                        |
| Pe. albidum       |                               | Y      |             |                                                 |
| Pe. astrolabium   |                               | Y      |             |                                                 |
| Pe. atramentosum  |                               | Y      |             | Vanderwolf et al. (2013), Jacobs et al. (2017), Nováková et al. (2018) |
| Pe. atrosanguineum|                               | Y      |             | Nováková et al. (2018)                         |
| Pe. aurantiogriseum|                             | Y      |             | Vanderwolf et al. (2013), Mitova et al. (2017), Nováková et al. (2018), Ogórek (2018b), Popkova and Mazina (2019) |
| Pe. bialowiecense |                               |        |             | Visagie et al. (2019)                           |
| Pe. bilaiense     |                               | Y      |             |                                                 |
| Pe. biourgeianum  |                               | Y      |             | Ogórek et al. (2017), Pusz et al. (2017), Zhang (2019) |
| Pe. brasiliense   |                               |        |             | Nováková et al. (2018), Zhang (2019)            |
| Pe. brevicipactum |                               | Y      | Y           | Taylor et al. (2013), Vanderwolf et al. (2013), Zhang et al. (2014), Pusz et al. (2015), Oút et al. (2016), Jiang et al. (2017a, b), Ogórek et al. (2017, 2018), Belyagoubi et al. (2018), Nováková et al. (2018), Ogórek (2018a, b) |
| Pe. brevispitatum |                               |        |             | Visagie et al. (2019)                           |
| Pe. buchwaldii    |                               | Y      |             | Zhang et al. (2017)                             |
| Pe. bussumense    |                               | Y      |             |                                                 |
| Pe. cairensense   |                               | Y      |             | Zhang (2019)                                    |
| Pe. camemberti    |                               | Y      |             | Vanderwolf et al. (2013), Zhang et al. (2017)   |
| Pe. canariense    |                               | Y      |             |                                                 |
| Pe. canescens     |                               | Y      |             | Vanderwolf et al. (2013), Nováková et al. (2018) |
| Pe. capsulatum    |                               |        |             | Vanderwolf et al. (2013)                        |
| Pe. cavernicola   |                               |        |             | Vanderwolf et al. (2013)                        |
| Pe. chalabuade    |                               | Y      |             | Vanderwolf et al. (2013)                        |
| Pe. chermesinum   |                               | Y      |             |                                                 |
| Pe. chrysogenum   |                               | Y      |             | Ogórek et al. (2013, 2014a, b, c, 2016b, c, d, 2017), Taylor et al. (2013), Vanderwolf et al. (2013, 2019), Pusz et al. (2014, 2015, 2018a, b), Jacobs et al. (2017), Jiang et al. (2017a, b), Zhang et al. (2017), Nováková et al. (2018), Pusz et al. (2018a), Dylag et al. (2019), Popkova and Mazina (2019), Visagie et al. (2019) |
| Pe. citreonigrum  |                               | Y      |             | Vanderwolf et al. (2013), Pusz et al. (2018a)   |
| Pe. citrinum      |                               | Y      |             | Taylor et al. (2013), Vanderwolf et al. (2013), Ogórek et al. (2014a, b, c), Pusz et al. (2014, 2018a, b) |
| Genus     | Species         | China | This study | References                                                                 |
|-----------|-----------------|-------|------------|-----------------------------------------------------------------------------|
| Pe. commune | Y Y             | Vanderwolf et al. (2013), Pusz et al. (2014, 2017), Oút et al. (2016), Jacobs et al. (2017), Mitova et al. (2017), Ogórek et al. (2017, 2018) |
| Pe. concentricum | Y Y          | Vanderwolf et al. (2013), Mitova et al. (2017), Visagie et al. (2019) |
| Pe. consobrinum |               | Visagie et al. (2019) |
| Pe. contaminatum | Y             | Zhang (2019) |
| Pe. coprobiacum | Y Y           | Mitova et al. (2017), Zhang et al. (2017) |
| Pe. coprophilum | Y Y           | Visagie et al. (2019) |
| Pe. corylophilum |               | Visagie et al. (2019) |
| Pe. daleae | Y Y             | Vanderwolf et al. (2013) |
| Pe. decumbens |               | Taylor et al. (2013), Vanderwolf et al. (2013) |
| Pe. dierckxii | Y              | Vanderwolf et al. (2013), Man et al. (2015), Zhang et al. (2017) |
| Pe. digitatum | Y Y             | Vanderwolf et al. (2013) |
| Pe. dipodomyicola | Y             | Zhang (2019) |
| Pe. dipodomys | Y Y             | Visagie et al. (2019) |
| Pe. echinulatum | Y Y           | Vanderwolf et al. (2013), Oút et al. (2016) |
| Pe. expansum | Y Y             | Ogórek et al. (2013, 2014a, b, c), Taylor et al. (2013), Vanderwolf et al. (2013, 2015), Pusz et al. (2014), Zhang et al. (2017), Nováková et al. (2018), Pusz et al. (2018a), Dyląg et al. (2019), Visagie et al. (2019) |
| Pe. flavigenum | Y Y             | Nováková et al. (2018), Tavares et al. (2018) |
| Pe. funiculosum | Y Y             | Vanderwolf et al. (2013) |
| Pe. glabrum | Y Y             | Taylor et al. (2013), Vanderwolf et al. (2013), Zhang et al. (2014), Pusz et al. (2015), Ogórek et al. (2017), Zhang et al. (2017), Visagie et al. (2019) |
| Pe. gladioli | Y Y             | Vanderwolf et al. (2013) |
| Pe. glandicola | Y Y             | Vanderwolf et al. (2013), Ogórek et al. (2016a), Nováková et al. (2018) |
| Pe. glaucoalbidum |               | Vanderwolf et al. (2013, 2015, 2019), Pusz et al. (2017), Nováková et al. (2018), Visagie et al. (2019) |
| Pe. granulatum |               | Ogórek et al. (2016b, c) |
| Pe. griseofulvum | Y              | Taylor et al. (2013), Vanderwolf et al. (2013, 2019), Pusz et al. (2014), Zhang et al. (2014), Ogórek et al. (2016b, c, d), Jacobs et al. (2017), Zhang et al. (2017), Nováková et al. (2018), Pusz et al. (2018a) |
| Pe. griseolum |               | Vanderwolf et al. (2013) |
| Pe. guanacastense | Y Y          | Vanderwolf et al. (2013) |
| Pe. halotolerans | Y Y            | Vanderwolf et al. (2013) |
| Pe. herquei | Y Y             | Vanderwolf et al. (2013) |
| Pe. hirsutum |               | Vanderwolf et al. (2013) |
| Pe. hordei |               | Vanderwolf et al. (2013) |
| Pe. implicatum |               | Vanderwolf et al. (2013), Pusz et al. (2018a) |
| Pe. inflatum | Y               | Zhang et al. (2017) |
| Pe. italicum |               | Vanderwolf et al. (2013) |
| Pe. jacksonii | Y Y             | Vanderwolf et al. (2013) |
| Pe. janczewskii |               | Vanderwolf et al. (2013) |
| Pe. javanicum |               | Vanderwolf et al. (2013) |
| Pe. jenseni  |               | Vanderwolf et al. (2013) |
| Pe. jagerheimii |              | Vanderwolf et al. (2013) |
| Pe. jonassonii | Y Y             | Vanderwolf et al. (2013) |
| Pe. jovanus |               | Vanderwolf et al. (2013) |
| Pe. jividum | Y Y             | Vanderwolf et al. (2013) |
| Pe. ludwigii | Y Y             | Vanderwolf et al. (2013) |
| Pe. madritii | Y Y             | Vanderwolf et al. (2013) |
| Pe. magneliptisporum | Y Y       | Mitova et al. (2017), Zhang et al. (2017) |
| Pe. malachitriacum | Y Y           | Mitova et al. (2017), Zhang et al. (2017) |
| Pe. mollsohxii | Y Y             | Man et al. (2015), Pusz et al. (2018a) |
| Pe. melagrinum | Y Y             | Vanderwolf et al. (2013) |
| Pe. melanocomodium |            | Vanderwolf et al. (2013) |
| Pe. melinii |               | Vanderwolf et al. (2013) |
| Pe. mexicanum | Y Y             | Vanderwolf et al. (2013) |
| Pe. miczynskii |               | Vanderwolf et al. (2013) |
| Pe. niglovense | Y Y             | Vanderwolf et al. (2013) |
Table 4 (continued)

| Genus           | Species            | China<sup>a</sup> | This study<sup>b</sup> | References                                                                                     |
|-----------------|--------------------|-------------------|------------------------|------------------------------------------------------------------------------------------------|
| Pe. notatum     |                    | Y                 |                        | Jiang et al. (2017a, b), Pusz et al. (2018a)                                                   |
| Pe. ochrochloron|                    | Y                 |                        | Vanderwolf et al. (2013)                                                                      |
| Pe. olsonii     |                    | Y                 |                        | Connell and Staudigel (2013), Taylor et al. (2013), Vanderwolf et al. (2013),                   |
|                 |                    |                   |                        | Busquets et al. (2014), Popovic et al. (2015), Yoder et al. (2015), Kokurewicz et al. (2016),  |
|                 |                    |                   |                        | Jiang et al. (2017a, b), Zhang et al. (2017), Belyagoubi et al. (2018), Novaková et al. (2018), |
|                 |                    |                   |                        | Leplat et al. (2018), Pusz et al. (2018a)                                                     |
| Pe. oxalicum    |                    | Y                 |                        | Vanderwolf et al. (2013)                                                                      |
| Pe. palitans    |                    |                   |                        | Vanderwolf et al. (2013)                                                                      |
| Pe. pannosumium |                    | Y                 |                        | Mitova et al. (2017), Zhang et al. (2017)                                                     |
| Pe. parvulum    |                    | Y                 |                        | Zhang et al. (2017)                                                                           |
| Pe. paxilli      |                    | Y                 |                        | Vanderwolf et al. (2013), Jiang et al. (2017a, b), Pusz et al. (2018a)                         |
| Pe. phoeniceum  |                    |                   |                        | Novaková et al. (2018)                                                                       |
| Pe. piceum      |                    |                   |                        | Vanderwolf et al. (2013)                                                                      |
| Pe. pimeliteiense|                    | Y                 |                        | Vanderwolf et al. (2013), Jacobs et al. (2017), Ogorek et al. (2017), Novaková et al. (2018)  |
| Pe. polonicum   |                    | Y                 |                        | Vanderwolf et al. (2013), Jacobs et al. (2017), Ogorek et al. (2017), Novaková et al. (2018)  |
| Pe. polystictum |                    |                   |                        | Vanderwolf et al. (2013)                                                                      |
| Pe. purpurascens|                    |                   |                        | Vanderwolf et al. (2013), Pusz et al. (2018a)                                                 |
| Pe. purpurogenum|                    |                   |                        | Taylor et al. (2013), Vanderwolf et al. (2013), Novaková et al. (2018)                         |
| Pe. raperi      |                    | Y                 |                        | Vanderwolf et al. (2013)                                                                      |
| Pe. raphiae     |                    | Y                 |                        | Vanderwolf et al. (2013)                                                                      |
| Pe. restrictum  |                    | Y                 |                        | Vanderwolf et al. (2013)                                                                      |
| Pe. roxsamsonii |                    | Y                 |                        | Vanderwolf et al. (2013)                                                                      |
| Pe. roqueforti  |                    |                   |                        | Vanderwolf et al. (2013)                                                                      |
| Pe. roseopurpureum|                  | Y                 |                        | Vanderwolf et al. (2013), Ogorek et al. (2016b, d)                                             |
| Pe. rubens      |                    | Y                 |                        | Visagie et al. (2019)                                                                         |
| Pe. rubrum      |                    | Y                 |                        | Jiang et al. (2017a, b)                                                                       |
| Pe. sacculum    |                    |                   |                        | Vanderwolf et al. (2013)                                                                      |
| Pe. sanguifluum |                    | Y                 |                        | Vanderwolf et al. (2013)                                                                      |
| Pe. scabrosum   |                    | Y                 |                        | Vanderwolf et al. (2013)                                                                      |
| Pe. sclerotiorum|                    | Y                 |                        | Vanderwolf et al. (2013)                                                                      |
| Pe. simplicissimum|                  | Y                 |                        | Taylor et al. (2013), Vanderwolf et al. (2013), Mitova et al. (2017), Ogorek et al. (2017),    |
|                 |                    |                   |                        | Zhang et al. (2017), Novaková et al. (2018), Popkova and Mazina (2019)                         |
| Pe. sizovae     |                    | Y                 |                        | Vanderwolf et al. (2013), Jacobs et al. (2017), Mitova et al. (2017), Ogorek et al. (2017, 2018)|
| Pe. solitum     |                    | Y                 |                        | Visagie et al. (2019)                                                                         |
| Pe. spathulatum |                    |                   |                        | Visagie et al. (2019)                                                                         |
| Pe. speluncae   |                    |                   |                        | Visagie et al. (2019)                                                                         |
| Pe. spinulosum  |                    | Y                 |                        | Vanderwolf et al. (2013), Pusz et al. (2015, 2017), Ogorek et al. (2017), Zhang (2019)        |
| Pe. sumatraense |                    | Y                 |                        | Vanderwolf et al. (2013), Jacobs et al. (2017), Mitova et al. (2017), Ogorek et al. (2017, 2018)|
| Pe. twecickii   |                    | Y                 |                        | Ogorek (2018a, b)                                                                              |
| Pe. tardochryssogenum|              | Y                 |                        | Visagie et al. (2019)                                                                         |
| Pe. thomii      |                    | Y                 |                        | Zhang et al. (2014), Pusz et al. (2017)                                                       |
| Pe. tulairens   |                    |                   |                        | Taylor et al. (2013), Vanderwolf et al. (2013, 2019), Ogorek et al. (2017), Zhang et al. (2017)|
| Pe. ubiquetum   |                    | Y                 |                        | Visagie et al. (2019)                                                                         |
| Pe. virgatum    |                    | Y                 |                        | Zhang et al. (2014)                                                                            |
| Pe. viticola    |                    | Y                 |                        | Vanderwolf et al. (2013), Ogorek et al. (2014b), Pusz et al. (2014), Pusz et al. (2018a)       |
| Pe. vulpinum    |                    | Y                 |                        | Vanderwolf et al. (2013), Zhang et al. (2014), Zhang (2019)                                   |
| Pe. waksmanii   |                    |                   |                        | Vanderwolf et al. (2013), Ogorek et al. (2014b), Pusz et al. (2014), Pusz et al. (2018a)       |
| Pe. westlingii  |                    |                   |                        | Visagie et al. (2019)                                                                         |
| Penicillium sp. |                    | Y                 |                        | Vanderwolf et al. (2013, 2015, 2019), Martin-Sanchez et al. (2014), Zhang et al. (2014),      |
|                 |                    |                   |                        | Man et al. (2015), Popovic et al. (2015), Yoder et al. (2015), Kokurewicz et al. (2016), Jacobs |
|                 |                    |                   |                        | et al. (2017), Jiang et al. (2017a, b), Mitova et al. (2017), Zhang et al. (2017), Belyagoubi  |
|                 |                    |                   |                        | et al. (2018), Novaková et al. (2018), Pusz et al. (2018a), Leplat et al. (2018), Burew et al.  |
|                 |                    |                   |                        | (2019), Pfendler et al. (2019), Popkova and Mazina (2019)                                      |
| Genus       | Species                          | China | This study | References                      |
|-------------|----------------------------------|-------|------------|---------------------------------|
| Periconia   | Periconia macrospinosa           | Y     | Y          | Vanderwolf et al. (2013), Brad et al. (2018) |
| Periconia sp. |                                  | Y     | Y          | Vanderwolf et al. (2013), Zhang et al. (2017), Novákůvá et al. (2018) |
| Peroneutypa | Peroneutypa scoparia             | Y     | Y          | Zhang et al. (2017)             |
| Peroneutypa sp. |                                  | Y     | Y          |                                  |
| Pestalotia  | Pestalotia cocculi              | Y     | Y          | Vanderwolf et al. (2013)        |
| Pestalotiopsis | Pestalotiopsis cocculi         | Y     |            | Zhang (2019)                    |
|             | Pes. guepinii                    | Y     |            | Zhang et al. (2017)             |
|             | Pes. hainanensis                 | Y     |            | Zhang (2019)                    |
|             | Pes. maculiformans               | Y     |            | Vanderwolf et al. (2013)        |
|             | Pes. mangiferae                  | Y     | Y          |                                  |
|             | Pes. microspora                  | Y     | Y          | Zhang et al. (2017)             |
|             | Pes. palmarum                    | Y     |            | Vanderwolf et al. (2013)        |
|             | Pes. uvicola                     | Y     |            | Zhang (2019)                    |
|             | Pes. viensis                     | Y     | Y          |                                  |
|             | Pestalotiopsis sp.              | Y     |            | Vanderwolf et al. (2013)        |
| Petriella   | Petriella setifera               | Y     |            | Vanderwolf et al. (2013)        |
| Petriella sp. |                                  | Y     | Y          | Vanderwolf et al. (2013)        |
| Peziza      | Peziza micropus                  | Y     |            | Vanderwolf et al. (2013)        |
|             | Peziza sp.                       | Y     |            | Vanderwolf et al. (2013)        |
| Phaeoacremonium | Phaeoacremonium argentinense    | Y     |            | Zhang et al. (2017)             |
|             | Ph. iraniam                      | Y     |            | Zhang (2019)                    |
|             | Ph. minimum                      | Y     |            | Zhang (2019)                    |
|             | Ph. novae-zealandiae             | Y     | Y          |                                  |
|             | Ph. occidentale                  | Y     |            | Zhang (2019)                    |
|             | Ph. rubiginum                    | Y     |            | Jiang et al. (2017a, b)         |
|             | Ph. viticola                     | Y     |            | Zhang (2019)                    |
|             | Phaeoacremonium sp.             | Y     |            | Jiang et al. (2017a, b), Vanderwolf et al. (2019) |
| Phaeococcomyces | Phaeococcomyces nigricans     | Y     |            | Connell and Staudigel (2013)    |
| Phaeocystostroma | Phaeocystostroma ambiguum  | Y     | Y          |                                  |
|             | Phaeocystostroma sp.            | Y     |            |                                  |
| Phaeoisaria | Phaeoisaria clematitidis        | Y     |            | Zhang (2019)                    |
| Phaeosphaeria | Phaeosphaeria annulata         | Y     |            | Vanderwolf et al. (2013)        |
|             | Phaeosphaeria fassipora          | Y     |            | Vanderwolf et al. (2013)        |
|             | Phaeosphaeria microsporica       | Y     |            | Vanderwolf et al. (2013)        |
|             | Phaeosphaeria nodorum           | Y     |            | Vanderwolf et al. (2013)        |
|             | Phaeosphaeria oryzae             | Y     |            | Zhang (2019)                    |
|             | Phaeosphaeria sp.               | Y     |            | Connell and Staudigel (2013), Zhang (2019) |
| Phaeosphaeriopsis | Phaeosphaeriopsis sp.   | Y     |            | Zhang (2019)                    |
| Phaeostilbella | Phaeostilbella sp.             | Y     |            | Vanderwolf et al. (2013)        |
| Phaeotrichum | Phaeotrichum hystricinum        | Y     |            | Vanderwolf et al. (2013, 2015, 2019) |
|             | Phaeotrichum sp.                | Y     |            | Vanderwolf et al. (2015)        |
| Phialemoniopsis | Phialemoniopsis sp.            | Y     | Y          | Jiang et al. (2017a, b)         |
| Phialemonium | Phialemonium dimorphosporum     | Y     | Y          | Vanderwolf et al. (2013)        |
|             | Phialemonium sp.                | Y     | Y          | Zhang et al. (2017)             |
| Phialocepha | Phialocepha humicola            | Y     | Y          | Vanderwolf et al. (2013)        |
| Phialophora | Phialophora cinerecens          | Y     |            | Vanderwolf et al. (2013)        |
|             | Phia. fastigiata                | Y     |            | Vanderwolf et al. (2013)        |
|             | Phia. foetens                    | Y     | Y          | Vanderwolf et al. (2013)        |
|             | Phia. hyalina                    | Y     |            | Vanderwolf et al. (2013)        |
|             | Phia. olivacea                   | Y     | Y          | Pusz et al. (2018a)             |
|             | Phia. verrucosa                  | Y     |            | Vanderwolf et al. (2013, 2019), Leplat et al. (2018) |
| Phoma       | Phoma herbarum                  | Y     | Y          | Ogórek et al. (2014c), Zhang et al. (2017) |
|             | Pho. insulana                    | Y     | Y          | Zhang et al. (2017)             |
|             | Pho. leveillei                   | Y     |            | Ogórek et al. (2016d)           |
Table 4 (continued)

| Genus            | Species                   | China | This study | References                                                                 |
|------------------|----------------------------|-------|------------|-----------------------------------------------------------------------------|
| Pho              | radicina                  |       |            | Vanderwolf et al. (2019)                                                   |
| Pho              | senecionis                | Y     | Y          | Zhang et al. (2017)                                                        |
| Phoma            | sp.                        | Y     | Y          | Vanderwolf et al. (2013, 2015), Man et al. (2015), Kokurewicz et al. (2016), Zhang et al. (2017), Leplat et al. (2018) |
| Phomopsis        | Phomopsis vaccinii         | Y     |            | Zhang (2019)                                                               |
| Phylacia         | Phylacia bomba             |       |            | Vanderwolf et al. (2013)                                                   |
| Phyllachora      | Phylachora sp.             | Y     | Y          | Vanderwolf et al. (2013), Zhang et al. (2017)                              |
| Phymatotrichopsis| Phymatotrichopsis omnivora |       |            | Vanderwolf et al. (2013)                                                   |
| Pidoplichkiowej  | Pidoplichkiowej terricola  |       |            | Vanderwolf et al. (2013)                                                   |
| Pilidiun         | Pilidiun concavum          | Y     |            | Zhang (2019)                                                               |
| Pirostoma        | Pirostoma sp.              |       |            | Vanderwolf et al. (2013)                                                   |
| Pitioascus       | Pitioascus ater            | Y     | Y          |                                                                            |
|                  | Pt. platysporus            | Y     | Y          |                                                                            |
| Pitomyces        | Pitomyces chartarum        |       |            | Vanderwolf et al. (2013)                                                   |
|                  | Pitomyces sp.              |       |            | Vanderwolf et al. (2013), Leplat et al. (2018)                            |
| Plagiosoma       | Plagiosoma pulchellum      | Y     |            | Zhang (2019)                                                               |
| Plagiosoma       | Plagiosoma sp.             | Y     |            | Zhang (2019)                                                               |
| Plectosphaerella | Plectosphaerella cucumerina| Y     | Y          | Vanderwolf et al. (2013), Jiang et al. (2017a, b), Zhang et al. (2017)       |
|                  | Pl. niemeyeri              | Y     |            | Zhang (2019)                                                               |
|                  | Pl. oligotrophica          | Y     | Y          | Jiang et al. (2017a, b)                                                    |
|                  | Plectosphaerella sp.       | Y     |            | Zhang et al. (2017)                                                        |
| Pleospora        | Pleospora sp.              |       |            | Vanderwolf et al. (2013)                                                   |
| Pleotrichocladium| Pleotrichocladium opacum   |       |            | Vanderwolf et al. (2013)                                                   |
| Pochonia         | Pochonia sp.               | Y     |            | Vanderwolf et al. (2013), Zhang (2019)                                     |
| Podospora        | Podospora sp.              | Y     | Y          | Vanderwolf et al. (2013), Zhang et al. (2014)                              |
| Polycephalomyces | Polycephalomyces usaricus  | Y     | Y          |                                                                            |
|                  | Po. ramosus                |       |            | Vanderwolf et al. (2013)                                                   |
| Polythrinicum    | Polythrinicum sp.          |       |            | Vanderwolf et al. (2013)                                                   |
| Preussia         | Preussia aemulans          | Y     | Y          | Zhang et al. (2017)                                                        |
|                  | Pr. funiculata             | Y     |            | Vanderwolf et al. (2015), Zhang (2019)                                     |
| Preussia         | Preussia sp.               | Y     | Y          | Vanderwolf et al. (2013, 2015, 2019)                                       |
|                  | Pr. terricola              | Y     |            |                                                                            |
| Prosthecium      | Prosthecium sp.            | Y     | Y          |                                                                            |
| Protocrea        | Protocrea farinosa         | Y     |            | Zhang et al. (2017)                                                        |
| Pseudallescheria | Pseudallescheria boydii    | Y     | Y          | Vanderwolf et al. (2013)                                                   |
|                  | Ps. fimeti                 | Y     | Y          | Zhang et al. (2017)                                                        |
| Pseudallescheria | Pseudallescheria sp.       | Y     | Y          | Vanderwolf et al. (2013)                                                   |
| Pseudoarachniotus| Pseudoarachniotus trochle-|       |            | Vanderwolf et al. (2013)                                                   |
|                  | oxoporus                  |       |            |                                                                            |
| Pseudocercosporella| Pseudocercosporella fraxini| Y     |            | Zhang (2019)                                                               |
|                  | Pseudocercosporella sp.    | Y     |            | Vanderwolf et al. (2013), Jiang et al. (2017a, b)                          |
| Pseudocoleophoma | Pseudocoleophoma sp.       | Y     | Y          |                                                                            |
| Pseudocosmospora | Pseudocosmospora rogersonii| Y     | Y          |                                                                            |
| Pseudogymnoascus| Pseudogymnoascus destructans|       |            |                                                                            |
|                  | Pseu. pannorum             | Y     | Y          | Zhang et al. (2014), Vanderwolf et al. (2015, 2019), Kokurewicz et al. (2016), Burow et al. (2019) |
|                  | Pseu. roeseus              |       |            |                                                                            |
|                  | Pseudogymnoascus sp.       |       |            |                                                                            |
| Pseudopestalotiopsis| Pseudopestalotiopsis theae| Y     | Y          | Vanderwolf et al. (2013, 2015, 2019), Zhang et al. (2014), Out et al. (2016), Jiang et al. (2017a, b), Mitova et al. (2017), Ogórek et al. (2017), Popkova and Mazina (2019) |
| Pseudopithomyces | Pseudopithomyces chartarum |       |            |                                                                            |
| Pseudocroupulariopsis| Pseudocroupulariopsis asperi-| Y     | Y          |                                                                            |
|                  | ispore                     |       |            |                                                                            |
### Table 4 (continued)

| Genus                | Species                  | Chinaa | This studyb | References                                              |
|----------------------|--------------------------|--------|-------------|---------------------------------------------------------|
| Pseudo. hibernica    |                          | Y Y    |             | Jiang et al. (2017a, b)                                  |
| Purpureocillium      | Purpureocillium lavendula| Y Y    |             | Taylor et al. (2013), Zhang et al. (2017), Nováková et al. (2018), Pusz et al. (2018a) |
| Pu. lilacinum        |                          | Y Y    |             |                                                        |
| Purpureocillium sp.  |                          | Y      |             | Jiang et al. (2017a, b)                                  |
| Pynostysanus         | Pynostysanus sp.         |        |             | Vanderwolf et al. (2013)                                |
| Pyrenocheata         | Pyrenocheata sp.         |        |             | Vanderwolf et al. (2013)                                |
| Pyrenocheatopsis     | Pyrenocheatopsis decipiens|      |             | Zhang (2019)                                             |
|                      | Pyrenocheatopsis sp.     | Y Y    |             | Jiang et al. (2017a, b)                                  |
| Pyrenopeziza         | Pyrenopeziza dilatella   |        |             | Vanderwolf et al. (2013)                                |
| Pyrenophora          | Pyrenophora tritici-repentis| Y Y    |             |                                                        |
| Radulum              | Radulum sp.              |        |             | Vanderwolf et al. (2013)                                |
| Ramichloridium       | Ramichloridium indicum   |        |             | Vanderwolf et al. (2013)                                |
|                      | Ramichloridium sp.       | Y Y    |             | Vanderwolf et al. (2013)                                |
| Ramophialophora      | Ramophialophora globispora|      |             | Zhang et al. (2017)                                     |
|                      | R. petraea               | Y      |             | Zhang et al. (2017)                                     |
|                      | Ramophialophora sp.      | Y Y    |             |                                                        |
| Readeriella          | Readeriella eucalypti    |        |             | Belyagoubi et al. (2018)                                |
| Rhachomyces          | Rhachomyces alliaudii    |        |             | Vanderwolf et al. (2013)                                |
|                      | Rh. anophthalmi          |        |             | Vanderwolf et al. (2013)                                |
|                      | Rh. aphaenopsis          |        |             | Vanderwolf et al. (2013)                                |
|                      | Rh. beronii              |        |             | Vanderwolf et al. (2013)                                |
|                      | Rh. boliviari            |        |             | Vanderwolf et al. (2013)                                |
|                      | Rh. bucciarellii         |        |             | Vanderwolf et al. (2013)                                |
|                      | Rh. canariensis          |        |             | Vanderwolf et al. (2013)                                |
|                      | Rh. capucinus            |        |             | Vanderwolf et al. (2013)                                |
|                      | Rh. deyi                 |        |             | Vanderwolf et al. (2013)                                |
|                      | Rh. girardi              |        |             | Vanderwolf et al. (2013)                                |
|                      | Rh. gratiellae           |        |             | Vanderwolf et al. (2013)                                |
|                      | Rh. hypogaeus            |        |             | Vanderwolf et al. (2013)                                |
|                      | Rh. ilerdensis           |        |             | Vanderwolf et al. (2013)                                |
|                      | Rh. maublancii           |        |             | Vanderwolf et al. (2013)                                |
|                      | Rh. middelhoekii         |        |             | Vanderwolf et al. (2013)                                |
|                      | Rh. orotrechorum         |        |             | Vanderwolf et al. (2013)                                |
|                      | Rh. pucei                |        |             | Vanderwolf et al. (2013)                                |
|                      | Rh. peyerimhoffii        |        |             | Vanderwolf et al. (2013)                                |
|                      | Rh. profijerans          |        |             | Vanderwolf et al. (2013)                                |
|                      | Rh. pyreneanus           |        |             | Vanderwolf et al. (2013)                                |
|                      | Rh. quetzalcoati         |        |             | Vanderwolf et al. (2013)                                |
|                      | Rh. reveilletii          |        |             | Vanderwolf et al. (2013)                                |
|                      | Rh. reymondi             |        |             | Vanderwolf et al. (2013)                                |
|                      | Rh. richardi             |        |             | Vanderwolf et al. (2013)                                |
|                      | Rh. spadiceus            |        |             | Vanderwolf et al. (2013)                                |
|                      | Rh. speluncalis          |        |             | Vanderwolf et al. (2013)                                |
|                      | Rh. stipitatus           |        |             | Vanderwolf et al. (2013)                                |
|                      | Rh. urbaini              |        |             | Vanderwolf et al. (2013)                                |
|                      | Rh. vauxsierei           |        |             | Vanderwolf et al. (2013)                                |
|                      | Rh. venetianus           |        |             | Vanderwolf et al. (2013)                                |
|                      | Rh. vignae               |        |             | Vanderwolf et al. (2013)                                |
|                      | Rhachomyces sp.          |        |             | Vanderwolf et al. (2013)                                |
| Rhinocladiella       | Rhinocladiella sp.       |        |             | Vanderwolf et al. (2013)                                |
| Rhytidhysteron       | Rhytidhysteron Rufulum   | Y Y    |             | Vanderwolf et al. (2013)                                |
| Rosellinia           | Rosellinia arcauta       |        |             | Vanderwolf et al. (2013)                                |
| Rousoella            | Ro. siamensis            | Y Y    |             |                                                        |
|                      | Rousoella sp.            | Y Y    |             |                                                        |
| Saccharomyces        | Saccharomyces bayanus    |        |             | Vanderwolf et al. (2013)                                |
|                      | S. carlsbergensis        |        |             | Vanderwolf et al. (2013)                                |
|                      | S. cerevisiae            |        |             | Connell and Staudigel (2013), Vanderwolf et al. (2013)   |
|                      | S. paradoxus             |        |             | Vanderwolf et al. (2013)                                |
Table 4  (continued)

| Genus         | Species                          | China$^a$ | This study$^b$ | References                                      |
|---------------|----------------------------------|----------|----------------|------------------------------------------------|
| Saccharomyces | Saccharomyces fibuligera         | Y        | Y              | Vanderwolf et al. (2013)                        |
| Sagenomella   | Sagenomella sp.                  |          |                |                                                 |
| Sarocladium   | Sarocladium bacillosporum        |          |                | Vanderwolf et al. (2013)                        |
|               | Sa. bactrocephalum               |          |                | Vanderwolf et al. (2013)                        |
|               | Sa. glaucum                      |          |                | Vanderwolf et al. (2013)                        |
|               | Sa. implicatum                   |          |                | Connell and Staudigel (2013), Vanderwolf et al. (2013) |
|               | Sa. kilimense                    | Y        | Y              | Vanderwolf et al. (2013)                        |
|               | Sarocladium sp.                  | Y        | Y              | Jiang et al. (2017a, b)                         |
|               | Sa. strictum                     | Y        | Y              | Ogórek et al. (2013, 2014a, b), Vanderwolf et al. (2013), Kokurewicz et al. (2016), Pusz et al. (2018a, dylag et al. (2019) |
|               | Sa. zeae                         |          |                | Mitova et al. (2017)                            |
| Scedosporium  | Scedosporium sp.                 | Y        | Y              |                                                 |
| Schizothecium | Schizothecium inaequale          | Y        | Y              | Jiang et al. (2017a, b)                         |
| Sclerotinia   | Sclerotinia sclerotiorum         |          |                | VanderWolf et al. (2013)                        |
|               | Sclerotinia sp.                  |          |                | VanderWolf et al. (2013)                        |
| Scolobasidium | Scolobasidium anellii            |          |                | VanderWolf et al. (2013)                        |
|               | Sc. anomalous                    |          |                | VanderWolf et al. (2013)                        |
|               | Sc. constrictum                  |          |                | VanderWolf et al. (2013)                        |
|               | Sc. lascauxense                  |          |                | VanderWolf et al. (2013), Martin-Sanchez et al. (2014), Pfendler et al. (2019) |
|               | Sc. terreum                      |          |                | VanderWolf et al. (2013)                        |
| Scopulariopsis| Scopulariopsis asperula           | Y        | Y              | VanderWolf et al. (2013)                        |
|               | Sco. brumptii                    |          |                | VanderWolf et al. (2013)                        |
|               | Sco. candida                     |          |                | VanderWolf et al. (2013), Dylag et al. (2019)   |
|               | Sco. crassa                      | Y        |                | Zhang et al. 2017                               |
|               | Sco. flavus                      | Y        | Y              | VanderWolf et al. (2013)                        |
|               | Sco. fusca                       |          |                | VanderWolf et al. (2013)                        |
|               | Sco. lamosa                      |          |                | VanderWolf et al. (2013)                        |
|               | Scopulariopsis sp.               |          |                | VanderWolf et al. (2013)                        |
|               | Sco. sphacopsis                  | Y        | Y              | VanderWolf et al. (2013)                        |
| Scutellinia   | Scutellinia sp.                  | Y        |                | Zhang et al. 2017                               |
| Scytalidium   | Scytalidium cuboideum            |          |                | VanderWolf et al. (2013)                        |
|               | Scy. liglicola                   | Y        | Y              | VanderWolf et al. (2013)                        |
|               | Scytalidium sp.                  |          |                | VanderWolf et al. (2015)                        |
| Seimatosporium| Seimatosporium sp.               | Y        | Y              | VanderWolf et al. (2013)                        |
| Selinia       | Selinia sp.                      |          |                | VanderWolf et al. (2013)                        |
| Sepedonium    | Sepedonium sp.                   |          |                | VanderWolf et al. (2013)                        |
| Septonema     | Septonema secedens               |          |                | VanderWolf et al. (2013)                        |
| Septoria      | Septoria arundinae               | Y        | Y              | VanderWolf et al. (2013), Jiang et al. (2017a, b) |
| Septoriella   | Septoriella oudemansii           | Y        | Y              | VanderWolf et al. (2013)                        |
| Setophaeosphaeria | Setophaeosphaeria hemeroscul- latis | Y        | Y              |                                                 |
|               | Se. microspora                   | Y        | Y              | Zhang (2019)                                    |
|               | Setophaeosphaeria sp.            | Y        | Y              | Zhang (2019)                                    |
| Setophoma     | Setophoma terrestris             | Y        | Y              | Jiang et al. (2017a, b)                         |
|               | Set. vernoniae                   | Y        |                | Zhang (2019)                                    |
|               | Setophoma sp.                    | Y        |                | Zhang (2019)                                    |
| Shanorella    | Shanorella sp.                   |          |                | VanderWolf et al. (2013)                        |
| Simplicillium | Simplicillium album              | Y        | Y              |                                                 |
|               | Si. aogashimaense                | Y        | Y              | Zhang et al. (2017)                             |
|               | Si. calcicola                    | Y        |                | Zhang et al. (2019)                             |
|               | Si. cylindrosporum               | Y        |                | Zhang (2019)                                    |
|               | Si. humicola                     | Y        | Y              | VanderWolf et al. (2013), Nováková et al. (2018) |
|               | Si. lamellicola                  | Y        | Y              | Zhang et al. (2014)                             |
|               | Si. lamosinivum                  |          |                |                                                 |

$^a$ Presence of genus in China

$^b$ Presence of species in this study
| Genus        | Species                   | Chinaa | This studyb | References                                                                 |
|-------------|---------------------------|--------|-------------|-----------------------------------------------------------------------------|
| *Si. minatense* | Y                         | Y      | Mitova et al. (2017)                                                                 |
| *Si. subtropicum* | Y                         | Y      | Vanderwolf et al. (2013), Jiang et al. (2017a, b), Leplat et al. (2018)              |
| *Simplicillium* sp. | Y                         |        | Vanderwolf et al. (2013)                                                                 |
| *Siraxstachys* | *Siraxstachys longisporns* | Y      | Zhang et al. (2017)                                                                  |
| *Sir. phaseospora* | Y                         | Y      | Vanderwolf et al. (2013), Ogórek et al. (2014a, b), Jiang et al. (2017a, b), Pusz et al. (2017) |
| *Sordaria* | *Sordaria fmicola* | Y      | Vanderwolf et al. (2013)                                                                 |
|              | *Sordaria sp.* | Y      | Vanderwolf et al. (2013)                                                                 |
| *Spegazzinia* | *Spegazzinia sp.* | Y      | Vanderwolf et al. (2013)                                                                 |
| *Sphaeroides* | *Sphaeroides fmicola* | Y      | Vanderwolf et al. (2013)                                                                 |
| *Sphaerostilbella* | *Sphaerostilbella penicillioides* | Y      | Vanderwolf et al. (2013)                                                                 |
| *Sporidesmium* | *Sporidesmium atrum* | Y      | Vanderwolf et al. (2013)                                                                 |
| *Sporocybe* | *Sporocybe sp.* | Y      | Vanderwolf et al. (2013)                                                                 |
| *Sporormia* | *Sporormia subicinensis* | Y      | Nováková et al. (2018)                                                                |
|              | *Sp. minima* | Y      | Vanderwolf et al. (2013)                                                                 |
|              | *Sp. minimoides* | Y      | Vanderwolf et al. (2013)                                                                 |
|              | *Sporormiella sp.* | Y      | Vanderwolf et al. (2013)                                                                 |
| *Sporothrix* | *Sporothrix catenata* | Y      | Vanderwolf et al. (2013)                                                                 |
|              | *Spo. inflata* | Y      | Burow et al. (2019)                                                                  |
|              | *Spo. schenckii* | Y      | Vanderwolf et al. (2013)                                                                 |
|              | *Sporothrix sp.* | Y      | Vanderwolf et al. (2013), Leplat et al. (2018), Burow et al. (2019)                |
| *Stachybotrys* | *Stachybotrys chartarum* | Y      | Vanderwolf et al. (2013), Zhang et al. (2017), Nováková et al. (2018)            |
|              | *St. chlorohalonatus* | Y      | Vanderwolf et al. (2013)                                                                 |
|              | *St. cylindrosporus* | Y      | Vanderwolf et al. (2013), Pusz et al. (2017)                                      |
|              | *St. echinatus* | Y      | Vanderwolf et al. (2013)                                                                 |
|              | *St. parvisporus* | Y      | Vanderwolf et al. (2013), Leplat et al. (2018)                                      |
|              | *Stachybotrys sp.* | Y      | Vanderwolf et al. (2013)                                                                 |
| *Stachylidium* | *Stachylidium sp.* | Y      | Vanderwolf et al. (2013)                                                                 |
| *Stagonospora* | *Stagonospora sp.* | Y      | Jiang et al. (2017a, b), Leplat et al. (2018)                                      |
| *Stagonosporopsis* | *Stagonosporopsis cucurbitacearum* | Y      | Jiang et al. (2017a, b)                                                                |
| *Staphylotrichum* | *Staphylotrichum boninense* | Y      | Zhang et al. (2017)                                                                  |
|              | *Sta. coccosporum* | Y      | Vanderwolf et al. (2013)                                                                 |
|              | *Staphylotrichum sp.* | Y      | Zhang et al. (2017)                                                                  |
| *Stemphylium* | *Stemphylium botryosum* | Y      | Vanderwolf et al. (2013)                                                                 |
|              | *Ste. vescarium* | Y      | Vanderwolf et al. (2013)                                                                 |
|              | *Stemphylium sp.* | Y      | Vanderwolf et al. (2013)                                                                 |
| *Stephanonectria* | *Stephanonectria keithii* | Y      | Jiang et al. (2017a, b), Zhang et al. (2017)                                      |
| *Stigmatomyces* | *Stigmatomyces ooecothae* | Y      | Vanderwolf et al. (2013)                                                                 |
| *Stilbellia* | *Stilbellia sp.* | Y      | Vanderwolf et al. (2013), Man et al. (2015)                                       |
| *Spiriathotrypsis* | *Spiriathotrypsis eucylindrosporus* | Y      | Vanderwolf et al. (2013), Leplat et al. (2018)                                      |
| *Styloanus* | *Styloanus amyli* | Y      | Vanderwolf et al. (2013)                                                                 |
|              | *Styloanus sp.* | Y      | Vanderwolf et al. (2013)                                                                 |
|              | *Sy. typhoides* | Y      | Vanderwolf et al. (2013)                                                                 |
| *Sydowia* | *Sydowia polyspora* | Y      | Martin-Sanchez et al. (2014), Ogórek et al. (2017), Pusz et al. (2017)           |
| *Symplectomyces* | *Symplectomyces sp.* | Y      | Vanderwolf et al. (2013)                                                                 |
|              | *Sy. vulgaris* | Y      | Vanderwolf et al. (2013)                                                                 |
| *Synnematium* | *Synnematium sp.* | Y      | Vanderwolf et al. (2013)                                                                 |
| *Talaromycetes* | *Talaromycetes aculeatus* | Y      | Vanderwolf et al. (2015), Zhang (2019)                                               |
|              | *T. brinnea* | Y      | Paula et al. (2019)                                                                  |
|              | *T. cellulolyticus* | Y      | Zhang (2019)                                                                         |
|              | *T. diversus* | Y      | Vanderwolf et al. (2013)                                                                 |
|              | *T. duclauxii* | Y      | Vanderwolf et al. (2013)                                                                 |
|              | *T. flavus* | Y      | Vanderwolf et al. (2015), Pusz et al. (2014), Ogórek et al. (2017), Pusz et al. (2018a), Popkova and Mazina (2019) |
|              | *T. funiculosus* | Y      | Vanderwolf et al. (2013)                                                                 |
|              | *T. islandicus* | Y      | Taylor et al. (2013)                                                                  |
|              | *T. kendeckii* | Y      | Nováková et al. (2018)                                                                |
| Genus       | Species                     | China<sup>a</sup> | This study<sup>b</sup> | References                                      |
|-------------|-----------------------------|-------------------|------------------------|-------------------------------------------------|
| T. loliensis| Vanderwolf et al. (2013)    |                   |                        |                                                 |
| T. luteus   | Vanderwolf et al. (2013), Pusz et al. (2014), Pusz et al. (2018a) |                   |                        |                                                 |
| T. minioluteus | Vanderwolf et al. (2013)  |                   |                        |                                                 |
| T. pinophilus| Taylor et al. (2013), Vanderwolf et al. (2013), Zhang et al. (2017), Nováková et al. (2018) | Y                   |                        |                                                 |
| T. purpureogenus | Popková and Mazina (2019)    | Y                  |                        |                                                 |
| T. radicus  | Jiang et al. (2017a, b)     |                   |                        |                                                 |
| T. rugulosus| Vanderwolf et al. (2013), Pusz et al. (2018a) | Y                   |                        |                                                 |
| T. sublevisporus | Vanderwolf et al. (2013)   | Y                  |                        |                                                 |
| T. thermophilus | Vanderwolf et al. (2013) |                   |                        |                                                 |
| T. variabilis| Taylor et al. (2013), Vanderwolf et al. (2013) |                   |                        |                                                 |
| T. varians  | Vanderwolf et al. (2013)    |                   |                        |                                                 |
| T. verruculosus | Vanderwolf et al. (2013) |                   |                        |                                                 |
| T. wortmannii | Vanderwolf et al. (2013)   |                   |                        |                                                 |
| Talaromyces sp. | Vanderwolf et al. (2013), Popović et al. (2015), Zhang et al. (2017), Nováková et al. (2018) | Y                   |                        |                                                 |
| Tapesia     | Vanderwolf et al. (2013)    |                   |                        |                                                 |
| Tapesia fusca | Vanderwolf et al. (2013)   |                   |                        |                                                 |
| Tarzetta    | Vanderwolf et al. (2013)    |                   |                        |                                                 |
| Teichospora | Vanderwolf et al. (2013)    | Y                  |                        |                                                 |
| Tetracladium| Vanderwolf et al. (2013)    |                   |                        | Connell and Staudigel (2013), Zhang et al. (2014), Out et al. (2016) |
| Tetracoecosporium | Vanderwolf et al. (2013) |                   |                        |                                                 |
| Thelebolus  | Vanderwolf et al. (2013, 2015) |                   |                        |                                                 |
| Th. ellipsoideus | Out et al. (2016)           | Y                  |                        |                                                 |
| Th. globosus | Vanderwolf et al. (2013)    |                   |                        |                                                 |
| Th. microsporus | Brad et al. (2018)         |                   |                        |                                                 |
| Th. sp.     | Vanderwolf et al. (2013), Out et al. (2016), Brad et al. (2018) | Y                   |                        |                                                 |
| Thielopsis  | Vanderwolf et al. (2013)    |                   |                        |                                                 |
| Thermomyces | Vanderwolf et al. (2013)    |                   |                        |                                                 |
| Thermothelomyces | Vanderwolf et al. (2013) |                   |                        |                                                 |
| Thiellavia  | Vanderwolf et al. (2013)    |                   |                        |                                                 |
| Th. hyalocarpa | Vanderwolf et al. (2013)   | Y                  |                        |                                                 |
| Th. terricola | Vanderwolf et al. (2013)   |                   |                        |                                                 |
| Th. sp.     | Vanderwolf et al. (2013), Zhang et al. (2017), Leplat et al. (2018) | Y                   |                        |                                                 |
| Thysanopora | Vanderwolf et al. (2013, 2019) |                   |                        |                                                 |
| Thysanorea  | Vanderwolf et al. (2013)    |                   |                        |                                                 |
| Tilachlidium| Vanderwolf et al. (2013)    |                   |                        |                                                 |
| Togninia    | Vanderwolf et al. (2013)    |                   |                        |                                                 |
| Tolypocladium| Vanderwolf et al. (2013)   |                   |                        |                                                 |
| Tolyposporum| Vanderwolf et al. (2013)    |                   |                        |                                                 |
| Tol. inflatum | Vanderwolf et al. (2013, 2015) |                   |                        |                                                 |
| Tolypocladium sp. | Vanderwolf et al. (2013, 2019), Man et al. (2015), Zhang et al. (2017) | Y                   |                        |                                                 |
| Torrubiella | Vanderwolf et al. (2013)    |                   |                        |                                                 |
| Tor. minusatissa | Vanderwolf et al. (2013) |                   |                        |                                                 |
| Torrubiella sp. | Vanderwolf et al. (2013)   |                   |                        |                                                 |
| Torula      | Vanderwolf et al. (2013), Zhang et al. (2017), Pusz et al. (2018a), Zhang (2019) | Y                   |                        |                                                 |
| Torula sp.  | Vanderwolf et al. (2013)    |                   |                        |                                                 |
| Torulasporea| Mitova et al. (2017)        |                   |                        |                                                 |
| Torulomyces | Vanderwolf et al. (2013)    |                   |                        |                                                 |
| Toxicocelosporium | Connell and Staudigel (2013), Vanderwolf et al. (2013) |                   |                        |                                                 |
| Trematia    | Vanderwolf et al. (2013)    |                   |                        |                                                 |
| Tricellula  | Vanderwolf et al. (2019)    |                   |                        |                                                 |
| Trichobotrys| Vanderwolf et al. (2013)    |                   |                        |                                                 |
| Genus               | Species                | China<sup>a</sup> | This study<sup>b</sup> | References                                                                 |
|---------------------|------------------------|-------------------|-------------------------|---------------------------------------------------------------------------|
| *Trichobotrys*      | sp.                    | Y                 |                         | Zhang (2019)                                                              |
| *Trichocladium*     | asperum                | Y                 |                         | Zhang et al. (2017)                                                       |
| *Trichocladium*     | sp.                    | Y                 |                         | Vanderwolf et al. (2013)                                                  |
| *Trichoderma*       | asperelloides          |                   |                         | Nováková et al. (2018)                                                   |
| *Trichoderma*       | sp.                    | Y                 |                         |                                                                           |
| *Trichoderma*       | asperellum             |                   |                         | Vanderwolf et al. (2013), Zhang et al. (2017), Nováková et al. (2018)    |
| *Trichoderma*       | aureoviride            | Y                 |                         | Vanderwolf et al. (2013), Zhang et al. (2017)                            |
| *Trichoderma*       | brevicompactum         | Y                 |                         | Zhang (2019)                                                              |
| *Trichoderma*       | citrinoviride          | Y                 |                         | Zhang et al. (2017), Ogórek (2018a, b)                                    |
| *Trichoderma*       | deliquecens            |                   |                         | Vanderwolf et al. (2013)                                                  |
| *Trichoderma*       | gamsii                 | Y                 |                         |                                                                           |
| *Trichoderma*       | hamatum                | Y                 |                         | Vanderwolf et al. (2013), Zhang et al. (2017), Popkova and Mazina (2019) |
| *Trichoderma*       | harzianum              | Y                 |                         | Ozórek et al. (2013, 2016c), Vanderwolf et al. (2013), Kokurewicz et al. (2016), Jiang et al. (2017a, b), Mitová et al. (2017), Pusz et al. (2017), Nováková et al. (2018), Popkova and Mazina (2019) |
| *Trichoderma*       | koningii               |                   |                         | Vanderwolf et al. (2013), Nováková et al. (2018)                         |
| *Trichoderma*       | koningiopsis           | Y                 |                         | Pusz et al. (2017), Zhang et al. (2017)                                   |
| *Trichoderma*       | lixii                  | Y                 |                         | Vanderwolf et al. (2013), Zhang et al. (2017)                            |
| *Trichoderma*       | longibrachiatum        | Y                 |                         | Vanderwolf et al. (2015), Ogórek et al. (2017, 2018), Zhang et al. (2017) |
| *Trichoderma*       | paraerseii             | Y                 |                         |                                                                           |
| *Trichoderma*       | paraviridescens        | Y                 |                         | Zhang et al. (2014), Zhang (2019)                                        |
| *Trichoderma*       | piliferum              |                   |                         | Vanderwolf et al. (2013)                                                  |
| *Trichoderma*       | polysporum             | Y                 |                         | Vanderwolf et al. (2015), Popkova and Mazina (2019)                       |
| *Trichoderma*       | reesei                 | Y                 |                         | Man et al. (2015)                                                        |
| *Trichoderma*       | rossicum               | Y                 |                         | Zhang et al. (2017)                                                      |
| *Trichoderma*       | samuelii               | Y                 |                         |                                                                           |
| *Trichoderma*       | saturnisporm           | Y                 |                         |                                                                           |
| *Trichoderma*       | spirale                | Y                 |                         |                                                                           |
| *Trichoderma*       | stramineum             | Y                 |                         |                                                                           |
| *Trichoderma*       | strictipile            | Y                 |                         |                                                                           |
| *Trichoderma*       | tomentosum             | Y                 |                         | Jiang et al. (2017a, b)                                                   |
| *Trichoderma*       | velutinum              | Y                 |                         | Vanderwolf et al. (2013), Popović et al. (2015), Nováková et al. (2018) |
| *Trichoderma*       | viride                 | Y                 |                         | Taylor et al. (2013), Vanderwolf et al. (2013), Pusz et al. (2017, 2018a), Burow et al. (2019), Popkova and Mazina (2019) |
| *Trichoderma*       | viridescens            | Y                 |                         |                                                                           |
| *Trichoderma*       | sp.                    | Y                 |                         | Vanderwolf et al. (2013, 2015, 2019), Martin-Sanchez et al. (2014), Yoder et al. (2015), Minova et al. (2017), Zhang et al. (2017), Nováková et al. (2018), Leplat et al. (2018) |
| *Trichophyton*      | ajelloi                |                   |                         | Vanderwolf et al. (2013)                                                  |
| *Trichophyton*      | mentagrophytes         |                   |                         | Vanderwolf et al. (2013)                                                  |
| *Trichophyton*      | rubrum                 | Y                 |                         | Vanderwolf et al. (2013), Zhang et al. (2017)                            |
| *Trichophyton*      | schoenleinii           |                   |                         | Vanderwolf et al. (2013)                                                  |
| *Trichophyton*      | terrestrae             | Y                 |                         | Vanderwolf et al. (2013), Zhang et al. (2014)                            |
| *Trichophyton*      | sp.                    | Y                 |                         | Vanderwolf et al. (2013, 2019), Martin-Sanchez et al. (2014)              |
| *Trichosporiella*   | cerebriformis          |                   |                         | Vanderwolf et al. (2013)                                                  |
| *Trichosporiella*   | multisporum            |                   |                         | Vanderwolf et al. (2013)                                                  |
| *Trichosporiella*   | sp.                    |                   |                         | Vanderwolf et al. (2013, 2015, 2019)                                     |
| *Trichothecium*     | roseum                 |                   |                         | Vanderwolf et al. (2013), Pusz et al. (2018a, b)                          |
| *Trichothecium*     | crotocinigenum         | Y                 |                         |                                                                           |
| *Trichures*         | terrophilus            | Y                 |                         | Vanderwolf et al. (2013)                                                  |
| *Trichures*         | sp.                    |                   |                         | Vanderwolf et al. (2013)                                                  |
| *Tricladium*        | brunneum               |                   |                         | Vanderwolf et al. (2013)                                                  |
| *Tripospermum*      | sp.                    |                   |                         | Vanderwolf et al. (2013)                                                  |
| *Tritirachium*      | cinnamomeum            |                   |                         | Vanderwolf et al. (2013)                                                  |
| *Tritirachium*      | dependens              |                   |                         | Vanderwolf et al. (2013)                                                  |
| *Tritirachium*      | isariae                |                   |                         | Vanderwolf et al. (2013)                                                  |
| *Tritirachium*      | oryzae                 |                   |                         | Vanderwolf et al. (2013)                                                  |
| *Tritirachium*      | sp.                    |                   |                         | Vanderwolf et al. (2013)                                                  |
| Genus            | Species                                    | China<sup>a</sup> | This study<sup>b</sup> | References                                      |
|------------------|--------------------------------------------|-------------------|------------------------|------------------------------------------------|
| Troglomyces      | Troglomyces bilabiatus                     |                   |                        | Enghoff and Santamaria (2015)                   |
|                  | Tro. manfredi                              |                   |                        | Vanderwolf et al. (2013)                        |
|                  | Tro. pusillus                              |                   |                        | Enghoff and Santamaria (2015)                   |
|                  | Tro. triandrus                             |                   |                        | Enghoff and Santamaria (2015)                   |
| Truncatella      | Truncatella angustata                      |                   |                        | Vanderwolf et al. (2013), Burow et al. (2019)  |
|                  | Truncatella sp.                            |                   |                        | Burow et al. (2019)                            |
| Tubercularia     | Tubercularia sp.                           |                   |                        | Vanderwolf et al. (2013)                        |
| Ulocladium       | Ulocladium sp.                             |                   |                        | Vanderwolf et al. (2013)                        |
| Uncinocarpus     | Uncinocarpus ancimatus                     |                   |                        | Vanderwolf et al. (2013)                        |
| Varicosporium    | Varicosporium giganteum                    |                   |                        | Vanderwolf et al. (2013)                        |
|                  | Varicosporium sp.                          |                   |                        | Vanderwolf et al. (2013)                        |
| Venturia         | Venturia sp.                               |                   |                        | Vanderwolf et al. (2013)                        |
| Veronaea         | Veronaea compacta                          | Y                 | Y                      | Vanderwolf et al. (2013), Zhang (2019)          |
|                  | Veronaea sp.                               | Y                 | Y                      | Vanderwolf et al. (2013), Jiang et al. (2017a, b) |
| Verticillium     | Verticillium albo-atrum                    | Y                 | Y                      | Vanderwolf et al. (2013), Zhang (2019)          |
|                  | V. dahliae                                 |                   |                        | Connell and Staudigel (2013), Vanderwolf et al. (2013) |
|                  | V. insectorum                              | Y                 |                        | Vanderwolf et al. (2013), Zhang (2019)          |
|                  | V. nanum                                   |                   |                        | Vanderwolf et al. (2013)                        |
|                  | V. terrestre                               |                   |                        | Vanderwolf et al. (2013)                        |
|                  | V. tricornus                               | Y                 | Y                      | Jiang et al. (2017a, b)                         |
|                  | Verticillium sp.                           | Y                 | Y                      | Vanderwolf et al. (2013, 2019), Yoder et al. (2015), Zhang et al. (2017), Leplat et al. (2018) |
| Vibrissea        | Vibrissea truncorum                        |                   |                        | Vanderwolf et al. (2013)                        |
| Virgaria         | Virgaria nigra                             | Y                 |                        | Zhang et al. (2017)                             |
| Volatella        | Volatella aeria                            | Y                 | Y                      | Zhang et al. (2017)                             |
|                  | Vo. ciliata                                | Y                 | Y                      | Vanderwolf et al. (2013), Jiang et al. (2017a, b) |
|                  | Vo. citrinella                             | Y                 | Y                      | Vanderwolf et al. (2013)                        |
|                  | Vo. roseola                                |                   |                        | Vanderwolf et al. (2013)                        |
|                  | Volatella sp.                              |                   |                        | Vanderwolf et al. (2013)                        |
| Volatellonectria | Volatellonectria consors                   | Y                 | Y                      | Vanderwolf et al. (2013)                        |
| Wardomyces       | Wardomyces anomalus                        |                   |                        | Vanderwolf et al. (2013)                        |
|                  | W. giganteus                               |                   |                        | Vanderwolf et al. (2019)                        |
|                  | W. humicola                                |                   |                        | Vanderwolf et al. (2013, 2015)                  |
|                  | W. inflatus                                | Y                 |                        | Vanderwolf et al. (2013, 2015, 2019), Zhang (2019) |
|                  | W. sp.                                     |                   |                        | Vanderwolf et al. (2013, 2015, 2019), Leplat et al. (2018) |
| Wardomycesopsis  | Wardomycesopsis dolichii                   | Y                 | Y                      | Vanderwolf et al. (2013)                        |
|                  | Wa. ellipsospondiophora                    | Y                 | Y                      | Vanderwolf et al. (2013)                        |
|                  | Wa. fusca                                  | Y                 | Y                      | Vanderwolf et al. (2013)                        |
|                  | Wa. humicola                               | Y                 | Y                      | Vanderwolf et al. (2013)                        |
|                  | Wa. longicatenata                          | Y                 |                        | Zhang et al. (2017)                             |
| Whalleya         | Whalleya microplaca                        | Y                 | Y                      | Vanderwolf et al. (2013)                        |
| Wickerhamomyces  | Wickerhamomyces anomalus                   |                   |                        | Vanderwolf et al. (2013)                        |
|                  | Wi. subpelliculosus                        |                   |                        | Vanderwolf et al. (2013)                        |
| Xenosporium      | Xenosporium anomalus                       |                   |                        | Vanderwolf et al. (2013)                        |
| Xepicula         | Xepicula sp.                               | Y                 | Y                      | Vanderwolf et al. (2013)                        |
| Xylaria          | Xylaria arbuscula                          | Y                 |                        | Zhang et al. (2017)                             |
|                  | X. anisopleura                             |                   |                        | Vanderwolf et al. (2013)                        |
|                  | X. coriniformis                            |                   |                        | Vanderwolf et al. (2013)                        |
|                  | X. hypoxylon                               | Y                 |                        | Vanderwolf et al. (2013), Zhang (2019)          |
|                  | X. kegeliana                               |                   |                        | Vanderwolf et al. (2013)                        |
|                  | X. longipes                                |                   |                        | Vanderwolf et al. (2013)                        |
|                  | X. palmicola                               | Y                 | Y                      | Vanderwolf et al. (2013)                        |
|                  | X. polymorpha                              |                   |                        | Vanderwolf et al. (2013)                        |
|                  | X. schweinitzii                            | Y                 |                        | Zhang et al. (2017)                             |
|                  | X. venosula                                | Y                 | Y                      | Vanderwolf et al. (2013), Zhang et al. (2017)  |
| Yarrowia         | Yarrowia bubula                            |                   |                        | Burow et al. (2019)                             |
| Yunnania         | Yunnania carbonaria                        | Y                 | Y                      | Vanderwolf et al. (2013)                        |
|                  | Yunnania penicilliata                      | Y                 | Y                      | Yoder et al. (2015), Zhang et al. (2017), Leplat et al. (2018) |
| Genus              | Species                      | Chinaa             | This studyb | References                             |
|--------------------|-------------------------------|--------------------|-------------|----------------------------------------|
| Zakatosha          | Zakatosha sp.                 |                    |             | Vanderwolf et al. (2013)               |
| Zalerion           | Zalerion sp.                  |                    |             | Vanderwolf et al. (2019)               |
| Zasmidium          | Zasmidium cellare             |                    |             | Vanderwolf et al. (2013)               |
|                   | Z. xyzygii                    | Y                  |             | Zhang (2019)                           |
| Zopfella           | Zopfella pleurospora          |                    |             | Vanderwolf et al. (2013, 2015)         |
|                   | Z. tubulata                   | Y Y                |             |                                       |
| Zygosaccharomyces  | Zygosaccharomyces microel-    |                    |             | Vanderwolf et al. (2013)               |
|                   | lipsoides                    |                    |             |                                       |
| **Basidiomycota**  |                               |                    |             |                                       |
| Abortiporus        | Abortiporus biennis           |                    |             | Vanderwolf et al. (2013)               |
|                   | Abortiporus sp.               |                    |             | Busquets et al. (2014)                 |
| Agaricus           | Agaricus sp.                  |                    |             | Vanderwolf et al. (2013)               |
| Agrocybe           | Agrocybe sp.                  |                    |             | Vanderwolf et al. (2013)               |
| Alysidium          | Alysidium sp.                 |                    |             | Vanderwolf et al. (2013)               |
| Amyloporia         | Amyloporia sinuosa            |                    |             | Vanderwolf et al. (2013)               |
| Antrodia           | Antrodia xantha               |                    |             | Vanderwolf et al. (2013)               |
| Apiostrichium      | Apiostrichium dehoogii        | Y Y                |             | Burow et al. (2019)                    |
|                   | Api. dulcitum                 | Y Y                |             | Vanderwolf et al. (2013, 2019), Burow et al. (2019) |
|                   | Api. lithbachii               | Y Y                |             | Vanderwolf et al. (2013), Zhang et al. (2017) |
|                   | Api. lignicola                |                    |             | Vanderwolf et al. (2013)               |
|                   | Apiotrichium sp.              | Y Y                |             | Vanderwolf et al. (2013, 2015)         |
| Armillaria         | Armillaria mellea             |                    |             | Vanderwolf et al. (2013)               |
| Asterotremella     | Asterotremella sp.            |                    |             | Vanderwolf et al. (2013, 2015, 2019)   |
| Atheniella         | Atheniella flavoalba          |                    |             | Vanderwolf et al. (2013)               |
| Auricularia        | Auricularia auricularis-judae |                    |             | Vanderwolf et al. (2013)               |
|                   | Aur. fuscosuccinea            |                    |             | Vanderwolf et al. (2013)               |
|                   | Aur. polytricha               |                    |             | Vanderwolf et al. (2013)               |
| Baeospora          | Baeospora myosura             |                    |             | Vanderwolf et al. (2013)               |
|                   | Ba. myriadophylla             |                    |             | Vanderwolf et al. (2013)               |
|                   | Baeospora sp.                 |                    |             | Vanderwolf et al. (2013, 2015)         |
| Bjerkandera        | Bjerkandera adusta            | Y Y                |             | Vanderwolf et al. (2013), Man et al. (2015), Ogorek (2018a, b) |
| Boletus            | Boletus sp.                   |                    |             | Vanderwolf et al. (2013)               |
| Bovista            | Bovista sp.                   |                    |             | Vanderwolf et al. (2013)               |
| Bridgeoporus       | Bridgeoporus nobilessimus     |                    |             | Vanderwolf et al. (2013)               |
| Buglossoporus      | Buglossoporus pulvinus        |                    |             | Vanderwolf et al. (2013)               |
| Bulleribasidium    | Bulleribasidium variabile     |                    |             | Vanderwolf et al. (2013)               |
| Bulleromyces       | Bulleromyces albus            |                    |             | Martin-Sanchez et al. (2014)           |
| Byssomerulius      | Byssomerulius corium          |                    |             | Vanderwolf et al. (2013)               |
| Calvatia           | Calvatia sp.                  |                    |             | Vanderwolf et al. (2013)               |
| Ceratobasidium     | Ceratobasidium sp.            | Y                  |             | Vanderwolf et al. (2013), Zhang et al. (2017) |
| Cerioporus         | Cerioporus mollis             | Y                  |             | Zhang et al. (2017)                    |
|                   | Ceri. varius                  |                    |             | Vanderwolf et al. (2013)               |
| Ceriporia          | Ceriporia lacerata            | Y                  |             | Man et al. (2015)                      |
| Ceriporiopsis      | Ceriporiopsis subvermispor    |                    |             | Connell and Staudeg (2013)             |
| Cerrena            | Cerrena unicolor              |                    |             | Vanderwolf et al. (2013)               |
| Clavaria           | Clavaria sp.                  |                    |             | Vanderwolf et al. (2013)               |
| Climacocystis      | Climacocystis borealis        |                    |             | Vanderwolf et al. (2013)               |
| Clitocybe          | Clitocybe sp.                 |                    |             | Vanderwolf et al. (2013)               |
| Clitopilus         | Clitopilus kamaka             | Y                  |             | Zhang et al. (2017)                    |
|                   | Cli. prunulus                 | Y                  |             | Vanderwolf et al. (2013)               |
|                   | Cli. scyphoides               | Y                  |             | Vanderwolf et al. (2013)               |
|                   | Cli. sp.                      | Y Y                |             | Vanderwolf et al. (2013)               |
| Collybia           | Collybia sp.                  |                    |             | Vanderwolf et al. (2013)               |
| Coniophora         | Coniophora cerebella          |                    |             | Vanderwolf et al. (2013)               |
| Coni. puteana      | Coniophora sp.                |                    |             | Vanderwolf et al. (2013)               |
| Coniophora         | Coniophora subtilis           |                    |             | Vanderwolf et al. (2013)               |
| Coprinarius        | Coprinarius disseminatus      |                    |             | Vanderwolf et al. (2013)               |
| Coprinellus        | Coprinellus subtilis          |                    |             | Vanderwolf et al. (2013)               |
|                   |                               |                    |             | Vanderwolf et al. (2013), Ogorek (2018b) |
Table 4 (continued)

| Genus            | Species                        | China$^a$ | This study$^b$ | References                                      |
|------------------|--------------------------------|-----------|----------------|------------------------------------------------|
| Coprinellus      | domesticus                     | Vanderwolf et al. (2013) |
|                  | ephemerus                      | Vanderwolf et al. (2013) |
|                  | micaceus                       | Y Y       | Vanderwolf et al. (2013) |
|                  | radians                        | Y Y       | Vanderwolf et al. (2013), Zhang et al. (2017) |
|                  | truncorum                      | Vanderwolf et al. (2013) |
|                  | xanthothrix                    | Y Y       | Vanderwolf et al. (2013), Man et al. (2015) |
| Coprinopsis      | atramentaria                   | Vanderwolf et al. (2013), (Zhang 2019) |
|                  | cinerea                        | Vanderwolf et al. (2013) |
|                  | radiata                        | Vanderwolf et al. (2013) |
| Coprinus         | sterculinus                    | Vanderwolf et al. (2013) |
|                  | sp.                            | Vanderwolf et al. (2013) |
| Coriolopsis      | gallica                        | Vanderwolf et al. (2013) |
| Cortinarius      | sp.                            | Vanderwolf et al. (2013) |
| Cotylidia        | aurantia                       | Vanderwolf et al. (2013) |
| Craterellus      | minimus                        | Vanderwolf et al. (2013) |
| Crepidotus       | applanatus                      | Vanderwolf et al. (2013) |
|                  | mollis                         | Vanderwolf et al. (2013) |
| Crucibulum       | crucibuliforme                 | Vanderwolf et al. (2013) |
| Cryptococcus     | festucosus                     | Y Y       | Vanderwolf et al. (2013) |
|                  | macerans                       | Vanderwolf et al. (2013) |
|                  | neoformans                     | Vanderwolf et al. (2013) |
|                  | tephrensis                     | Y         | Zhang (2019)    |
| Cryptococcus sp. |                                 | Burow et al. (2019) |
| Cutaneotrichosporon| curvatum                      | Ogórek et al. (2017, 2018), Ogórek (2018a, b) |
|                  | cutaneum                       | Vanderwolf et al. (2013) |
|                  | dermatis                       | Y Y       | Vanderwolf et al. (2013) |
|                  | guehose                        | Y Y       | Vanderwolf et al. (2013) |
|                  | jirovecii                      | Mitova et al. (2017) |
|                  | moniliforme                    | Y Y       | Burow et al. (2019) |
|                  | mucoides                       | Vanderwolf et al. (2013) |
|                  | smithiae                       | Y Y       | Vanderwolf et al. (2013) |
| Cylindrobasidium | evolvens                       | Vanderwolf et al. (2013) |
| Cystobasidium    | minuta                         | Vanderwolf et al. (2013) |
|                  | sloeoffiae                     | Y         | Zhang (2019)    |
| Cystoflibasidium | macerus                        | Connell and Staudigel (2013) |
|                  | sp.                            | Vanderwolf et al. (2013, 2015) |
| Daudalea         | quercina                       | Vanderwolf et al. (2013) |
| Deconica         | hartii                         | Vanderwolf et al. (2013) |
| Delicatula       | integrella                      | Vanderwolf et al. (2013) |
|                  | microscopica                   | Vanderwolf et al. (2013) |
| Donkioporia      | expansa                        | Vanderwolf et al. (2013) |
| Duportella       | lassa                          | Vanderwolf et al. (2013) |
| Effuseotrichosporon| vanderwaltii                  | Vanderwolf et al. (2013) |
| Elmerina         | carvae                         | Vanderwolf et al. (2013) |
| Entomocorticium  | sp.                            | Vanderwolf et al. (2013) |
| Exidia           | glandulosa                     | Connell and Staudigel (2013) |
| Exobasidium      | sp.                            | Connell and Staudigel (2013) |
| Favolus          | tenaculus                      | Vanderwolf et al. (2013) |
| Fayodia          | grucilpes                      | Vanderwolf et al. (2013) |
|                  | sp.                            | Vanderwolf et al. (2013) |
| Fibroporia       | vaillantii                     | Vanderwolf et al. (2013) |
| Filobasidium     | floriforme                     | Connell and Staudigel (2013) |
| Filov.           | magnun                         | Vanderwolf et al. (2013) |
|                  | wieringae                      | Connell and Staudigel (2013) |
| Fistulina        | hepatica                       | Vanderwolf et al. (2013) |
| Flaviporus       | brownii                        | Vanderwolf et al. (2013) |
| Flavodon         | flavus                         | Y Y       | Vanderwolf et al. (2013) |
| Genus   | Species                     | China\(^a\) | This study\(^b\) | References                          |
|---------|-----------------------------|-------------|------------------|-------------------------------------|
| Fomes   | *Fomes fomentarius*         |             | Vanderwolf et al. (2013), Ogórek et al. (2017, 2018) |
|         | *Fomes* sp.                 |             | Vanderwolf et al. (2013) |
| Fomitopsis | *Fomitopsis pinicola*         |             | Vanderwolf et al. (2013) |
| Galerina | *Galerina camerina*          |             | Vanderwolf et al. (2013) |
|         | *Ga. pratitcola*             |             | Vanderwolf et al. (2013) |
|         | *Ga. pumila*                 |             | Vanderwolf et al. (2013) |
|         | *Galerina* sp.              |             | Vanderwolf et al. (2013) |
| Ganoderma | *Ganoderma applanatum*      | Y           | Y                | Connell and Staudigel (2013)       |
|         | *Gan. carnosum*             |             | Vanderwolf et al. (2013) |
|         | *Gan. gibbosum*             | Y           | Vanderwolf et al. (2017) |
|         | *Gan. lipsiense*            |             | Vanderwolf et al. (2013) |
|         | *Gan. lucidum*              |             | Vanderwolf et al. (2013) |
|         | *Gan. resinaceum*           |             | Vanderwolf et al. (2013) |
|         | *Ganoderma* sp.             |             | Vanderwolf et al. (2013) |
| Geastrum | *Geastrum minimum*          |             | Vanderwolf et al. (2013) |
|         | *Ge. saccatum*              |             | Vanderwolf et al. (2013) |
| Glaciozyma | *Glaciozyma antarctica*     |             | Brad et al. (2018) |
|         | *Gla. watsonii*             |             | Connell and Staudigel (2013) |
| Gloeohypochnicium | *Gloeohypochnicium analogum* |             | Vanderwolf et al. (2013) |
| Gloeophyllum | *Gloeophyllum abietinum*    |             | Vanderwolf et al. (2013) |
|         | *Glo. odoratum*             |             | Vanderwolf et al. (2013) |
|         | *Glo. sepiarium*            |             | Vanderwolf et al. (2013) |
|         | *Glo. trabeum*              |             | Vanderwolf et al. (2013) |
|         | *Gloeophyllum* sp.          |             | Vanderwolf et al. (2013) |
| Golubevia | *Golubevia pallescens*      | Y           | Y                | Vanderwolf et al. (2013) |
| Gymnopus | *Gymnopus johnstonii*       |             | Vanderwolf et al. (2013) |
| Hennaelea | *Hennaelea luteola*         |             | Vanderwolf et al. (2013) |
|         | *Ha. oryzae*                | Y           | Y                | Vanderwolf et al. (2013) |
| Hemimycena | *Hemimycena cucullata*     |             | Vanderwolf et al. (2013) |
|         | *He. lactea*                |             | Vanderwolf et al. (2013) |
| Heterobasidion | *Heterobasidion annosum*  |             | Vanderwolf et al. (2013), Nováková et al. (2018) |
| Hexagonia | *Hexagonia hydroides*       |             | Vanderwolf et al. (2013) |
| Hohenbuehelia | *Hohenbuehelia petalooides* |             | Vanderwolf et al. (2013) |
| Holtermanniella | *Holtermanniella watticus* |             | Zhang et al. (2014) |
| Hydnopolyporus | *Hydnopolyporus palmae*  |             | Vanderwolf et al. (2013) |
| Hydnum | *Hydnum spinuliferum*        |             | Vanderwolf et al. (2013) |
| Hygrophorus | *Hygrophorus* sp.          |             | Vanderwolf et al. (2013) |
| Hymenochaete | *Hymenochaete corrugata*  |             | Vanderwolf et al. (2013) |
|         | *Hymenochaete* sp.          |             | Vanderwolf et al. (2013) |
| Hymenogaster | *Hymenogaster vulgaris*    |             | Vanderwolf et al. (2013) |
|         | *Hymenogaster* sp.          |             | Vanderwolf et al. (2013) |
| Hyphodermella | *Hyphodermella corrugata* | Y           | Zhang et al. (2017) |
|         | *Hyphodermella* sp.         | Y           | Zhang et al. (2017) |
| Hyphodontia | *Hyphodontia arguta*       |             | Vanderwolf et al. (2013) |
|         | *Hyp. hastata*              |             | Vanderwolf et al. (2013) |
| Hypholoma | *Hypholoma dispersum*       |             | Vanderwolf et al. (2013) |
|         | *Hyph. fasciculare*         |             | Vanderwolf et al. (2013) |
|         | *Hyph. radicosum*           |             | Vanderwolf et al. (2013) |
|         | *Hypholoma* sp.             |             | Vanderwolf et al. (2013) |
| Hypochnicium | *Hypochnicium punctulatum* |             | Vanderwolf et al. (2013) |
| Inocybe | *Inocybe* sp.               |             | Vanderwolf et al. (2013) |
| Irpex   | *Irpex lacteus*             | Y           | Y                | Connell and Staudigel (2013)       |
| Junghuhnia | *Junghuhnia nitida*        |             | Vanderwolf et al. (2013) |
| Laccaria | *Laccaria laccata*          |             | Vanderwolf et al. (2013) |
| Lentinus | *Lentinus* sp.              |             | Vanderwolf et al. (2013) |
| Lenzites | *Lenzites betulae*          |             | Vanderwolf et al. (2013) |
| Lepiota | *Lepiota* sp.               |             | Vanderwolf et al. (2013) |
Table 4 (continued)

| Genus          | Species                  | Chinaa | This studyb | References                      |
|----------------|--------------------------|--------|-------------|---------------------------------|
| Leucogyrophana | Leucogyrophana mollusca  |        |             | Vanderwolf et al. (2013)        |
|                | Leu. pinastri            |        |             | Vanderwolf et al. (2013)        |
| Leucosporidium | Leucosporidium fellii    |        |             | Vanderwolf et al. (2013)        |
| Lycoperdon     | Lycoperdon perlatum      | Y      | Y           | Vanderwolf et al. (2013)        |
|                | Lycoperdon sp.           | Y      | Y           | Vanderwolf et al. (2013)        |
| Malassezia     | Malassezia furfur        |        |             | Vanderwolf et al. (2013)        |
|                | Mal. globosa             |        |             | Connell and Staudigel (2013)    |
|                | Mal. restricta           |        |             | Connell and Staudigel (2013)    |
| Marasmiellus   | Marasmiellus ramealis    |        |             | Vanderwolf et al. (2013)        |
| Marasmius      | Marasmius atrorubens     |        |             | Vanderwolf et al. (2013)        |
|                | Mar. epiphyllus          |        |             | Vanderwolf et al. (2013)        |
| Meira          | Meira nashicola          | Y      | Y           | Vanderwolf et al. (2013)        |
| Merulius       | Merulius melanoceras     |        |             | Vanderwolf et al. (2013)        |
|                | Merulius sp.             |        |             | Vanderwolf et al. (2013)        |
| Moeziomyces    | Moeziomyces antarcticus  |        |             | Vanderwolf et al. (2013)        |
| Mrakia         | Mrakia gelida            |        |             | Brad et al. (2018)              |
|                | Mra. frigida             |        |             | Brad et al. (2018)              |
| Mycena         | Mycena acicula           |        |             | Vanderwolf et al. (2013)        |
|                | Myc. amicta              |        |             | Vanderwolf et al. (2013)        |
|                | Myc. capillaris          |        |             | Vanderwolf et al. (2013)        |
|                | Myc. galericulata        |        |             | Vanderwolf et al. (2013)        |
|                | Myc. metata              |        |             | Vanderwolf et al. (2013)        |
|                | Myc. mucor               |        |             | Vanderwolf et al. (2013)        |
|                | Myc. polyadelphana       |        |             | Vanderwolf et al. (2013)        |
|                | Myc. polygramma          |        |             | Vanderwolf et al. (2013)        |
|                | Myc. strebilicola        |        |             | Vanderwolf et al. (2013)        |
|                | Myc. stylobates          |        |             | Vanderwolf et al. (2013)        |
|                | Myc. sapina              |        |             | Vanderwolf et al. (2013)        |
|                | Myc. virilis             |        |             | Vanderwolf et al. (2013)        |
|                | Mycena sp.               |        |             | Connell and Staudigel (2013), Vanderwolf et al. (2013) |
| Naganishia     | Naganishia albida        |        |             | Vanderwolf et al. (2013)        |
|                | Na. diffuens             |        |             | Vanderwolf et al. (2013)        |
| Naucoria       | Naucoria sp.             |        |             | Vanderwolf et al. (2013)        |
| Neoantrodia    | Neoantrodia serialis     |        |             | Vanderwolf et al. (2013)        |
| Neolentinus    | Neolentinus sulphurens   |        |             | Vanderwolf et al. (2013)        |
| Omphalina      | Omphalina sp.            |        |             | Vanderwolf et al. (2013)        |
| Omnia          | Omnia tomentosa          |        |             | Vanderwolf et al. (2013)        |
| Osteina        | Osteina obducta          |        |             | Vanderwolf et al. (2013)        |
| Ozonium        | Ozonium aureum           |        |             | Vanderwolf et al. (2013)        |
|                | Oc. auricomum            |        |             | Vanderwolf et al. (2013)        |
|                | Oc. stuposum             |        |             | Vanderwolf et al. (2013)        |
| Panellus       | Panellus stipiticus      |        |             | Vanderwolf et al. (2013)        |
| Panus          | Panus neostriatus        |        |             | Vanderwolf et al. (2013)        |
|                | Panus sp.                |        |             | Vanderwolf et al. (2013)        |
| Piptidostrema  | Piptidostrema flavescens | Y      | Y           | Vanderwolf et al. (2013)        |
|                | Pup. laurentii           | Y      | Y           | Vanderwolf et al. (2013)        |
| Parasola       | Parasola plicatilis      |        |             | Vanderwolf et al. (2013)        |
| Paxillus       | Paxillus sp.             |        |             | Vanderwolf et al. (2013)        |
| Peniophora     | Peniophora cinerea       | Y      |             | Zhang et al. (2017)             |
|                | Pen. incarnata           | Y      |             | Zhang (2019)                    |
|                | Pen. limitata            | Y      |             | Zhang et al. (2017)             |
|                | Pen. fuscus              |        |             | Connell and Staudigel (2013)    |
|                | Pen. quercina            |        |             | Vanderwolf et al. (2013)        |
|                | Peniophora sp.           | Y      | Y           | Zhang et al. (2017)             |
| Perenniporia   | Perenniporia medulla-panis| Y   | Y           | Vanderwolf et al. (2013)        |
| Phaeocollybia  | Phaeocollybia sp.        | Y      | Y           | Vanderwolf et al. (2013)        |
| Phaeomarasmius | Phaeomarasmius sp.       |        |             | Vanderwolf et al. (2013)        |
| Genus          | Species                        | China<sup>a</sup> | This study<sup>b</sup> | References                                                                 |
|----------------|--------------------------------|-------------------|------------------------|-----------------------------------------------------------------------------|
| Phanerochaete  | Phanerochaete sordida          | Y                 |                        | Zhang et al. (2017)                                                         |
|                | Phanerochaete sp.              |                   |                        | Connell and Staudigel (2013), Vanderwolf et al. (2013)                      |
| Phanerodontia  | Phanerodontia chrysosporium    |                   |                        | Vanderwolf et al. (2013)                                                    |
| Phellinus      | Phellinus ferruginosus         |                   |                        | Vanderwolf et al. (2013)                                                    |
|                | Phe. gigas                      |                   |                        | Vanderwolf et al. (2013)                                                    |
|                | Phe. punctatus                  |                   |                        | Vanderwolf et al. (2013)                                                    |
| Phlebia        | Phlebia livida                  | Y                 | Y                      | Vanderwolf et al. (2013)                                                    |
|                | Phl. rufa                       |                   |                        | Vanderwolf et al. (2013)                                                    |
|                | Phl. tremella                   |                   |                        | Vanderwolf et al. (2013)                                                    |
| Phlebiopsis    | Phlebiopsis gigantea            |                   | Y                      | Ogórek (2018b)                                                              |
|                | Phlebiopsis sp.                 |                   | Y                      | Vanderwolf et al. (2013)                                                    |
| Phloeomana     | Phloeomana alta                 |                   |                        | Vanderwolf et al. (2013)                                                    |
|                | Philo. minutula                 |                   |                        | Vanderwolf et al. (2013)                                                    |
| Pholiota       | Pholiota multicingulata         |                   |                        | Vanderwolf et al. (2013)                                                    |
| Physiophorinus | Physiophorinus vitreus          |                   | Y                      | Vanderwolf et al. (2013)                                                    |
| Plateus        | Plateus sp.                     |                   |                        | Vanderwolf et al. (2013)                                                    |
| Podoscypha     | Podoscypha sp.                  |                   |                        | Vanderwolf et al. (2013)                                                    |
| Polyporus      | Polyporus sp.                   |                   |                        | Connell and Staudigel (2013), Vanderwolf et al. (2013)                      |
|                | Poly. venetus                   |                   |                        | Vanderwolf et al. (2013)                                                    |
| Poria          | Poria sp.                       |                   |                        | Vanderwolf et al. (2013)                                                    |
| Postia         | Postia balsamea                 |                   |                        | Vanderwolf et al. (2013)                                                    |
|                | Poz. caesia                     |                   |                        | Vanderwolf et al. (2013)                                                    |
|                | Poz. floreformis                |                   |                        | Vanderwolf et al. (2013)                                                    |
|                | Poz. stipitata                  |                   |                        | Vanderwolf et al. (2013)                                                    |
| Psathyrella    | Psathyrella corrugis            |                   |                        | Vanderwolf et al. (2013)                                                    |
| Psathyrella    | Psathyrella candolleana         | Y                 |                        | Vanderwolf et al. (2013), Zhang et al. (2017)                              |
|                | Psa. corrugis                   | Y                 |                        | Zhang et al. (2017)                                                         |
|                | Psathyrella sp.                 |                   |                        | Vanderwolf et al. (2013)                                                    |
| Pseudonoinotus | Pseudonoinotus dryadeus         |                   |                        | Vanderwolf et al. (2013)                                                    |
| Pseudocyma     | Pseudocyma sp.                  |                   |                        | Vanderwolf et al. (2013)                                                    |
| Psilocybe      | Psilocybe sp.                   |                   | Y                      | Vanderwolf et al. (2013)                                                    |
| Puccinia       | Puccinia sp.                    |                   | Y                      | Vanderwolf et al. (2013)                                                    |
| Ramaria        | Ramaria sp.                     |                   |                        | Vanderwolf et al. (2013)                                                    |
| Resinicium     | Resinicium bicolor              |                   |                        | Connell and Staudigel (2013)                                                |
| Resinoporia    | Resinoporia crassa              |                   |                        | Vanderwolf et al. (2013)                                                    |
| Rhizoctonia    | Rhizoctonia solani              |                   |                        | Pusz et al. (2018a)                                                         |
| Rhizomarasmius | Rhizomarasmius setosus          |                   |                        | Vanderwolf et al. (2013)                                                    |
| Rhizomorpha    | Rhizomorpha sp.                 |                   |                        | Vanderwolf et al. (2013)                                                    |
| Rhodofomes     | Rhodofomes roseus               |                   |                        | Vanderwolf et al. (2013)                                                    |
| Rhodonia       | Rhodonia placenta               |                   |                        | Vanderwolf et al. (2013)                                                    |
| Rhodotomula    | Rhodotomula dairenensis         |                   |                        | Vanderwolf et al. (2013)                                                    |
|                | Rho. glutinis                   |                   |                        | Vanderwolf et al. (2013), Ogórek et al. (2013, 2016b, d)                   |
|                | Rho. mucilaginosus              | Y                 | Y                      | Connell and Staudigel (2013), Vanderwolf et al. (2013)                      |
|                | Rho. rubra                      |                   |                        | Ogórek et al. (2013, 2016c, d), Kokurewicz et al. (2016)                    |
|                | Rhodotomula sp.                 |                   |                        | Vanderwolf et al. (2013)                                                    |
| Rigidoporus    | Rigidoporus lineatus            |                   |                        | Vanderwolf et al. (2013)                                                    |
|                | Ri. microporus                  |                   |                        | Vanderwolf et al. (2013)                                                    |
|                | Ri. xanganolentus               |                   |                        | Vanderwolf et al. (2013)                                                    |
|                | Ri. undatus                     |                   |                        | Vanderwolf et al. (2013)                                                    |
|                | Ri. vincent                     | Y                 |                        | Zhang (2019)                                                                |
|                | Rigidoporus sp.                 | Y                 |                        | Zhang et al. (2017)                                                         |
| Rusula         | Ruxula sp.                      |                   |                        | Vanderwolf et al. (2013)                                                    |
| Saitozyma      | Saitozyma podzolica             | Y                 | Y                      | Vanderwolf et al. (2013)                                                    |
| Sampaiozyma    | Sampaiozyma ingeniosa           | Y                 | Y                      | Vanderwolf et al. (2013)                                                    |
| Schizophyllum   | Schizophyllum commune            | Y                 | Y                      | Vanderwolf et al. (2013), Zhang et al. (2017)                              |
| Schizopora     | Schizopora paradoxa              |                   |                        | Vanderwolf et al. (2013)                                                    |
| Scleroderma    | Scleroderma sp.                 |                   |                        | Vanderwolf et al. (2013)                                                    |
| Genus     | Species                     | Chinaa | This studyb | References                                      |
|-----------|-----------------------------|--------|-------------|------------------------------------------------|
| Serpula   | Serpula himantioides        |        |             | Vanderwolf et al. (2013)                        |
|           | Ser. lacrymans              |        |             | Vanderwolf et al. (2013)                        |
| Sistotrema| Sistotrema brinkmannii      |        |             | Connell and Staudigel (2013)                    |
| Skeletocatis | Skeletocaris crysella      |        |             | Connell and Staudigel (2013)                    |
| Sporabolomyces | Sporabolomyces coprosmae    |        |             | Vanderwolf et al. (2013)                        |
|           | Spor. roseus                |        |             | Vanderwolf et al. (2013), Martin-Sanchez et al. (2014) |
|           | Spor. ruberrimus            |        |             | Martin-Sanchez et al. (2014)                    |
| Sporabolomyces sp. | Sporabolomyces sp.       |        |             | Connell and Staudigel (2013), Martin-Sanchez et al. (2014) |
| Sporotrichum | Sporotrichum flavissimum    |        |             | Vanderwolf et al. (2013)                        |
|           | Sporotrichum sp.            |        |             | Vanderwolf et al. (2013)                        |
| Steccerinum| Steccerinum sp.             | Y      |             | Zhang (2019)                                    |
| Stereum   | Stereum hirsutum            |        |             | Vanderwolf et al. (2013)                        |
|           | Ster. sanguinolentum        |        |             | Connell and Staudigel (2013)                    |
|           | Stereum sp.                 |        |             | Connell and Staudigel (2013), Vanderwolf et al. (2013) |
| Strobilarius | Strobilarius esculentus     |        |             | Vanderwolf et al. (2013)                        |
| Tapinella | Tapinella panuoides         |        |             | Vanderwolf et al. (2013)                        |
| Taxonixa  | Taxonixa palliata           |        |             | Vanderwolf et al. (2013), Zhang et al. (2014)   |
| Tetrapyrgos | Tetrapyrgos nigripes        |        |             | Vanderwolf et al. (2013)                        |
| Thanatephorus | Thanatephorus cucumeris    |        |             | Vanderwolf et al. (2013)                        |
| Thelephora | Thelephora penicillata      |        |             | Vanderwolf et al. (2013)                        |
| Tilletia  | Tilletia sp.                |        |             | Vanderwolf et al. (2013)                        |
| Tinctoporellus | Tinctoporellus epimitinus  | Y      |             | Zhang et al. (2017)                             |
| Tomentella| Tomentella lapida           |        |             | Vanderwolf et al. (2013)                        |
|           | Tomentella sp.              |        |             | Vanderwolf et al. (2013)                        |
| Trametes  | Trametes cubensis           |        |             | Connell and Staudigel (2013)                    |
|           | Tra. gibbosa                |        |             | Vanderwolf et al. (2013)                        |
|           | Tra. hirsuta                | Y      |             | Vanderwolf et al. (2013), Man et al. (2015), Ogórek et al. (2017, 2018a) |
|           | Tra. ochracea               |        |             | Vanderwolf et al. (2013)                        |
|           | Tra. pubescens              |        |             | Vanderwolf et al. (2013)                        |
|           | Trametes sp.                |        |             | Vanderwolf et al. (2013)                        |
|           | Tra. trogii                 | Y      | Y           | Vanderwolf et al. (2013)                        |
|           | Tra. versicolor             | Y      |             | Vanderwolf et al. (2013), Zhang et al. 2017    |
| Trechispora| Trechispora alnicola        |        |             | Vanderwolf et al. (2013)                        |
| Tremella  | Tremella mesenterica        |        |             | Vanderwolf et al. (2013)                        |
|           | Tremella sp.                |        |             | Vanderwolf et al. (2013)                        |
| Trichaptum| Trichaptum sp.              |        |             | Connell and Staudigel (2013)                    |
| Tricholoma| Tricholoma saponaceum       |        |             | Vanderwolf et al. (2013)                        |
| Tricholomopsis | Tricholomopsis aurea      |        |             | Vanderwolf et al. (2013)                        |
| Trichosporon | Trichosporon aggregataiens |        |             | Novákůvá et al. (2015)                         |
|           | Tricho. akiyoshidatsum      | Y      | Y           | Vanderwolf et al. (2013), Zhang et al. (2017)   |
|           | Tricho. dallicum            |        |             | Zhang et al. (2014), Vanderwolf et al. (2015)   |
|           | Tricho. cavernicola         | Y      | Y           | Vanderwolf et al. (2013)                        |
|           | Tricho. chiroptororium      | Y      | Y           | Vanderwolf et al. (2013)                        |
|           | Tricho. coprophilum         |        |             | Vanderwolf et al. (2013)                        |
|           | Tricho. ovoides             |        |             | Vanderwolf et al. (2013)                        |
|           | Tricho. porosum             |        |             | Vanderwolf et al. (2013), Mitova et al. (2017)  |
|           | Tricho. shinodae            | Y      | Y           | Novákůvá et al. (2015)                         |
|           | Tricho. speluncum           |        |             | Vanderwolf et al. (2013, 2015, 2019), Man et al. (2015), Bercea et al. (2018), Burow et al. (2019) |
| Tubaria   | Tubaria furfuracea          |        |             | Vanderwolf et al. (2013)                        |
| Ustilago  | Ustilago tritici            |        |             | Connell and Staudigel (2013), Vanderwolf et al. (2013) |
|           | Ustilago sp.                |        |             | Connell and Staudigel (2013)                    |
| Vishniacozyma | Vishniacozyma dimenae    |        |             | Martin-Sanchez et al. (2014)                    |
| Vanrija   | Vanrija fragicola           |        |             | Zhang et al. (2014)                             |
| Volvariella | Volvariella sp.            |        |             | Vanderwolf et al. (2013)                        |
| Wallemia  | Wallemia mellicola          | Y      | Y           | Vanderwolf et al. (2013)                        |
|           | Wal. sebi                   |        |             | Vanderwolf et al. (2013)                        |
### Table 4 (continued)

| Genus          | Species                      | China<sup>a</sup> | This study<sup>b</sup> | References                                                                 |
|----------------|-------------------------------|-------------------|--------------------------|-----------------------------------------------------------------------------|
| Xylodon        | Xylodon rimosissimus          |                   |                          | Connell and Staudigel (2013)                                                |
| Mortierellomycotina | Mortierella alliacea          |                   |                          | Vanderwolf et al. (2013)                                                   |
|                | Mo. alpina                    | Y                 | Y                        | Vanderwolf et al. (2013), Zhang et al. (2014), Man et al. (2015), Zhang et al. (2017), Dyląg et al. (2019), Popkova and Mazina (2019) |
|                | Mo. amoeboides                |                   |                          | Zhang et al. (2014)                                                        |
|                | Mo. baumieri                   |                   |                          | Vanderwolf et al. (2013)                                                   |
|                | Mo. cheni                    |                   |                          | Vanderwolf et al. (2013)                                                   |
|                | Mo. clonocystis               | Y                 | Y                        | Vanderwolf et al. (2013), Zhang et al. (2014)                              |
|                | Mo. dichotoma                 | Y                 | Y                        | Vanderwolf et al. (2013)                                                   |
|                | Mo. elongata                  |                   |                          | Vanderwolf et al. (2013)                                                   |
|                | Mo. epilacia                  | Y                 | Y                        | Vanderwolf et al. (2013)                                                   |
|                | Mo. exigua                    |                   |                          | Vanderwolf et al. (2013)                                                   |
|                | Mo. fimbricystis              |                   |                          | Out et al. (2016)                                                          |
|                | Mo. gamasia                   |                   |                          | Vanderwolf et al. (2013), Zhang et al. (2014)                              |
|                | Mo. histoplasmatoides         |                   |                          | Zhang et al. (2014)                                                        |
|                | Mo. horticola                 | Y                 |                          | Zhang et al. (2017)                                                        |
|                | Mo. humilis                   |                   |                          | Vanderwolf et al. (2013)                                                   |
|                | Mo. hyalinia                  | Y                 | Y                        | Vanderwolf et al. (2013), Zhang et al. (2014), Pusz et al. (2015), Out et al. (2016), Pusz et al. (2017), Zhang et al. (2017) |
|                | Mo. hypnichladia              | Y                 | Y                        | Zhang et al. (2017)                                                        |
|                | Mo. indolii                   | Y                 | Y                        | Zhang et al. (2017)                                                        |
|                | Mo. jenkinsi                  |                   |                          | Zhang et al. (2014)                                                        |
|                | Mo. minatissima               | Y                 |                          | Zhang et al. (2017)                                                        |
|                | Mo. nantahalensis             |                   |                          | Vanderwolf et al. (2013)                                                   |
|                | Mo. oligospora                |                   |                          | Vanderwolf et al. (2013)                                                   |
|                | Mo. parvispora                |                   |                          | Ogórek et al. (2017), Burow et al. (2019)                                  |
|                | Mo. polycephala               |                   |                          | Vanderwolf et al. (2013), Zhang et al. (2014), Out et al. (2016)            |
|                | Mo. pulchella                 |                   |                          | Vanderwolf et al. (2013)                                                   |
|                | Mo. reticulata                | Y                 | Y                        | Vanderwolf et al. (2013), Zhang et al. (2014)                              |
|                | Mo. sarnyensis                |                   |                          | Vanderwolf et al. (2013), Zhang et al. (2014)                              |
|                | Mo. sclerotialla              |                   |                          | Out et al. (2016)                                                          |
|                | Mo. selenospora               | Y                 |                          | Man et al. (2015)                                                          |
|                | Mo. stylospora                |                   |                          | Zhang et al. (2014)                                                        |
|                | Mo. verticillata              | Y                 | Y                        | Vanderwolf et al. (2013)                                                   |
|                | Mo. zonata                    | Y                 | Y                        | Vanderwolf et al. (2013)                                                   |
|                | Mortierella sp.               | Y                 | Y                        | Vanderwolf et al. (2013, 2015, 2019), Martin-Sanchez et al. (2014), Zhang et al. (2014), Yoder et al. (2015), Out et al. (2016), Mitova et al. (2017), Zhang et al. (2017), Novák, Novákova et al. (2018), Leplat et al. (2019), Burow et al. (2019) |
| Mucoromycotina | Absidia caerulea              |                   |                          | Vanderwolf et al. (2013)                                                   |
|                | Ab. cylindrospora             |                   |                          | Vanderwolf et al. (2013), Popkova and Mazina (2019)                        |
|                | Ab. glauca                    |                   |                          | Vanderwolf et al. (2013), Kokurewicz et al. (2016), Ogórek et al. (2016b) |
|                | Ab. repens                    |                   |                          | Vanderwolf et al. (2013)                                                   |
|                | Ab. spinosa                   |                   |                          | Vanderwolf et al. (2013), Novákova et al. (2018)                          |
|                | Absidia sp.                   |                   |                          | Vanderwolf et al. (2013), Leplat et al. (2018), Dylag et al. (2019), Popkova and Mazina (2019) |
| Actinomucor    | Actinomucor elegans           |                   |                          | Vanderwolf et al. (2013, 2015, 2019), Novákova et al. (2018)               |
|                | Actinomucor sp.               | Y                 |                          | Jiang et al. (2017a, b)                                                   |
| Choanephora    | Choanephora cucurbitarum      |                   |                          | Vanderwolf et al. (2013)                                                   |
| Circinella     | Circinella muscae             |                   |                          | Vanderwolf et al. (2013)                                                   |
|                | Ci. simplex                   |                   |                          | Vanderwolf et al. (2013)                                                   |
|                | Ci. umbellata                 | Y                 | Y                        | Vanderwolf et al. (2013)                                                   |
|                | Circinella sp.                | Y                 | Y                        | Vanderwolf et al. (2013)                                                   |
| Cunninghamella | Cunninghamella echinulata     | Y                 | Y                        | Vanderwolf et al. (2013, 2015, 2019), Novákova et al. (2018)               |
|                | Can. elegans                  |                   |                          | Vanderwolf et al. (2013, 2015, 2019), Novákova et al. (2018)               |
|                | Cunninghamella sp.            | Y                 | Y                        | Vanderwolf et al. (2013)                                                   |
| Gongronella    | Gongronella sp.               | Y                 | Y                        | Vanderwolf et al. (2013)                                                   |
| Genus       | Species                | China | This study | References                                                                 |
|-------------|------------------------|-------|------------|-----------------------------------------------------------------------------|
| Helicostylum| *Helicostylum elegans*  |       |            | Vanderwolf et al. (2013), Zhang et al. (2014)                               |
|             | *Hel. pulchrum*        |       |            | Zhang et al. (2014)                                                         |
|             | *Helicostylum sp.*     |       |            | Vanderwolf et al. (2013)                                                   |
| Lichtheimia | *Lichtheimia blakesleeanana* |     |            | Vanderwolf et al. (2013)                                                   |
|             | *L. corymbifera*       |       |            | Vanderwolf et al. (2013)                                                   |
| Mucor       | *Mucor abundans*       |       |            | Burow et al. (2019)                                                        |
|             | *M. aligarensis*       |       |            | Mitova et al. (2017), Ogórek et al. (2017), Dylag et al. (2019)             |
|             | *M. bacilliformis*     | Y     | Y          | Vanderwolf et al. (2013)                                                   |
|             | *M. circinelloides*    | Y     |            | Vanderwolf et al. (2013), Jacobs et al. (2017), Mitova et al. (2017)       |
|             | *M. corticola*         |       |            | Vanderwolf et al. (2013)                                                   |
|             | *M. flavus*            | Y     |            | Vanderwolf et al. (2013), Zhang et al. (2014), Kokurewicz et al. (2016),  |
|             |                        |       |            | Jacobs et al. (2017), Jiang et al. (2017a, b), Zhang et al. (2017), Burow  |
|             |                        |       |            | et al. (2019)                                                               |
|             | *M. fragilis*          | Y     | Y          | Vanderwolf et al. (2013), Zhang et al. (2014), Puṣz et al. (2015), Kokure-  |
|             |                        |       |            | wicz et al. (2016), Ogórek et al. (2016b, c, 2017, 2018), Puṣz et al. (2017), |
|             |                        |       |            | Zhang et al. (2017), Popkova and Mazina (2019)                             |
|             | *M. fuscus*            | Y     |            | Vanderwolf et al. (2013), Man et al. (2015)                                |
|             | *M. hiemalis*          | Y     | Y          | Vanderwolf et al. (2013), Zhang et al. (2014), Puṣz et al. (2015), Kokure-  |
|             |                        |       |            | wicz et al. (2016), Ogórek et al. (2016b, c, 2017, 2018), Puṣz et al. (2017), |
|             |                        |       |            | Zhang et al. (2017), Popkova and Mazina (2019)                             |
|             | *M. indicus*           |       |            | Vanderwolf et al. (2013)                                                   |
|             | *M. irregularis*       | Y     |            | Zhang et al. (2017)                                                        |
|             | *M. luteus*            |       |            | Kokurewicz et al. (2016), Zhang et al. (2014), Puṣz et al. (2015)           |
|             | *M. moelleri*          | Y     |            | Zhang et al. (2017)                                                        |
|             | *M. mucedo*            |       |            | Ogórek et al. (2013, 2014a), Vanderwolf et al. (2013)                       |
|             | *M. piriformis*        | Y     |            | Vanderwolf et al. (2013)                                                   |
|             | *M. plumbeus*          | Y     |            | Vanderwolf et al. (2013), Dylag et al. (2019)                              |
|             | *M. racemosus*         | Y     |            | Vanderwolf et al. (2013), Out et al. (2016), Kokurewicz et al. (2016), Zhang |
|             |                        |       |            | et al. (2017)                                                               |
|             | *M. ramossissimus*     | Y     |            | Vanderwolf et al. (2013)                                                   |
|             | *M. rouxi*             | Y     |            | Jiang et al. (2017a, b), Popkova and Mazina (2019)                          |
|             | *M. silvaticus*        | Y     |            | Vanderwolf et al. (2013)                                                   |
|             | *M. strictus*          | Y     |            | Out et al. (2016)                                                          |
|             | *M. subtilissimus*     | Y     |            | Vanderwolf et al. (2013)                                                   |
|             | *M. troglrophilus*     | Y     |            | Vanderwolf et al. (2013)                                                   |
| Macor sp.   |                       | Y     | Y          | Taylor et al. (2013), Vanderwolf et al. (2013, 2015, 2019), Ogórek et al.  |
|             |                        |       |            | (2014b, c), Zhang et al. (2014), Popović et al. (2015), Yoder et al. (2015),|
|             |                        |       |            | Jiang et al. (2017a, b), Mitova et al. (2017), Zhang et al. (2017), Leplat | |
|             |                        |       |            | et al. (2018), Burow et al. (2019)                                         |
| Phycomyces   | *Phycomyces sp.*       | Y     |            | Vanderwolf et al. (2013)                                                   |
| Pilobolus    | *Pilobolus sp.*        | Y     |            | Vanderwolf et al. (2013)                                                   |
| Rhizomacor   | *Rhizomacor pusillus*  |       |            | Vanderwolf et al. (2013)                                                   |
| Rhizopus     | *Rhizopus arrhizus*    |       |            | Vanderwolf et al. (2013)                                                   |
|             | *Rhi. microsporus*     |       |            | Vanderwolf et al. (2013)                                                   |
|             | *Rhi. oryzae*          | Y     |            | Zhang et al. (2017)                                                        |
|             | *Rhi. stolonifer*      | Y     |            | Ogórek et al. (2013, 2014a, 2016b, c, d), Vanderwolf et al. (2013), Kokure- |
|             |                        |       |            | wicz et al. (2016), Jiang et al. (2017a, b), Novákóvá et al. (2018), Popkova |
|             |                        |       |            | and Mazina (2019)                                                          |
| Rhizopus sp. |                       | Y     |            | Taylor et al. (2013), Vanderwolf et al. (2013), Ogórek et al. (2014a, b),  |
|             |                        |       |            | Yoder et al. (2015)                                                        |
| Syncphalastrum| *Syncphalastrum racemosum* |     |            | Vanderwolf et al. (2013)                                                   |
| Syncephalastrum| *Syncephalastrum sp.* |       |            | Vanderwolf et al. (2013)                                                   |
| Thamnidium   | *Thamnidium elegans*   |       |            | Vanderwolf et al. (2013, 2015)                                             |
| Thamnostylus | *Thamnostyllum piriforme* |       |            | Vanderwolf et al. (2013)                                                   |
| Umbelopsis   | *Umbelopsis angularis* |       |            | Burow et al. (2019)                                                        |
|             | *Um. dimorpha*         | Y     | Y          | Vanderwolf et al. (2013)                                                   |
|             | *Um. isabellina*       | Y     | Y          | Vanderwolf et al. (2013)                                                   |
|             | *Um. ramanniana*       |       |            | Vanderwolf et al. (2013), Zhang et al. (2014)                              |
| Entomophthoromycotina | *Conidiobolus coronatus* |     |            | Burow et al. (2019)                                                        |
| Conidiobolus | *Conidiobolus sp.*     |       |            | Vanderwolf et al. (2013)                                                   |
| Genus       | Species               | China | This study | References               |
|-------------|-----------------------|-------|------------|--------------------------|
| Entomophaga | Entomophaga grylli    | Y     | Y          | Vanderwolf et al. (2013) |
| Entomophthora| Entomophthora dextruens|       |            | Vanderwolf et al. (2013) |
| Chytridiomycota | Batrachochytrium dendrobatis | Y     | Y          | Vanderwolf et al. (2013) |
| Cladochytrium | Cladochytrium tenue   | Y     | Y          | Vanderwolf et al. (2013) |
| Rhizophydium | Rhizophydium sp.      | Y     | Y          | Vanderwolf et al. (2013) |
| Zoopagomyctina | Rholamomyces elegans | Y     | Y          | Vanderwolf et al. (2013) |
| Syncephalis | Syncephalis sp.       | Y     | Y          | Vanderwolf et al. (2013) |
| Kickxella   | Kickxella alabastrina | Y     | Y          | Vanderwolf et al. (2019) |
| Kickxellomyctina | Coemansia aciculifera | Y     | Y          | Vanderwolf et al. (2013) |
| Glomeromycota | Entrophospora sp.     | Y     | Y          | Vanderwolf et al. (2013) |

**Paraphaeosphaeria** O.E. Erikss.

*Paraphaeosphaeria* was introduced by Eriksson (1967) to accommodate four species with oblong-cylindric ascospores, and placed in *Didymosphaeriaceae* (= Montagulaceae) by Ariyawansa et al. (2014) based on multi-locus phylogeny. Currently there are 33 species in *Paraphaeosphaeria* (Wijayawardene et al. 2020). Here, we introduce a new species of *Paraphaeosphaeria* named as *P. hydei* isolated from plant debris (Fig. 5).

**Paraphaeosphaeria hydei** Z.F. Zhang & L. Cai, sp. nov.

*Index Fungorum number:* 556392, *Facesoffungi number:* FoF 08425, Fig. 6

*Etymology:* “hydei” named for in honour of Prof. Kevin D. Hyde for his contribution to ascomycetes taxonomy.

*Holotype:* HMAS 247988.

*Hyphae* hyaline to brown, septate, branched, sometimes swollen to chlamydospore-like cell, brown, thick-walled, up to 12 µm diam. *Asexual morph* *Conidiotoma* pycnidial, erumpent, single, or eustromatic and more complex, mostly superficial, globose, glabrous, dark brown, up to 200 µm diam, with central ostiole. *Pycnidial wall* composed of an outer layer of yellow-brown, thick-walled textura angularis, and an inner layer with hyaline, thin-walled cells. *Conidiogenous cells* lining the inner cavity, ampulliform or flask-shaped, smooth, hyaline, 4.0–7.5 × 5.0–8.0 µm. *Conidia* abundant, solitary, unicellular, ovoid or ellipsoidal with obtuse ends, smooth, thick-walled, brown, 6.0–8.0 × 4.0–6.0 µm (± SD = 7.1 ± 0.55 × 5.2 ± 0.45 µm, n = 60), average L/W ratio 1.36 ± 0.15. *Sexual morph* not observed.

*Culture characteristics*—Colonies on PDA attaining 45 mm diam. after 21 days, flat, felty, margin entire, dark olive (27F2) at margin, pale gray (28B1) at middle, olive (27D3) in center with pale gray (28B1) patches, aerial mycelia sparse. Reverse dark olive (27F2). Colonies on OA attaining 45 mm diam. after 21 days, flat, black to dark olive (26F5), aerial mycelia sparse, with abundant black conidiomata scattered. Reverse black. Colonies on SNA attaining 45 mm diam. after 21 days, aerial mycelia sparse, colorless. Reverse colorless. Sporulation within 20 days on PDA and OA.

*Material examined:* CHINA, Yunnan, Yiliang, Sanjiao Cave, N 25.134°, E 103.383°, on plant debris, May 2016, Z.F. Zhang, HMAS 247988 (holotype designated here), ex-type living culture CGMCC3.19317 = LC12564; ibid., LC12565.

*Notes:* In the multi-locus phylogenetic analysis, this new species clustered with *Paraphaeosphaeria arecacearum* Verkley, Göker & Stielow in a distinct clade (Fig. 5). However, conidia of *P. arecacearum* are longer than that of *P. dispersa* (3.5–6.0 µm vs. 3.0–4.0 µm, 2.0 ± 0.04 vs. 1.36 ± 0.15 for average L/W ratio). In addition, *P. dispersa* growing on OA (45 mm/14 days) is much slower than *P. arecacearum* (70–75 mm/10 days).

**Setophaeosphaeria** Crous & Y. Zhang ter

*Setophaeosphaeria* was established by Crous et al. (2014) to accommodate ascomycetes that are dissimilar to *Phaeosphaeria* in the absence of ascomatal setae, and with phoma-like anamorphs. *Setophaeosphaeria* currently comprises six species, with *S. hemerocallidis* Crous & Y. Zhang ter as type, and one new species described herein as *S. microsporai* (Fig. 7).

**Setophaeosphaeria microspora** Z.F. Zhang & L. Cai, sp. nov.

*Index Fungorum number:* 556393, *Facesoffungi number:* FoF 08426; Fig. 8

*Etymology:* Referring to its smaller conidia than other species in this genus.
Fig. 4 Maximum likelihood (ML) tree based on LSU sequences showing the order placements of new species described in this study. 122 strains belong to eight orders are used. The tree is rooted with Sarcoscypha coccinea (FF176859). Tree topology of the ML analysis was similar to the BI. The Best scoring RAxML tree with a final likelihood value of –9721.274792. The matrix had 422 distinct alignment patterns, with 7.98% of undetermined characters or gaps. Base frequencies estimated by jModelTest were as follows, A = 0.1940, C = 0.2411, G = 0.3481, T = 0.2168; substitution rates AC = 0.9460, AG = 3.5105, AT = 1.8719, CG = 0.5969, CT = 8.3876, GT = 1.0000; gamma shape = 0.5390. ML, bootstrap values (≥70%) and Bayesian posterior probability (≥90%) are indicated along branches (ML/PP). Novel species are indicated in bold font and the orders are shown on the right side of the figure.
Sporulation within 15 d on OA and SNA. Cottony, margin entire, beige (3B3). Reverse beige (3B3). Nies on SNA attaining 39–40 mm diam. after 10 days, flat, from margin to center. Reverse white to olive (28E5). Colonial diam. after 10 days, flat, ulotrichy, white to pale gray (3B1) to olive (2E3). Colonies on OA attaining 34–37 mm diam. from margin to center. Reverse beige (3B3).

Sexual morph not observed.

Conidia abundant, unicellular, cylindrical, Phialides arising laterally on vegetative hyphae. Asexual morph Conidiomata pycnidial, single or eustromatic, superficial or immersed, globose, brown to pale brown, up to 260 µm diam, with central ostiole.

Pycnial wall of 2–3 layers of the brown texture angularis. Setae slightly flexuous, septate, unbranched, smooth, thick-walled, brown to pale brown from base to apex, more abundant surrounding ostiole, with obtuse ends, 45–130 µm long, 2.0–4.0 µm wide. Conidiogenous cells lining the inner cavity, ampulliform, proliferating several times percurrently at apex, smooth, hyaline, 7.0–10.0 × 2.5–4.0 µm. Conidia abundant, unicellular, cylindrical, guttulate, with obtuse ends, smooth, brown, 3.0–4.5 × 1.5–2.0 µm (± SD = 4.0 ± 0.25 × 1.7 ± 0.13 µm, n = 60). Sexual morph not observed.

Culture characteristics—Colonies on PDA attaining 30–34 mm diam. after 10 days, flat, margin entire, beige (2B4) to olive (2E3) from margin to center. Reverse beige (2B4) to olive (2E3). Colonies on OA attaining 34–37 mm diam. after 10 days, flat, ulotrichy, white to pale gray (3B1) from margin to center. Reverse white to olive (2B8E5). Colonies on SNA attaining 39–40 mm diam. after 10 days, flat, cottony, margin entire, beige (3B3). Reverse beige (3B3). Sporulation within 15 d on OA and SNA.

Material examined: CHINA, Guangxi, Laibin, Sanshan Cave, N 23.41°, E 108.931°, on soil, May 2016, Z.F. Zhang, HMAS 247990 (holotype designated here), ex-type living culture CGMCC3.19301 = LC9240; ibid., LC10444.

Notes: Our strains form a distinct clade with Setophaeosphaeria species based on ITS, LSU and TUB sequences (Fig. 7), but can be distinguished from known species by its smaller conidia (> 6.0 µm long and 2.0–3.0 µm wide in other species) and larger conidiogenous cells (< 7.0 µm wide in other species).

Class Eurotiomycetes

Eurotiomycetes is one of the most diverse classes in the subphylum Pezizomycotina. We follow the latest classification of Gueidan et al. (2014) and Geiser et al. (2015).

Subclass Eurotiomycetidae

Eurotiomycetidae comprises some of the most commonly encountered microfungi, including the well known genera Aspergillus and Penicillium, some species of which can survive at extreme environments, such as deep water and high temperature (Geiser et al. 2015).

Aspergillaceae Link

Aspergillaceae was established by Link (1826), and re-instated by Houbraken and Samson (2011) based on multi-locus phylogeny. Species belonging to this family have diverse physiological properties; some could tolerate extreme conditions, such as high sugar or salt concentrations, low or high temperatures, low acidity or low oxygen levels (Houbraken et al. 2014). Aspergillaceae species are predominantly saprobic, while a few species are pathogenic (Houbraken et al. 2014).

Aspergillus P. Micheli ex Haller

Aspergillus is one of the most economically important genera of fungi. The aspergillum-like sporebearing structure is the defining characteristic of Aspergillus. Currently, 4 subgenera and 19 sections are accepted in Aspergillus (Houbraken et al. 2014). In this study, three new species are described as A. limoniformis, A. phialiformis and A. phialosimplex (Fig. 9).

Aspergillus limoniformis Z.F. Zhang & L. Cai, sp. nov.

Index Fungorum number: 556394, Facesoffungi number: FoF 08427; Fig. 10

Etymology: Referring to the shape of its limoniform conidia.

Holotype: HMAS 248014.

Hyphae hyaline, septate, smooth, branched, 1.0–2.5 µm wide. Asexual morph Conidiogenous cells simple phialides arising laterally on vegetative hyphae. Phialides cylindrical, ampulliform, or tapering with enlarged base, smooth, hyaline,
variable in length, 4.0–10.0 µm long, 1.5–5.0 µm diam. at base, tapering to 1.0–2.0 µm diam. at apex. Conidia formed in long chains, limoniform or subglobose, obviously apiculate, thick-walled, rough initially, then becoming smooth with age, hyaline, 3.0–4.5 × 2.5–4.0 µm (\(\bar{x} \pm SD = 3.7 \pm 0.33 \times 3.3 \pm 0.25 \mu m, n = 60\)). Sexual morph not observed.

**Culture characteristics**—Colonies on PDA attaining 25–31 mm diam. after 4 weeks, flat, felty to pulverulent, margin entire, beige (5B3) at fruiting region, white to dark brown (5F8) from middle to aging region. Reverse cream yellow (3A2) to dark brown (6D8). Colonies on OA attaining 24–35 mm diam. after 4 weeks, flat, margin entire, white to pale brown (5A2), aerial mycelia extremely sparse. Reverse pale brown (5A2) to brown (6D8). Colonies on SNA attaining 29–39 mm diam. after 4 weeks, flat, pulverulent, whitesmoke. Reverse whitesmoke. Sporulation within 3 weeks.

**Material examined**: CHINA, Yunnan, Mengzi, Mingjiu old Cave, N 23.487°, E 103.619°, on bat guano, May 2016, Z.F. Zhang, HMAS 248014 (holotype designated here), ex-type living culture CGMCC3.19323 = LC126098; ibid., LC12610.

**Notes**: Phylogenetic analyses based on ITS, RPB2, Tsr and TUB sequences showed that our new species should be classified in *Aspergillus* subgenus *Polypaecilum* (Fig. 9), which were also supported by the phialosimplex-like morphologies. *Aspergillus limoniformis* is phylogenetically closely related...
Asexual morph

Conidiogenous cells simple phialides arising laterally on vegetative hyphae. Phialides cylindrical or tapering with enlarged base, occasionally branched, smooth, hyaline, variable in length, 4.0–12.0 μm long, 1.0–4.0 μm diam at base, tapering to 1.0–2.0 μm diam. at apex. Conidia formed in long chains, limoniform, subglobose or globose, apiculate, thick-walled, rough initially, then becoming smooth with age, hyaline, 2.5–4.0 μm \((x \pm SD = 3.3 \pm 0.28, n = 60)\).

Sexual morph

not observed.

Culture characteristics—Colonies on PDA attaining 36–41 mm diam. after 4 weeks, flat, margin undulate, aerial mycelia sparse, pulverulent in center, white. Reverse orangeyellow (4A2). Colonies on OA attaining 31–36 mm diam. after 4 weeks, flat, margin undulate, aerial mycelia sparse. Reverse cream-yellow (4A2) to brown (5C7). Colonies on SNA attaining 43–47 mm diam. after 4 weeks, flat, margin undulate, aerial mycelia sparse, pulverulent in center, white. Reverse floralwhite (4A2). Sporulation within 3 weeks.

Material examined: CHINA, Yunnan, Yiliang, Sanjiao Cave, N 25.134°, E 103.383°, on rock, May 2016, Z.F. Zhang, HMAS 248017 (holotype designated here), ex-type living culture CGMCC3.19314 = LC12536; ibid., LC12537.

Notes: Aspergillus phialiformis is phylogenetically closely related to A. phialosimplex (Fig. 9). While, phialides of A. phialiformis are cylindrical or basal enlarged, which are mostly cylindrical in A. phialosimplex. Meanwhile, limoniform conidia are not observed in A. phialosimplex and color of A. phialosimplex and A. phialiformis on PDA and OA are different.

Aspergillus phialosimplex Z.F. Zhang & L. Cai, sp. nov.

Index Fungorum number: 556395, Facesoffungi number: FoF 08429; Fig. 11

Etymology: Referring to its phialidic conidiogenous cells.

Holotype: HMAS 248017.

Hyphae hyaline, septate, smooth, branched, 1.0–2.5 μm wide. Asexual morph Conidiogenous cells simple phialides arising laterally on vegetative hyphae. Phialides cylindrical or tapering with enlarged base, occasionally branched, smooth, hyaline, variable in length, 4.0–12.0 μm long, 1.0–4.0 μm diam at base, tapering to 1.0–2.0 μm diam. at apex. Conidia formed in long chains, limoniform, subglobose or globose, apiculate, thick-walled, rough initially, then becoming smooth with age, hyaline, 2.5–4.0 μm \((x \pm SD = 3.3 \pm 0.28, n = 60)\). Sexual morph not observed.

Culture characteristics—Colonies on PDA attaining 36–41 mm diam. after 4 weeks, flat, margin fimbriate, cream yellow (4A2) at fruiting region, white to pale brown (5A2) from middle to aging region, with brown, radially striate and lobate ring, aerial mycelia sparse. Reverse cream-yellow (4A2) to brown (5C7). Colonies on OA attaining 31–36 mm diam. after 4 weeks, flat, margin undulate, aerial mycelia sparse, pulverulent in center, white. Reverse floralwhite (4A2). Colonies on SNA attaining 43–47 mm diam. after 4 weeks, flat, pulverulent, white. Reverse white. Sporulation within 3 weeks.

Material examined: CHINA, Yunnan, Yiliang, Sanjiao Cave, N 25.134°, E 103.383°, on rock, May 2016, Z.F. Zhang, HMAS 248017 (holotype designated here), ex-type living culture CGMCC3.19314 = LC12536; ibid., LC12537.

Notes: Aspergillus phialiformis is phylogenetically closely related to A. phialosimplex (Fig. 9). While, phialides of A. phialiformis are cylindrical or basal enlarged, which are mostly cylindrical in A. phialosimplex. Meanwhile, limoniform conidia are not observed in A. phialosimplex and color of A. phialosimplex and A. phialiformis on PDA and OA are different.
Hyphae hyaline, septate, smooth, branched, 1.0–3.5 μm wide, sometimes swollen, up to 7.0 μm. Asexual morph Conidiogenous cells simple phialides arising laterally on vegetative hyphae. Phialides cylindrical, occasionally ampulliform, variable in length, smooth, hyaline, 2.5–8.5 μm long, 1.0–2.0 μm diam. Conidia formed in long chains, subglobose to globose, thick-walled, rough initially, then becoming smooth with age, hyaline, 3.5–5.5 μm (x ± SD = 4.7 ± 0.42, n = 60). Sexual morph not observed.

Culture characteristics—Colonies on PDA attaining 20–29 mm diam. after 4 weeks, flat, felty to pulverulent, margin slightly undulate, brown (7C5) to dark brown (7F7) from margin to center. Reverse pale brown (6B3) to dark brown (7F8). Colonies on OA attaining 20–28 mm diam. after 4 weeks, flat, margin entire, white to pale lavender (6B2), aerial mycelia sparse. Reverse white to pale brown. Colonies on SNA attaining 42–46 mm diam. after 4 weeks, flat, pulverulent, margin unclear, white. Reverse white. Sporulation within 3 weeks.

Material examined: CHINA, Sichuan, Huaying, Liujia Cave, N 30.41°, E 106.878°, on plant debris, May 2016, Z.F. Zhang, HMAS 248007 (holotype designated here), ex-type living culture CGMCC3.19637 = LC12578; Guangxi, Guilin, E’gu Cave, N 24.942°, E 110.511°, on animal faeces.
May 2016, Z.F. Zhang, LC12658; Yunnan, Yuxi, Niumo Cave, N 28.192°, E 102.842°, on plant root, May 2016, Z.F. Zhang, LC12625.

Notes: Aspergillus phialosimplex is phylogenetically allied to A. phialiformis (Fig. 9), but they can be easily distinguished (see notes of A. phialiformis).

Onygenales Cif. ex Benny & Kimbr.

The Onygenales in Eurotiomycetes is characterized by smooth or appendiculate ascomata, with pseudoparenchymatous, membranous cleistoperidium or filamentous gymnoperidium of loosely interwoven hyphae, centrum of globose, irregularly disposed, pseudoprototunicate asci, and one-celled, hyaline or pale coloured ascospores (Currah 1985, Doveri et al. 2012). Species of Onygenales are usually keratinophilic, keratinolytic, cellulolytic or chitinoclastic (Doveri et al. 2012).

Gymnoascaceae Baran.

The family Gymnoascaceae was firstly established by Baranetzky 1872, with Gymnoascus and G. reesi as type genus and species respectively. Members of this family are often isolated from soil, plant debris, dung or animal components (Doveri et al. 2012).

Gymnoascus Baran.

The genus Gymnoascus was classified in Gymnoascaceae, Onygenales, with G. reesi as generic type (Baranetzky 1872). In the most recent treatment, genera Arachniotus Arachniotus J. Schröt., Gymnascella Peck, Gymnoascoides G.F. Orr, K. Roy & G.R. Ghosh and Narasimhella Thirum. & P.N. Mathur have been synonymized with Gymnoascus based on the morphological and molecular evidences, marking Gymnoascus one of the largest genera in the order Onygenales (Solé et al. 2002). Gymnoascus is characterized by spherical, yellowish to brownish ascomata with peridium composed of a loose network of hyaline or pigmented hyphae, with or without appendages, and by oblate and pigmented ascospores and chrysosporium-like conidia (von Arx 1977; Solé et al. 2002; Sharma and Singh 2013; Zhou et al. 2016). The genus currently comprises 22 species (Zhou et al. 2016). In this study, one new species is described as Gymnoascus flavus (Fig. 13).
Gymnoascus flavus Z.F. Zhang & L. Cai, sp. nov.

Index Fungorum number: 556397, Facesoffungi number: FoF 08430; Fig. 14

Etymology: Referring to the color of its conidia, yellow.

Holotype: HMAS 248010.

Hyphae pale yellow to yellow, septate, branched, smooth or slightly rough, 1.5–5.0 μm diam.; racquet hyphae present, ‘racquet’ up to 11.0 μm wide. Asexual morph—Fertile mycelia usually gathered into special, superficial yellow structure, where conidia borne mostly. Conidia mostly terminal or lateral, occasionally intercalary, sessile or borne on short protrusions or side branches, unicellular, pyriform, ellipsoidal or globose, smooth, thick-walled, hyaline initially, then becoming yellow, 4.5–7.0 × 4–6 μm (x ± SD = 6.0 ± 0.62 × 5.1 ± 0.64 μm, n = 60), with truncated base. Sexual morph not observed.

Culture characteristics—Colonies on PDA attaining 26–34 mm diam. after 3 weeks, coriaceous, plicated in center, margin entire, beige (1A2) to salmon (6A3), aerial mycelia sparse. Reverse beige (1A2) to orange (6A3). Colonies on OA not growing. Colonies on SNA attaining 24–27 mm diam. after 10 days, powdery, margin rhizoids, white initially, becoming light yellow (2A3-2A5) when sporulation, aerial mycelia sparse. Reverse white to pale yellow (2A3). Sporulation within 2 weeks on SNA.

Material examined: CHINA, Sichuan, Xingwen, Feng Cave, N 28.186°, E 105.148°, on soil, May 2016, Z.F. Zhang, HMAS 248010 (holotype designated here), ex-type living culture CGMCC3.19574 = LC12500; Sichuan, Xingwen, Tianliang Cave, N 28.19°, E 105.139°, on soil, May 2016, Z.F. Zhang, LC12511.

Notes: Phylogenetically, Gymnoascus flavus forms a distinct clade sister to G. exasperates Z.F. Zhang, F. Liu & L. Cai, G. reessii and G. uncinatus Eidam based on ITS and LSU sequences (Fig. 13). However, dissimilar to G. reessii and G. uncinatus, the sexual morph of G. flavus was not observed despite repeated attempts using OA, PDA and SNA media, as well as horse hair and chicken feather as inducers.
Conidia of *Gymnoascus flavus* are mostly terminal or lateral, as compared to the abundant intercalary conidia of *G. exasperates*. The *Onygenaceae* is characterised by pseudoparenchymatous cleistothecia or hyphal gymnothecia with a structure similar to *Gymnoascaceae*. The ascospores of *Onygenaceae* are oblate, discoidal, or spherical, sometimes reniform or allantoid, punctate, pitted or pitted- reticulate, and the anamorphs are predominantly one-celled arthro- and aleu- riconidium (Doveri et al. 2012).

**Auxarthron** G.F. Orr & Kueh

The *Auxarthron* was placed in *Gymnoascaceae* when established (Orr et al. 1963), while subsequent studies based on molecular data showed its actual affinity to *Onygenaceae* (Sugiyama et al. 1999; Sigler et al. 2002). Hitherto, *Auxarthron* encompasses 18 species. In this study, two new species are described as *Auxarthron chinense* and *A. guangxiense* (Fig. 15).

**Auxarthron chinense** Z.F. Zhang & L. Cai, sp. nov.

*Index Fungorum number: 556412, Facesoffungi number: FoF 08431; Fig. 16*

*Etymology:* Referring to the country where this fungus was firstly isolated.

*Holotype:* HMAS 247999.
Hyphae hyaline, septate, branched, smooth, 1.5–3.5 μm wide, sometimes swollen, up to 10.0 μm wide; racquet hyphae present, ‘racquet’ 4–5 μm wide. **Asexual morph Conidia** arthroconidial, abundant, mostly intercalary, few lateral and terminal, unicellular, cylindrical, ellipsoidal or clavate with one or two truncated bases, smooth, hyaline, 4.0–7.0 (–8.0) × 2.0–3.5 μm (̄x ± SD = 5.3 ± 0.92 × 2.6 ± 0.25 μm, n = 50), frequently separated by 1–3 autolytic connective cells. **Sexual morph** not observed.

**Culture characteristics**—Colonies on PDA 18–23 mm diam. after 4 weeks, flat, annular, margin dentate, cottony and white at center, pulverulent to felty and light yellow (1A2) at margin. Reverse orange (5A5) to pale orange (4A5). Colonies on OA 18–23 mm diam. after 4 weeks, flat, pulverulent, margin unclear, white, aerial mycelia sparse. Reverse beige (28A3). Colonies on SNA 21–25 mm diam. after 4 weeks, flat, powdery, margin crenate, cream-yellow. Reverse cream-yellow (1A2) to white. Sporulation within 3 weeks.

**Material examined**: CHINA. Guangxi, Guilin, Luotian Cave, N 24.948°, E 110.524°, on soil, May 2016, Z.F. Zhang, HMAS 247999 (holotype designated here), ex-type living culture CGMCC3.19572 = LC12475; ibid., LC12477; ibid., LC12550; ibid., LC12580 (animal faeces); Guangxi, Guilin, E’gu Cave, N 24.942°, E 110.511°, on soil, May 2016, Z.F. Zhang, LC12473; ibid., LC12474; Yunnan, Mengzi, Mingjiu old Cave, N 23.487°, E 103.619°, on soil, May 2016, Z.F. Zhang, LC12463.

**Notes**: Morphological and phylogenetic data (Figs. 15, 16) support our strains as new species of *Auxarthron*. *Auxarthron chinense* is phylogenetically closely related to *A. alboluteum* Sigler, Hambl. & Flis, *A. compactum* G.F. Orr & Plunkett and *A. zuffianum* (Morini) G.F. Orr & Kuehn (Fig. 15). However, *A. chinense* can be distinguished from *A. alboluteum* by less lateral and terminal conidia; from *A. compactum* by the hyaline conidia rather than pale yellow of *A. compactum*; from *A. zuffianum* by wider conidia (2.0–3.5 μm vs. 1.2–1.6 μm).
Culture characteristics—Colonies on PDA attaining 26–31 mm diam. after 4 weeks, flat, margin crenate, cottony, cream-white (2A1) to yellow (2A3) at fruiting region, floral white at aging region. Reverse pale yellow (2A3) to goldenrod (2A3) at margin, dark brown (4D8) at center. Colonies on OA attaining 32–40 mm diam. after 4 weeks, flat, annular, cottony at middle, white to pale yellow (2A3) from margin to center. Reverse pale yellow (2A3). Colonies on SNA attaining 28–32 mm diam. after 4 weeks, flat, white to pale yellow (1B3), aerial mycelia sparse, with ascomata scattered. Reverse white to pale yellow (1B3). Sporulation within 3 weeks on SNA.

Material examined: CHINA, Guangxi, Guilin, E’gu Cave, N 24.942°, E 110.511°, on soil, May 2016, Z.F. Zhang, HMAS 247993 (holotype designated here), ex-type living culture CGMCC3.19634 = LC12464; ibid., LC12465.

Notes: Phylogenetically, Auxarthron guangxiense is close to A. pseudauxarthron G.F. Orr & Kuehn (Fig. 15), but differs in the absence of ascomatal appendages.

Auxarthron guangxiense Z.F. Zhang & L. Cai, sp. nov.

Index Fungorum number: 556413, Facesoffungi number: FoF 08432; Fig. 17

Etymology: Referring to the province where the type strain was isolated.

Holotype: HMAS 247993.

Hyphae hyaline, septate, branched, smooth, 1.5–2.5 µm diam. Sexual morph Ascomata abundant, solitary or in clusters, subglobose to globose, white at first, becoming orange-brown at maturity, 250–380 µm diam. Peridial hyphae rough, thick-walled, septate, pale brown, branched and anastomosed to form a reticuloperidium, terminated by spine-like or blunt prominences, sometimes dichotomously branched, 1.5–2.5 µm diam, appendages not observed. Asci 8-spored, pyriform, subglobose or globose, hyaline, 8.5–12.0 × 6.5–9.0 µm. Ascospores oblate, smooth, hyaline, 2.5–3.5 µm (x ± SD = 3.1 ± 0.22 µm, n = 40). Asexual morph not observed.

Culture characteristics—Colonies on PDA attaining 26–31 mm diam. after 4 weeks, flat, margin crenate, cottony, cream-white (2A1) to yellow (2A3) at fruiting region, floral white at aging region. Reverse pale yellow (1A2) to goldenrod (2A3) at margin, dark brown (4D8) at center. Colonies on OA attaining 32–40 mm diam. after 4 weeks, flat, annular, cottony at middle, white to pale yellow (2A3) from margin to center. Reverse pale yellow (2A3). Colonies on SNA attaining 28–32 mm diam. after 4 weeks, flat, white to pale yellow (1B3), aerial mycelia sparse, with ascomata scattered. Reverse white to pale yellow (1B3). Sporulation within 3 weeks on SNA.

Material examined: CHINA, Guangxi, Guilin, E’gu Cave, N 24.942°, E 110.511°, on soil, May 2016, Z.F. Zhang, HMAS 247993 (holotype designated here), ex-type living culture CGMCC3.19634 = LC12464; ibid., LC12465.

Notes: Phylogenetically, Auxarthron guangxiense is close to A. pseudauxarthron G.F. Orr & Kuehn (Fig. 15), but differs in the absence of ascomatal appendages.
Morphologically, *A. guangxiense* is similar to *A. zuffianum*, whereas, the asci of *A. guangxiense* are larger than those of *A. zuffianum* (8.5–12.0 × 6.5–9.0 µm vs. 7.0–8.4 × 5.6–7.0 µm). In addition, sexual stage of *A. guangxiense* is absent.

**Auxarthronopsis** Rahul Sharma, Y. Gräser & S.K. Singh

The genus *Auxarthronopsis* was established by Sharma et al. (2013) and previously comprises only two species, *A. bandhavgarhensis* Rah. Sharma, Y. Gräser & S.K. Singh and *A. guizhouensis* Z.F. Zhang & L. Cai (Zhang et al. 2017). Species of *Auxarthronopsis* are characterized by interlaced peridium, tapering appendages with multiple swollen septa, oblate ascospores with finely punctate walls, and asexual morphs of terminal and intercalary arthro- and aleurioco-nidia (Sharma et al. 2013). In this study, four new species *A. globiasca*, *A. pedicellaris*, *A. pulverea* and *A. stercicola* are described (Fig. 15).

**Auxarthronopsis globiasca** Z.F. Zhang & L. Cai, *sp. nov.*

*Index Fungorum number*: 556414, *Facesoffungi number*: FoF 08433; Fig. 18

**Etymology**: Referring to its globose asci.

**Holotype**: HMAS 247994.

*Hyphae* hyaline, septate, branched, smooth, 1.5–3.0 µm diam., sometimes cross connected, racquet hyphae present, up to 6 µm wide. **Sexual morph** *Ascomata* abundant, solitary or in clusters, surface powdery, subglobose to globose, pale yellow, 270–450 µm diam. *Peridial hyphae* septate, rough, thick-walled, pale brown, branched and anastomosed to form a reticuloperidium, terminated by short blunt prominences, 1.5–3.0 µm diam. *Asci* 8-spored, subglobose or globose, hyaline, 5.5–8.0 × 5.5–7.5 µm. *Ascospores* oblate, ellipsoidal, subglobose or globose in front view, smooth, hyaline, 2.5–3.5 × 2.0–3.0 µm (x ± SD = 2.9 ± 0.21 × 2.0 ± 0.24 µm, n = 50). **Asexual morph** *Arthroconidia* presented, abundant, mostly intercalary, few terminal and lateral, unicellular, cylindrical, ellipsoidal or clavate with truncated base, smooth, hyaline, 3.5–6.5 × 2.0–3.5 µm (x ± SD = 4.8 ± 0.73 × 2.7 ± 0.34 µm, n = 50), frequently separated by 1–3 autolytic connective cells.
**Culture characteristics**—Colonies on PDA attaining 31–36 mm diam. after 4 weeks, flat, felty, annular, margin fimbriate, seashell (5A2) to light yellow (4A3) from margin to center. Reverse cream-yellow (4A2) to orange at margin, brown (6D8) at middle, black (6F1) at center. Colonies on OA attaining 46–48 mm diam. after 4 weeks, flat, beige (4A1), aerial mycelia extremely sparse. Reverse beige (3A2). Colonies on SNA attaining 23–30 mm diam. after 4 weeks, margin rhizoids, aerial mycelia sparse, with floralwhite (30A2) ascomata scattered. Reverse ivory. Sporulation within 25 days on SNA.

**Material examined:** CHINA, Guangxi, Guilin, Luotian Cave, N 24.942°, E 110.524°, on soil, May 2016, Z.F. Zhang, HMAS 247994 (holotype designated here), ex-type within 25 days on SNA.

**Notes:** Our strains form a well supported distinct clade with *Auxarthronopsis* species (Fig. 15). *Auxarthronopsis*...
globiasca is phylogenetically allied with A. bandhavgarhensis, A. guizhouensis and A. pedicellaris. Ascomata of A. bandhavgarhensis are white and much larger than those of A. globiasca (500–1000 μm vs. 270–450 μm). A. globiasca differs from A. guizhouensis by the presence of asexual morph. In contrast to A. globiasca, conidia of A. pedicellaris are lateral or terminal.

**Auxarthronopsis pedicellaris** Z.F. Zhang & L. Cai, sp. nov.

*Index Fungorum number*: 556415, *Facesoffungi number*: FoF 08434; Fig. 19

*Etymology*: Referring to the stalk-bearing arthroconidia.

*Holotype*: HMAS 248012.

*Hyphae* hyaline, septate, branched, smooth, 1.5–3.0 μm diam. *Asexual morph* Conidiophore-like stalk cylindrical, erect, straight or curved, septate, branched, smooth, thick-walled, hyaline, various in length, 1.0–2.5 μm wide. *Arthroconidia* abundant, lateral or terminal, stalked, occasionally sessile, unicellular, pyriform, ellipsoidal or globose with truncate base, smooth, hyaline, 3.5–6.5 × 2.0–3.5 μm (x ± SD = 4.8 ± 0.73 × 2.7 ± 0.34 μm, n = 50). *Sexual morph* not observed.

*Culture characteristics*—Colonies on PDA attaining 26–32 mm diam. after 4 weeks, flat, felty, annular, margin dentate, floralwhite (30A2). Reverse floralwhite (30A2) to bisque (7A2). Colonies on OA attaining 30–33 mm diam. after 4 weeks, flat, margin lobate, white. Reverse white. Colonies on SNA attaining 26–29 mm diam. after 4 weeks, margin entire, white, aerial mycelia sparse. Reverse white. Sporulation within 3 weeks.

*Material examined*: CHINA, Chongqing, Wulong, Erwang Cave, N 29.585°, E 108.001°, on rock, May 2016, Z.F. Zhang, HMAS 248012 (holotype designated here).
Notes: Auxarthronopsis pedicellaris is phylogenetically allied to A. bandhavgarhensis, A. guizhouensis and A. globiasca (Fig. 15), but can be distinguished by its lateral or terminal conidia and absence of intercalary conidia.

Auxarthronopsis pulverea Z.F. Zhang & L. Cai, sp. nov.
Index Fungorum number: 556416, Facesoffungi number: FoF 08435; Fig. 20
Etymology: Referring to the powdery conidia on OA medium.
Holotype: HMAS 248008.

Hyphae hyaline, septate, branched, smooth. Asexual morph Arthroconidia abundant, mostly intercalary or terminal, few lateral, unicellular, solitary, straight or slightly curved, hyaline, intercalary conidia cylindrical, terminal and lateral conidia cylindrical or ellipsoidal with truncated base, sessile or short stalked, frequently separated by 1–3 autolytic connective cells, 3.0–6.0 × 2.0–3.5 μm (x ± SD = 4.5 ± 0.76 × 2.6 ± 0.36 μm, n = 50). Sexual morph not observed.

Culture characteristics—Colonies on PDA attaining 25–28 mm diam. after 4 weeks, flat, felty, annular, margin radially striate with lobate edge, beige (2A2) at margin, yellow (3A3-3B5) at middle, white to pale orange (3A2) in center. Reverse beige (2A2) to brown (4B8), with pale yellow (3A5) ring at middle. Colonies on OA attaining 29–34 mm diam. after 4 weeks, flat, felty, annular, margin radially striate with lobate edge, beige (2A2) at margin, yellow (3A3-3B5) at middle, white to pale orange (3A2) in center. Reverse beige (2A2) to brown (4B8), with pale yellow (3A5) ring at middle. Colonies on OA attaining 29–34 mm diam. after 4 weeks, flat, felty, annular, margin radially striate with lobate edge, beige (2A2) at margin, yellow (3A3-3B5) at middle, white to pale orange (3A2) in center. Reverse beige (2A2) to brown (4B8), with pale yellow (3A5) ring at middle. Colonies on OA attaining 29–34 mm diam. after 4 weeks, flat, felty, annular, margin radially striate with lobate edge, beige (2A2) at margin, yellow (3A3-3B5) at middle, white to pale orange (3A2) in center. Reverse beige (2A2) to brown (4B8), with pale yellow (3A5) ring at middle. Colonies on OA attaining 29–34 mm diam. after 4 weeks, flat, felty, annular, margin radially striate with lobate edge, beige (2A2) at margin, yellow (3A3-3B5) at middle, white to pale orange (3A2) in center. Reverse beige (2A2) to brown (4B8), with pale yellow (3A5) ring at middle.

Fig. 17 Auxarthron guangxiense (from ex-holotype CGMCC3.19634). a–c Upper and reverse views of cultures on PDA, OA and SNA 4 weeks after inoculation; d ascomata; e, f peridial hyphae; g–i ascii; j ascospores. Scale bars: e 50 μm; f 20 μm; g–j 10 μm
Fig. 18 Auxarthronopsis globiasca (from ex-holotype CGMCC3.19305). a–c Upper and reverse views of cultures on PDA, OA and SNA 4 weeks after inoculation; d ascomata; e peridial hyphae; f–i asci; j ascospores; k–m arthroconidia; n racquet hyphae; o connected hyphae. Scale bars: e–o 10 μm
Auxarthronopsis pulverea is phylogenetically closely related to *A. stercicola* (Fig. 15). However, terminal and lateral conidia of *A. stercicola* are much more abundant than those of *A. pulverea*.

**Material examined:** CHINA, Sichuan, Huaying, LiuJia Cave, N 30.41°, E 106.878°, on plant debris, May 2016, Z.F. Zhang, HMAS 248008 (holotype designated here), ex-type living culture CGMCC3.19312 = LC12521; ibid., LC12522.

**Notes:** *Auxarthronopsis pulverea* is phylogenetically closely related to *A. stercicola* (Fig. 15). However, terminal and lateral conidia of *A. stercicola* are much more abundant than those of *A. pulverea*.

**Auxarthronopsis stercicola** Z.F. Zhang & L. Cai, *sp. nov.*

Index Fungorum number: 556417, Facesoffungi number: FoF 08436; Fig. 21

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Etymology: Referring to the substrate in which this species was isolated.

**Holotype:** HMAS 248015.

**Hyphae** hyaline, septate, branched, smooth, 1.0–3.0 μm wide. **Asexual morph** Arthroconidia abundant, intercalary, terminal, or lateral, unicellular, solitary, straight or curved, hyaline, intercalary conidia cylindrical, terminal and lateral conidia cylindrical or ellipsoidal with truncated base, sometimes irregularly swollen, sessile or short stalked, 2.5–5.0 × 2.0–3.0 μm (\( \bar{x} \pm SD = 3.7 \pm 0.56 \times 2.4 \pm 0.24 \mu m \), n = 60), frequently separated by 1–3 autolytic connective cells. **Sexual morph** not observed.

**Culture characteristics**—Colonies on PDA attaining 21–26 mm diam. after 4 weeks, flat, felty, annular, margin undulate, beige (30A2) at margin, white to pale orange (3A2) in center. Reverse annular, beige (30A2) to pale brown (4B6). Colonies on OA attaining 25–28 mm diam.
after 4 weeks, flat, pulverulent, margin undulate, white. Reverse floralwhite (1A2). Sporulation within 3 weeks on OA. Colonies on SNA attaining 16–18 mm diam. after 4 weeks, radially striate with rhizoid margin, white. Reverse white.

Material examined: CHINA. Yunan, Yiliang Sanjiao Cave, N 25.134°, E 103.383°, on animal faeces, May 2016, Z.F. Zhang, HMAS 248015 (holotype designated here), ex-type living culture CGMCC3.19639 = LC12635; Guilin, Luotian Cave, N 24.948°, E 110.524°, on animal faeces, May 2016, Z.F. Zhang, LC12611.

Notes: Auxarthronopsis stercicola is phylogenetically closely related to A. pulverea (Fig. 15), but can be easily distinguished (see notes of A. pulverea).

Chrysosporium Corda

Chrysosporium was introduced by Corda (1833), and revealed to be polyphyletic based on ITS phylogeny (Vidal et al. 2000). The genus currently comprises 66 species (Wijayawardene et al. 2020), most of which are saprophytic and keratinolytic isolated from various habitats such as air, sea, sludge, waste water (Zhang et al. 2016). In this study, one new species is described as Chrysosporium pallidum (Fig. 15).

Chrysosporium pallidum Z.F. Zhang & L. Cai, sp. nov.

Index Fungorum number: 556418, Facesoffungi number: FoF 08437; Fig. 22

Etymology: Referring to the color of ascomata, white to pale yellow.

Holotype: HMAS 247992.

Hyphae hyaline, septate, branched, smooth, 2.0–3.0 μm diam., racquet hyphae present, up to 6 μm wide. Sexual
**morph** Ascomata abundant, solitary, or in clusters, cottony, globose, white initially, becoming pale yellow when aging, with conidia produced on surface, up to 750 μm diam. Peridial hyphae difficult to distinguished from aerial hyphae, septate, branched and anastomosed, terminated by short blunt prominences, smooth, thick-walled, hyaline, 2.5–4.0 μm diam. Asci 8-spored, pyriform, subglobose or globose, hyaline, 8.0–13.0 × 7.5–10.5 μm. Ascospores oblate, globose in front view, hyaline, smooth, 2.5–3.5 μm (x ± SD = 3.0 ± 0.21 μm, n = 70). Sexual morph Arthroconidia abundant, intercalary, lateral or terminal, unicellular, hyaline; intercalary conidia cylindrical or ellipsoidal with truncated base, 3.5–6.5 × 2.0–3.5 μm (mean = 6.6 ± 1.28 × 2.9 ± 0.46 μm, n = 40); lateral or terminal conidia arising from aerial hyphae directly, pyriform or clavate with truncate base, 4.0–7.0 × 2.5–4.0 μm (mean = 5.3 ± 0.73 × 3.4 ± 0.43 μm, n = 40).

**Culture characteristics**—Colonies on PDA attaining 28–34 mm diam. after 4 weeks, flat, felty, annular, margin with fimbriate, ivory (1A1) to white from margin to center. Reverse ivory (1A1) to yellow (2A2) from margin to center. Colonies on OA attaining 27–30 mm diam. after 4 weeks, flat, felty, annular, white. Reverse white to beige (30A2). Colonies on SNA attaining 26–29 mm diam. after 4 weeks, margin rhizoids, floralwhite (1A2), aerial mycelia sparse. Reverse floralwhite (1A2). Sporulation within 3 weeks on SNA.

**Material examined**: CHINA, Guangxi, Guilin, E’gu Cave, N 24.942°, E 110.511°, on animal faeces, May 2016, Z.F. Zhang, HMAS 247992 (holotype designated here), ex-type living culture CGMCC3.19575 = LC12583; ibid., LC12670.

**Notes**: Chrysosporium pallidum is phylogenetically allied to C. carmichaelii Oorschot and Myriodontium keratinophilum Samson & Polon (Fig. 15). C. pallidum differs from C. carmichaelii by its more abundant intercalary conidia and sessile lateral conidia. Conidia of Myriodontium keratinophilum are lateral with short stem (conidiogenous cell), comparing with sessile lateral conidia and the presence of intercalary, lateral or terminal of C. pallidum. In addition,
neither C. carmichaelii nor myriodontium keratinophilum produces sexual stage.

**Class Sordariomycetes** O.E. Erikss. & Winka

The classification of Sordariomycetes follow the latest treatment by Hongsanan et al. (2017) and Wijayawardene et al. (2017, 2018, 2020)

![Fig. 22 Chrysosporium pallidum (from ex-holotype CGMCC3.19575).](image)

**Subclass Hypocreomycetidae** O.E. Erikss. & Winka

**Hypocreales** Lindau

_Hypocreales_ is characterized by pigment producing, brightly coloured perithecial ascomata, and typically ostiolate perithecial fruiting body (Rehner and Samuels 1995). Asexual morphs of _Hypocreales_, the form most frequently
encountered in nature, are moniliaceous and phialidic (Lombard et al. 2015). Hypocreales are highly diverse and currently comprise 14 families (Wijayawardene et al. 2020).

**Cordycipitaceae** Kreisel ex G.H. Sung et al.

*Cordycipitaceae* was validated by Sung et al. (2007a) to accommodate species of *Cordyceps* forming brightly coloured, fleshy stromata. Species of *Cordycipitaceae* are known as obligate saprotrophs, parasites and symbionts with insects and fungi or grasses, rushes or sedges (Phookamsak et al. 2019).

**Amphichorda** Fr.

*Amphichorda* was established by Fries (1825) with *A. felina* (DC.) Fr. as type. The genus is morphologically similar to *Beauveria* except its regular conidiogenous cells without elongate denticulate rachis. Currently there are two species in *Amphichorda*, and both of them are coprophilous (Zhang et al. 2017; Xu et al. 2018). We described *Amphichorda cavernicola* sp. nov. in this study (Fig. 23).

**Amphichorda cavernicola** Z.F. Zhang & L. Cai, sp. nov.

Index Fungorum number: 556419, Facesoffungi number: FoF 08438; Fig. 24

- **ARSEF 3405** *Beauveria pseudobassiana* CBS 250.34
- **ARSEF 7032** *Amphichorda cavernicola* IMI 228343
- **ARSEF 3436** *Beauveria varroae* CBS 607.80
- **ARSEF 2922** *Tolypocladium tundrense* ARSEF 4755
- **ARSEF 8257** *Amphichorda cavernicola* ARSEF 2694
- **ARSEF 2684** *Beauveria velata* CBS 541.81
- **ARSEF 5050** *Cordyceps militaris* CBS 607.80
- **ARSEF 5050** *Beauveria malwiensis*
- **ARSEF 1685** *Beauveria sunigi* ARSEF 250.34
- **ARSEF 4384** *Beauveria asiatica* ARSEF 7542
- **ARSEF 4598** *Beauveria australis* ARSEF 2694
- **ARSEF 4850** *Beauveria brongniartii* ARSEF 11741
- **ARSEF 611** *Beauveria brongniartii* ARSEF 2922
- **ARSEF 2641** *Beauveria amorpha* ARSEF 3405
- **ARSEF 1564** *Beauveria bassiana* ARSEF 1555
- **ARSEF 300** *Beauveria bassiana* ARSEF 2694
- **ARSEF 1711** *Beauveria australis* ARSEF 2641
- **ARSEF 1711** *Beauveria australis* ARSEF 2694
- **ARSEF 11741** *Beauveria australis* ARSEF 2641
- **ARSEF 300** *Beauveria bassiana* ARSEF 2641
- **ARSEF 1711** *Beauveria australis* ARSEF 2641
- **ARSEF 11741** *Beauveria australis* ARSEF 2641

**Fig. 23** Maximum likelihood (ML) tree of *Amphichorda* and allied genera based on ITS sequences. Forty-nine strains are used. The tree is rooted with *Parengyodontium album* (IFM 57481 and IFM 64296). Tree topology of the ML analysis was similar to the BI. The Best scoring RAxML tree with a final likelihood value of $-3338.441281$. The matrix had 298 distinct alignment patterns, with 16 % of undetermined characters or gaps. Base frequencies estimated by jModelTest were as follows, $A = 0.2103, C = 0.3352, G = 0.2666, T = 0.1878$; substitution rates $AC = 1.0000, AG = 2.2239, AT = 1.0000, CG = 1.0000, CT = 3.4151, GT = 1.0000$; gamma shape = 0.4260. ML bootstrap values ($\geq 70 \%$) and Bayesian posterior probability ($\geq 90 \%$) are indicated along branches (ML/PP). Novel species are in bold font and “T” indicates type derived sequences.
Etymology: Referring to the cavernicolous habitat it was isolated.

Holotype: HMAS 248011.

Hyphae hyaline, septate, smooth-walled, 1.5–2.5 μm diam. Asexual morph Synnemata arising in the center part of colonies on OA or PDA with peptone, cylindrical with apical apex, tomentose, white. Conidiophores arising laterally from hyphae, cylindrical, straight or slightly curved, occasionally branched, hyaline. Conidiogenous cells borne on conidiophores or mycelia, fusiform or ellipsoidal, straight or irregularly bent, 4.5–8.0 × 2.0–3.0 μm. Conidia holoblastic, solitary or clumped, unicellular, broadly ellipsoidal to sub-globose, smooth, hyaline, 2.5–4.0 × 2.0–3.5 μm (x ± SD = 3.4 ± 0.36 × 2.8 ± 0.24 μm, n = 60). Chlamydospores and Sexual morph not observed.

Culture characteristics—Colonies on PDA attaining 9–15 mm diam. after 14 days, irregular, compact, extremely plicated and crack, cream-yellow (4A1) to seashell (30A2) in fruiting zone and tan (5A2) in aging zone, aerial mycelia sparse. Reserve compact and crack, cream-yellow (1A2) to brown from fruiting zone and tan (4E8) in aging zone. Colony on OA attaining 18–22 mm diam. after 14 days, dense, compact and plicated, margin radially striate with lobate edge, white to milk-white, with synnemata in center. Reserve pale yellow (4A2) with yellow-brown (4B8) margin. Colonies on SNA slowly growing, attaining 9–13 mm diam. after 14 days, margin entire, white, mycelia sparse, with white hyphae body. Reverse white. Sporulation within 10 days on OA and SNA.

Material examined: CHINA, Sichuan, Xingwen, Feng Cave, N28.186°, E105.148°, on bird faeces, May 2016, Z.F. Zhang, HMAS 248011 (holotype designated here), ex-type living culture CGMCC3.19571 = LC12448; ibid., LC12554; ibid., LC12577; Chongqing, Wulong, Sanwang Cave, N29.591°, E108.001°, on soil, May 2016, Z.F. Zhang, LC12481; Guangxi, Guilin, E’gu Cave, N24.942°,

Fig. 24 Amphichorda cavernicola (from ex-holotype CGMCC3.19571). a A. cavernicola on bird faeces; b–d upper and reverse views of cultures on PDA, OA and SNA 14 days after inoculation; e synnemata; f–j conidiophores, conidiogenous cells and conidia; k conidia. Scale bars: f–k 10 μm.
is polyphyly (Sung et al. 2007a; Lecanicillium showed that Cordycipitaceae based on multi-locus phylogeny studies of 2007a; Park et al. 2015; Huang et al. 2018). While, previous Pers and L. lecanii Microhilum H.Y. Yip & A.C. Rath, with, tinctly septate. approximately the same length as the ascus, slender, indis-

Ascospores hyaline, filiform, spirally twisted in the ascus, prominently cap, narrowly cylindrical with an inflated vase. hyaline, delicate, wallacei only observed. only observed in Sexual morph ellipsoidal, falcate, lunate or reniform. Crystals occasion-

Asexual morph Conidiophores commonly arising from aerial hyphae, erect, hyaline. Conidiogenous cells discrete aculeate phialides, usually solitary or verticillate, sometimes branched. Conidia adhering in more or less globose slimy heads and of two types, macroconidia first usually and then microconidia, aseptate. Macroconidia fusiform or falcate with more or less pointed ends; microconidia ellipsoidal, falcate, lunate or reniform. Crystals occasionally observed. Sexual morph only observed in Gamszarea wallacei on the pupal host. Perithecium hyaline, delicate, smooth, obclavate to naviculate. Asci 8-spored, with a prominent cap, narrowly cylindrical with an inflated vase. Ascospores hyaline, filiform, spirally twisted in the ascus, approximately the same length as the ascus, slender, indistinctly septate.

Type: Gamszarea wallacei (H.C. Evans) Z.F. Zhang & L. Cai

Notes: Lecanicillium was introduced by Gams and Zare (2001) to accommodate the taxa with aculeate phialides that cannot be classified in the genera such as Beauveria, Isaria Pers and Microhilum H.Y. Yip & A.C. Rath, with L. lecanii (Zimm.) Zare & W. Gams as the generic type (Sung et al. 2007a; Park et al. 2015; Huang et al. 2018). While, previous studies of Cordycipitaceae based on multi-locus phylogeny showed that Lecanicillium is polyphyle (Sung et al. 2007a; Sanjuan et al. 2014; Chiriví-Salomón et al. 2015; Kepler et al. 2017), and several species of Lecanicillium, including the type L. lecanii, were transferred to genus Akanthomyces Lebert (Kepler et al. 2017). Nevertheless, several distinctly separate clades remained (Figs. 25, 26). Three of our new species clustered with L. wallacei (H.C. Evans) H.C. Evans & Zare (teleomorph synonym: Torrubiella wallacei H.C. Evans), L. kalimantanense Kurihara & Sukarno, Verticillium indonesiacum Kurihara & Sukarno and several new Lecan-

cillum species published recently in a single clade in Cordycipitaceae, which represented a new genus, herein named as Gamszarea (Figs. 25, 26). The most closely related genus to Gamszarea is Simplicillium Zare & W. Gams. Species of Simplicillium usually have discrete solitary phialides arising from prostrate hyphae and short-ellipsoidal to subglobose or obclavate conidia (Zare and Gams 2008). On contrary, phialides of Gamszarea are aculeate, solitary or verticillate and the dimorphic conidia are lunate, fusiform or falcate.

Gamszarea wallacei (H.C. Evans) Z.F. Zhang & L. Cai, comb. nov.

Index Fungorum number: 556421, Facesoffungi number: FoF 08440
Basionym: Simplicillium wallacei H.C. Evans, Nova Hedwigia 73 (1–2): 43 (2001).
Synonym: Torrubiella wallacei H.C. Evans, Nova Hedwigia 73 (1–2): 46 (2001).
Lecanicillium wallacei (H.C. Evans) H.C. Evans & Zare, Mycological Research 112 (7): 816 (2008).
Holotype: Indonesia, Sulawesi, Dumoga Bone forest, on lepidopteran larva, IMI 331549, ex-type living culture, CBS 101237.

Notes: This species was first described as Simplicillium wallacei by Gams and Zare (2001) based on morphological features, and then transferred to Lecanicillium based on ITS analyses (Zare and Gams 2008). While, in the cladogram of Zare and Gams (2008), Lecanicillium wallacei clustered in a distinct clade between Lecanicillium and Simplicillium, which was consistent with our multi-locus analyses (Figs. 25, 26). Therefore, a new combination is proposed here, as Gamszarea wallacei.

Gamszarea indonesiacum (Kurihara & Sukarno) Z.F. Zhang & L. Cai, comb. nov.

Index Fungorum number: 556422, Facesoffungi number: FoF 08441
Basionym: Verticillium indonesiacum Kurihara & Sukarno, Mycoscience 50 (5): 377 (2009).
Holotype: Indonesia, East Kalimantan, Kutai National Park, on synnemata growing on a spider, BO22577, ex-type living culture, BTCC-F36 = NBRC 105408 = ID06-F0380.
ever, ITS-based phylogeny suggested a close affinity to
Verticillium indonesiacum was introduced as a
member of the Volutella aeria (CGMCC3.17945 and CGMCC3.17946).

Fig. 25 Maximum likelihood (ML) tree of Gamszarea, Lecanicillium
and allied genera in Cordycipitaceae based on ITS, LSU, SSU, EF1-α,
and RPB1 and RPB2 sequences. Seventy-six strains are used. The tree
is rooted with Volutella aeria (CGMCC3.17945 and CGMCC3.17946).
Tree topology of the ML analysis was similar to the BI. The Best scor-
ing RAxML tree with a final likelihood value of −41813.806368. The
ML substitution rates AC = 1.4660, AG = 3.7913, AT = 0.9486, CG =
0.9281, CT = 7.8283, GT = 1.0000; gamma shape = 0.5830. ML
bootstrap values (≥ 70 %) and Bayesian posterior probability (≥ 90 %)
are indicated along branches (ML/PP). Novel species are in bold font
and "T" indicates type derived sequences

Notes: Verticillium indonesiacum was introduced as a
species of Verticillium Nees (Plectosphaerellaceae) based
on morphological characters (Sukarno et al. 2009). How-
ever, ITS-based phylogeny suggested a close affinity to
Lecanicillium (Sukarno et al. 2009), despite its verticillate
phialides with branches that is more similar to
Verticillium (Sukarno et al. 2009). In our phylogenetic tree of Cordycipi-
taceae, V. indonesiacum clustered within Gamszarea clade
and its solitary or verticillate phialides and the mostly falcate conidia fit well to the general features of *Gamszarea*, which are distinctly different from *Verticillium* species with mainly verticillate phialides arising below the transverse septum along conidiophores and the cylindrical to oval conidia (Inderbitzin et al. 2011). Although macroconidia and microconidia can be easily distinguished in Fig. 2i, j (Sukarno et al. 2009), conidia were too few to measure the size. *Gamszarea indonesiaca* can be easily distinguished from other *Gamszarea* species by its more abundant verticillate phialides on the erect, septate and branched hyphae. (Figs. 25, 26), and its solitary or verticillate phialides and the mostly falcate conidia fit well to the general features of *Gamszarea*, which are distinctly different from *Verticillium* species with mainly verticillate phialides arising below the transverse septum along conidiophores and the cylindrical to oval conidia (Inderbitzin et al. 2011). Although gaps. Base frequencies estimated by jModelTest were as follows, A = 0.2220, C = 0.3155, G = 0.2645, T = 0.1980; substitution rates AC = 2.3755, AG = 2.4987, AT = 1.5316, CG = 0.9389, CT = 5.6398, GT = 1.0000; gamma shape = 0.5370. ML bootstrap values (≥ 70 %) and Bayesian posterior probability (≥ 90 %) are indicated along branches (ML/PP). Novel species are in bold font and “T” indicates type derived sequences.
Gamszarea kalimantanensis (Kurihara & Sukarno) Z.F. Zhang & L. Cai, **comb. nov.**

*Index Fungorum number:* 556423, *Facesoffungi number:* FoF 08442

*Basionym:* Lecanicillium kalimantanense Kurihara & Sukarno, Mycoscience 50 (5): 376 (2009).

*Holotype:* Indonesia, East Kalimantan, Kutai National Park, on exoskeleton of staphylinid-like beetle, BO22579, ex-type living culture, BTCC-F23 = NBRC 105406 = ID06-F0406.

*Notes:* Although the conidia of *Lecanicillium kalimantanense* varied significantly in size (Sukarno et al. 2009), macroconidia and microconidia can be easily distinguished (Fig. 2e–g in Sukarno et al. 2009). Based on the provided scale bars, we managed to measure the conidial size using Fig. 2g in Sukarno et al. (2009), 9.0–12.0 × 1.0–2.0 µm for macroconidia, and 4.5–7.5 × 1.0–2.0 µm for microconidia, which fitted well to the generic features of *Gamszarea*. Combining with phylogenetic data (Figs. 25, 26), we proposed this species as a new combination, *G. kalimantanensis*. It differs from other *Gamszarea* species in its longer conidia and more abundant verticillate phialides along the prostrate aerial hyphae.

Gamszarea restricta (Hubka, Kubáto, Nonaka, Čmoková & Řehulka) Z.F. Zhang & L. Cai, **comb. nov.**

*Index Fungorum number:* 557629, *Facesoffungi number:* FoF 08443

*Basionym:* Lecanicillium restrictum Hubka, Kubáto, Nonaka, Čmoková & Řehulka, Persoonia 40: 291 (2018).

*Holotype:* Czech Republic, Starý Bohumín, surface of the wooden barrel found during archaeological excavations, PRM 946543, ex-type living culture, CCF 5252 = CBS 143072.

*Notes:* *Lecanicillium restrictum* and *L. testudineum* Hubka, Schauflerová, Děniel & Jany were published by Crous et al. (2018), while only *Lecanicillium* species and two loci, ITS and EF1-α, were used in their study phylogenetic study. However, both the single and six-locus phylogeny (Figs. 25, 26) presented a highly support clade of *L. restrictum* and *L. testudineum* within the new genus *Gamszarea*. Meanwhile, morphological features of *L. restrictum*

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**Fig. 27** *Gamszarea hunicola* (from ex-holotype CGMCC3.19303). a–c Upper and reverse views of cultures on PDA, OA and SNA 4 weeks after inoculation; d–e conidiophores and phialides; f–g conidia in globose heads; h germinated conidia; i macroconidia and microconidia. Scale bars: d–i 10 µm
and *L. testudineum*, such as solitary or verticillate phialides produced on aerial hyphae, dimorphic conidia, fusiform or falcate macroconidia with pointed ends, and curved reniform with rounded ends, were consistent with the generic concept of *Gamszarea*. Therefore, they were proposed as new combinations, *G. restricta* and *G. testudinea*. *G. restricta* can be distinguished from other *Gamszarea* species by its larger macroconidia but smaller microconidia.

**Gamszarea testudinea** (Hubka, Kubátová, Nonaka, Čmoková & Řehulka) Z.F. Zhang & L. Cai, *comb. nov.*

*Index Fungorum number:* 557630, *Facesoffungi number:* FoF 08444

*Basionym:* *Lecanicillium testudineum* Hubka, Kubátová, Schauflerová, Déniel & Jany, Persoonia 40: 293 (2018).

*Synonym:* *Lecanicillium coprophilum* Lei Su, Hua Zhu & C. Qin, Phytotaxa 387 (1): 58 (2019).

*Holotype:* Czech Republic, Prague, scales from the carapace of the captive red-eared slider, PRM 935078, ex-type living culture, CCF 5201 = CBS 141096.

*Notes:* See note of *Gamszarea restricta*. Blastn search with ITS sequence gave an almost 100% similarity between *Lecanicillium testudineum* and *L. coprophilum*, which was supported by our phylogenetic analyses (Figs. 25, 26). Morphological features of *L. testudineum* and *L. coprophilum* were very similar, except macroconidia, pointed ends in *L. testudineum* but rounded ends in *L. coprophilum*. However, it can be clearly noticed in Fig. 2e, g, h in Su’s article that the end of macroconidia *L. coprophilum* were slightly pointed more than that rounded. *L. coprophilum* was introduced by Su et al. in (2019), a bit later than *L. testudineum* (Crous et al. 2018). Therefore they were combined to *Gamszarea testudinea* here. *G. testudinea* morphological differed from other species of *Gamszarea* by its smaller conidia (macroconidia 3.5–6 × 1.0–1.5 μm, microconidia 2.5–3 × 1.0–1.5 μm for *G. testudinea*; 8.5–10.5 × 1.0–1.5 μm and 4.0–5.5 × 0.7–1.2 μm for *G. wallacei*; 9.0–12.0 × 1.0–2.0 μm and 4.5–7.5 × 1.0–2.0 μm for *G. kalimantanensis*; 9.0–13.0 × 1.5–2.5 μm and 3.5–6.5 × 1.0–1.5 for *G. humicola*; 7.0–9.5 × 1.5–2.5 μm and 3.0–5.0 × 1.5–2.0 μm for *G. lunata*; 6.0–10 × 1.0–1.5 μm and 2.5–3 × 1.0–1.5 μm for *Gamszarea restricta*) and the present of prismatic crystals (Crous et al. 2018; Su et al. 2019).

**Gamszarea humicola** Z.F. Zhang & L. Cai, *sp. nov.*

*Index Fungorum number:* 557631, *Facesoffungi number:* FoF 08445; Fig. 27

*Etymology:* Referring to the substrate where this fungus was isolated.

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![Fig. 28 Gamszarea lunata (from ex-holotype CGMCC3.19315). a–c Upper and reverse views of cultures on PDA, OA and SNA 4 weeks after inoculation; d–f phialides and conidia in globose heads; g conidiophores and phialides; h macroconidia and microconidia. Scale bars: d–h 10 μm](image-url)
Holotype: HMAS 247987.

Hyphae hyaline, septate, smooth, 1.5–2.5 μm wide. Asexual morph Conidiophores arising from prostrate aerial hyphae, erect, hyaline, 1.0–2.5 μm diam. Phialides arising from prostrate aerial hyphae solitary, or in whorls of 2–6 at the apex of conidiophores, erect, aculeate, tapering to the apex, hyaline, 14.0–34.0 μm long, 1.0–2.5 μm diam. at base. Conidia unicellular, long fusiform, or curved to falcate, smooth, hyaline, each phialide producing one macroconidia and several microconidia, variable in size, aggregated in slimy head; macroconidia 9.0–13.0 × 1.5–2.5 μm (\( \bar{x} \pm SD = 10.7 \pm 1.1 \times 2.0 \pm 0.19 \mu m, n = 35 \)); microconidia 3.5–6.5 × 1.0–1.5 μm (\( \bar{x} \pm SD = 5.1 \pm 0.88 \times 1.3 \pm 0.15 \mu m, n = 50 \)). Sexual morph not observed.

Culture characteristics—Colonies on PDA attaining 31–40 mm diam. after 4 weeks, flat, cottony, margin slightly undulate, white. Reverse plicate, cream yellow (4A1) to light yellow (3A3). Colonies on OA attaining 44–48 mm diam. after 4 weeks, flat, cottony, margin entire, white. Reverse cream-white. Colonies on SNA attaining 46–50 mm diam. after 4 weeks, flocculent, margin unclear, white. Reverse white. Sporulation within 20 days.

Material examined: CHINA, Guangxi, Guilin, E’gu Cave, N 24.942°, E 110.511°, on soil, May 2016, Z.F. Zhang, HMAS 247987 (holotype designated here), ex-type living culture CGMCC3.19303 = LC12461; ibid., LC12462.

Notes: Gamszarea humicola is phylogenetically close to G. kalimantanensis, G. lunata and G. wallacei (Fig. 25). Morphologically, G. humicola differs from G. kalimantanensis by its mostly solitary phialides; from G. lunata by its longer macroconidia (9.0–13.0 μm vs. 7.0–9.5 μm); from G. wallacei in its wider phialides (1.0–2.5 μm vs. 0.7–1.2 μm) and macroconidia (1.5–2.5 μm vs. 1.0–1.5 μm).

Gamszarea lunata Z.F. Zhang & L. Cai, sp. nov.

Index Fungorum number: 557632, Facesoffungi number: FoF 08446; Fig. 28

Etymology: Referring to the shape of its microconidia. Holotype: HMAS 247996.
Hyphae hyaline, septate, smooth, 1.0–2.5 μm wide. **Asexual morph** Conidiophores arising from prostrate aerial hyphae, erect, hyaline, 1.0–2.0 μm diam. Phialides arising from prostrate aerial hyphae solitary, or in whors of 2–4 at the apex of conidiophores, straight or slightly curved, tapering toward the apex, smooth, hyaline, 15.0–28.0 μm long, 1.0–2.0 μm diam. at base. Conidia unicellular, smooth, hyaline, each phialide producing one macroconidia and several microconidia, variable in size, aggregated in slimy head; microconidia, variable in size, aggregated in slimy head; macroconidia, 1.0–1.5 μm diam. at base. **Sexual morph** not observed.

**Culture characteristics**—Colonies on PDA attaining 45–48 mm diam. after 4 weeks, cottony to pulverulent, slightly convex, margin entire, white. Reverse plicate, cream white to pale brown (7B4). Colonies on OA attaining 42–47 mm diam. after 4 weeks, flat, felty, white. Reverse cream-white to pale salmon (6A2). Colonies on SNA attaining 44–48 mm diam. after 4 weeks, flat, colorless, aerial mycelia extremely sparse. Reverse colorless. Sporulation within 3 weeks on PDA and OA.

**Material examined**: CHINA, Sichuan, Xingwen, Tianliang Cave, N 28.19°, E 105.139°, on rock, May 2016, Z.F. Zhang, HMAS 248009 (holotype designated here), ex-type living culture CGMCC3.19315 = LC12545; ibid., LC12546.

Notes: *Gamszarea microspora* can be easily distinguished from most species of *Gamszarea* by its significantly smaller conidia and the occasionally branched phialides. *G. microspora* differs from *G. indonesiaca* in the phialides which are mostly produced on prostrating aerial hyphae, while that of *G. indonesiaca* are mostly at the apex of the erect hyphae (Sukarno et al. 2009).

**Lecanicillium** W. Gams & Zare

See short notes of *Gamszarea*.

**Lecanicillium magnisporum** Z.F. Zhang & L. Cai, **sp. nov.**

Index Fungorum number: 557634, Facesoffungi number: FoF 08448; Fig. 30

Etymology: Referring to its larger conidia than other species in this genus.

**Holotype**: HMAS 248013.

Hyphae hyaline, septate, smooth, 0.5–2.5 μm wide. **Asexual morph** Conidiophores arising from aerial hyphae, erect, smooth, hyaline, 1.0–1.5 μm diam. Phialides arising from aerial hyphae solitary, or in whors of 2–5 at the apex of conidiophores, straight or slightly curved, tapering to the apex, smooth, hyaline, 17.0–37.0 μm long, 1.0–1.5 μm diam. at base. Conidia rare, unicellular, smooth, hyaline, variable in size; macroconidia long fusiform or falcate, 9.0–16.0 × 1.0–3.5 μm (x ± SD = 2.7 ± 0.33 × 1.6 ± 0.12 μm, n = 60). **Sexual morph** not observed.

**Culture characteristics**—Colonies on PDA attaining 42–47 mm diam. after 4 weeks, plicated, flocculent to pulverulent, margin entire, white. Reverse plicated, cream white to pale brown (7B4). Colonies on OA attaining 43–47 mm diam. after 4 weeks, flat, felty, white. Reverse cream-white to pale salmon (6A2). Colonies on SNA attaining 44–48 mm diam. after 4 weeks, flat, colorless, aerial mycelia extremely sparse. Reverse colorless. Sporulation within 3 weeks on PDA and OA.

**Material examined**: CHINA, Sichuan, Xingwen, Tianliang Cave, N 28.19°, E 105.139°, on rock, May 2016, Z.F. Zhang, HMAS 248009 (holotype designated here), ex-type living culture CGMCC3.19313 = LC12530; ibid., LC12531.

Notes: *Gamszarea microspora* can be easily distinguished from most species of *Gamszarea* by its significantly smaller conidia and the occasionally branched phialides. *G. microspora* differs from *G. indonesiaca* in the phialides which are mostly produced on prostrating aerial hyphae, while that of *G. indonesiaca* are mostly at the apex of the erect hyphae (Sukarno et al. 2009).
Material examined: CHINA, Chongqing, Wulong, Erwang Cave, N 29.585°, E 108.001°, on soil, May 2016, Z.F. Zhang, HMAS 248013 (holotype designated here), ex-type living culture CGMCC3.19304 = LC12468; ibid., LC12469; ibid., LC12470; Chongqing, Wulong, Sanwang Cave, N 29.591°, E 108.001°, on soil, May 2016, Z.F. Zhang, LC12647; ibid., LC12663.

Notes: *Lecanicillium magnisporum* is phylogenetically allied to *L. antillanum* (R.F. Castañeda & G.R.W. Arnold) Zare & W. Gams, which belongs to one of the remaining clades of *Lecanicillium* (Fig. 25), but can be distinguished by the larger conidia (2.0–3.0 µm vs. 0.5–1.5 µm wide for marcoconidia, 5.0–7.0 × 1.5–2.5 µm vs. 2.0–3.5 × 0.5–1.5 µm for microconidia) and low sequence similarities (96% similarity, 23 bp difference in 524 bp of ITS; 99% similarity, 6 bp difference in 823 bp of LSU; 91% similarity, 73 bp difference in 820 bp of RPB2; 96% similarity, 38 bp difference in 912 bp of EF1-α). However, further revisions of the remaining species of *Lecanicillium* are required (see notes of Gamszarea).

*Simplicillium* W. Gams & Zare

The genus *Simplicillium* was introduced by Zare and Gams (2001) with *S. lanosoniveum* (J. F. H. Beyma) Zare & W. Gams as the type species. The genus is characterised by predominantly solitary phialides, conidial masses either in globose slimy heads, short chains, or in sympodial succession (Zare and Gams 2001; Nonaka et al. 2013). *Simplicillium* species are widely distributed and considered as mammal- and plant-parasitic, symbiotic, entomopathogenic, fungicolous and nematophagous fungi (Wei et al. 2019). In this study, two new species are described as *Simplicillium album* and *S. humicola* (Fig. 31).
**Simplicillium album** Z.F. Zhang & L. Cai, sp. nov.

*Index Fungorum number:* 557740, *Facesoffungi number:* FoF 08449; Fig. 32

**Etymology:** Referring to the color of its white colonies on plates.

**Holotype:** HMAS 248003.

Hyphae hyaline, separtate, smooth, 1.5–3.5 µm wide. **Asexual morph** Conidiophores simple, erect, cylindrical, smooth, hyaline. Phialides arising from prostrate aerial hyphae solitary, or in whorls of 2–3 at the apex of conidiophores, erect, tapering to the apex with basal septum, smooth, hyaline, 13.0–40.0 µm long, 1.5–3.0 µm wide at base. Conidia variable in size and shape, 1-celled, smooth, hyaline; *microconidia* oblong or ellipsoidal, 3.0–4.0 × 1.5–2.0 µm (x ± SD = 3.6 ± 0.37 × 1.7 ± 0.18 µm, n = 40), *macroconidia* fusiform or falcate, 8.0–11.0 (~13.0) × 2.0–3.5 µm (x ± SD = 9.7 ± 0.86 × 2.9 ± 0.31 µm, n = 20). Octahedral crystals present. **Sexual morph** not observed.

**Culture characteristics**—Colonies on PDA attaining 27–29 mm diam. after 10 days, flat, cottony, margin entire, white, light yellow secretions exuded. Reverse plicate, beige (1A1) to bisque (4A2). Colonies on OA attaining 28–31 mm diam. after 10 days, flat, cottony, margin entire, white. Reverse seashell (5A3) to wheat. Colonies on SNA attaining 30–34 mm diam. after 10 days, cottony, margin entire, white, aerial mycelia sparse. Reverse white. Sporulation within 10 days.

**Material examined:** CHINA, Guangxi, Laibin, Sanshan Cave, N 23.41°, E 108.931°, on soil, May 2016, Z.F. Zhang, HMAS 248003 (holotype designated here), ex-type living culture CGMCC3.19635 = LC12442; Guangxi, Guilin, E’gu Cave, N 24.942°, E 110.511°, on animal faeces, May 2016, Z.F. Zhang, LC12543; ibid., LC12557.

**Notes:** *Simplicillium album* is phylogenetically close to *S. calcicola* Z.F. Zhang, F. Liu & L. Cai, *S. lanelllica* (F.E.V. Sm.) Zare & W. Gams and *S. sympodiophorum* Nonaka, Kaifuchi & Masuma (Fig. 31), while *S. sympodiophorum* is distinguishable in producing monomorphic sympodial conidia. *S. album* shares similar morphological characters with *S. calcicola* and *S. lanelllica* in producing dimorphic...
conidia. However, *S. album* produces larger macroconidia (8.0–11.0 (–13.0) × 2.0–3.5 μm) than *S. calcicola* (4.5–8.0 × 1.0–2.0 μm) and *S. lamellicola* (4.5–9.0 × 0.8–1.2 μm). In addition, the octahedral crystals of *S. calcicola* are absent.

**Simplicillium humicola** Z.F. Zhang & L. Cai, sp. nov.

Index Fungorum number: 557741, Facesoffungi number: FoF 08450; Fig. 33

**Etymology**: Referring to the substrate in which this fungus was isolated.

**Holotype**: HMAS 247991.

**Hyphae** hyaline, septate, smooth, 1.5–3.5 μm wide. **Asexual morph** **Phialides** arising from prostrate aerial hyphae solitary, or up to 2–3 in whorls, sometimes with short stalks, erect, tapering to the apex, straight or slightly curved, with basal septum, smooth, hyaline, 20.0–35.0 (–47.0) μm long, 1.5–3.0 μm wide at base. **Conidia** 1-celled, oblong or ellipsoidal, smooth, hyaline, 3.0–5.0 × 1.5–3.0 μm (x± SD = 3.7 ± 0.56 × 2.3 ± 0.3 μm, n = 60). Octahedral crystals presented. **Sexual morph** not observed.

**Culture characteristics**—Colonies on PDA attaining 28–31 mm diam. after 15 days, plicate, felty, margin entire, white, light yellow secretions exuded. Reverse plicate, light yellow (4A2) to brown (5C8). Colonies on OA attaining 30–36 mm diam. after 15 days, aerial mycelia abundant, fluffy, cottony, margin entire, white. Reverse floral white (4A2) to pale brown (7B4). Colonies on SNA attaining 30–38 mm diam. after 15 days, flat, ulotrichy, margin entire, white. Reverse white. Sporulation within 10 days.

**Material examined**: CHINA, Guangxi, Guilin, E’gu Cav, N 24.942°, E 110.511°, on soil, May 2016, Z.F. Zhang, HMAS 247991 (holotype designated here), ex-type living culture CGMCC3.19573 = LC12493; ibid., LC12494.

**Notes**: *Simplicillium humicola* is phylogenetically allied to *S. formicae* Nonaka, Kaifuchi & Masuma and *S. obclavatum* Nonaka, Kaifuchi & Masuma (Fig. 31), but morphologically differs in conidial shape and size (globose to ellipsoidal, 2.0–3.5 μm long in *S. formicae*; 2.5–3.5 μm long in *S. obclavatum*). Meanwhile, phialides of *S. obclavatum* are always solitary.

**Nectriaceae** Tul. & C. Tul.

The family *Nectriaceae* is characterised by uniloculate, white, yellow, orange-red or purple ascomata that change colour in KOH. The asexual morphs of *Nectriaceae* are phialidic, producing amerosporous to phragmosporous conidia.
The majority of species are soil-borne saprobes or weak to virulent, facultative or obligate plant pathogens (Lombard et al. 2015).

**Paracremonium** L. Lombard & Crous

The genus *Paracremonium* was established to accommodate *Acremonium recifei* and could be distinguished from other acremonium-like genera by the formation of sterile coils from which conidiophores radiate with inconspicuously swollen septa in the hyphae (Lombard et al. 2015). However, among the currently accepted six species, *P. binewijzendii* Houbraken, van der Kleij & L. Lombard, *P. contagium* L. Lombard & Crous, *P. inflatum* L. Lombard & Crous, *P. moubasheri* Al-Bedak & M.A. Ismail, *P. pembeum* S.C. Lynch & Eskalen and *P. variiforme* Z.F. Zhang, F. Liu & L. Cai, only *P. inflatum* produces sterile coils (Lombard et al. 2015; Lynch et al. 2016; Crous et al. 2017; Zhang et al. 2017; Al-Bedak et al. 2019). Sterile coils is thus no longer a significant distinguishing character of the genus from allied genera. In this study, two new species named as *Paracremonium apiculatum* and *P. ellipsoideum* are described (Fig. 34).

**Paracremonium apiculatum** Z.F. Zhang & L. Cai, *sp. nov.*

Index Fungorum number: 557742, Facesoffungi number: FoF 08451; Fig. 35

*Etymology*: Referring to its terminally apiculate conidia.

*Holotype*: HMAS 248078.

*Hyphae* hyaline, smooth, thick-walled, septate, branched, 2.0–7.0 µm diam. *Asexual morph* Conidiophores arising from vegetative hyphae solitary or tightly aggregated in cream-white, slimy sporulation, erect, simple or mostly branched, septate, bearing whorls of 2–6 conidiogenous cells. *Conidiogenous cell* terminal or lateral, straight, acicular, tapering towards apex, smooth, hyaline, 14–24 µm long, 1.5–3.0 µm wide at base, with prominent periclinal thickening and inconspicuous collarette, 1.0–1.5 µm diam. *Conidia* abundant, unicellular, subglobose to globose, apiculate, smooth, thick-walled, hyaline, 3.5–5.0 µm (x ± SD =

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**Fig. 33** *Simplicillium humicola* (from ex-holotype CGMCC3.19573). a–c Upper and reverse views of cultures on PDA, OA and SNA 15 days after inoculation; d–f conidiophores and phialides; g conidia. Scale bars: d–g 10 µm
phylogenetically allied species (Fig. 34), living culture CGMCC3.19309 = LC12501; ibid., LC12502. Zhang, HMAS 248078 (holotype designated here), ex-type jiao Cave, N 25.134°, E 103.383°, on soil, May 2016, Z.F. (1A2). Sporulation within 10 days.

sporulation scattered. Reverse annular, white to floralwhite to floralwhite, aerial mycelia extremely sparse with slimy mm diam. after 15 days, flat, annular, margin entire, white to floralwhite, aerial mycelia extremely sparse with slimy sporulation in center. Reverse floralwhite (1A2). Colonies on SNA attaining 28–33 cream-white (1A1), aerial mycelia sparse. Reverse white to 25–30 mm diam. after 15 days, flat, felty, margin entire, not observed.

4.13 ± 0.3 µm, n = 60). Chlamydospores and Sexual morph not observed.

Culture characteristics—Colonies on PDA attaining 25–30 mm diam. after 15 days, flat, felty, margin entire, cream-white (1A1), aerial mycelia sparse. Reverse white to beige (30A1). Colonies on OA attaining 24–33 mm diam. after 15 days, flat, margin unclear, aerial mycelia extremely sparse, with cream-white and slimy sporulation in center. Reverse floralwhite (1A2). Colonies on SNA attaining 28–33 mm diam. after 15 days, flat, annular, margin entire, white to floralwhite, aerial mycelia extremely sparse with slimy sporulation scattered. Reverse annular, white to floralwhite (1A2). Sporulation within 10 days.

Material examined: CHINA, Yunnan, Yiliang, Sanjiao Cave, N 25.134°, E 103.383°, on soil, May 2016, Z.F. Zhang, HMAS 248078 (holotype designated here), ex-type living culture CGMCC3.19309 = LC12501; ibid., LC12502. Notes: P. apiculatum can be easily distinguished from phylogenetically allied species (Fig. 34), P. variiforme, by its smaller ellipsoidal conidia with apiculate bases, which are ovoid or elliptical in P. variiforme (3.5–5.0 µm vs. 9.0–14.5 µm). Moreover, its conidiogenous cells are much shorter than those of P. variiforme (14–24 µm vs. 18–41 µm).

Paracremonium ellipsoideum Z.F. Zhang & L. Cai, sp. nov. Index Fungorum number: 557743, Facesoffungi number: FoF 08452; Fig. 36

Etymology: Referring to the ellipsoidal conidia of this species.

Holotype: HMAS 248016.

Hyphae hyaline, smooth, thick-walled, septate, branched. Asexual morph Sporulation abundant, white, slimy. Conidiophores arising from vegetative hyphae solitary or in clusters, erect, branched, septate, thick-walled, hyaline, apex slightly swollen. Conidiogenous cells borne on aerial hyphae solitary or in whorls of 2–6 at apex of conidiophores, straight, acicular, tapering towards apex, smooth, hyaline, 22–38 µm long, 2.5–3.5 µm wide at base, with prominent

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periclinal thickening and inconspicuous collarette, 1.5–2.0 µm diam. Conidia in slimy head, abundant, unicellular, ellipsoidal with apiculate bases, smooth, thick-walled, hyaline, 5.5–8.0 × 3.5–5.0 µm (X ± SD = 6.5 ± 0.62 × 4.2 ± 0.28 µm, n = 60). Chlamydospires and not observed.

Culture characteristics—Colonies on PDA attaining 33–37 mm diam. after 15 days, flat, felty, margin entire, white to cream-yellow (30A2), aerial mycelia sparse. Reverse white to bisque (5A2). Colonies on OA attaining 33–37 mm diam. after 15 days, flat, margin unclear, aerial mycelia extremely sparse, with cream-white and slimy sporulation in center. Reverse light yellow (1A2). Colonies on SNA attaining 32–39 mm diam. after 15 days, flat, annular, margin entire, white to light yellow (1A2), aerial mycelia extremely sparse, with slimy sporulation scattered. Reverse annular, white to light yellow (1A2). Sporulation within 10 days.

Material examined: CHINA, Yunnan, Yiliang, Sanjiao Cave, N 25.134°, E 103.383°, on sewage, May 2016, Z.F. Zhang, HMAS 248016 (holotype designated here), ex-type living culture CGMCC3.19316 = LC12551; ibid., LC12552.

Notes: Phylogenetic analysis based on ITS, LSU and TUB sequences showed that new species Paracremonium...
ellipsoideum was closely related to Paracremonium inflatum and P. moubasheri (Fig. 34), but could be easily differentiated by its ellipsoidal conidia with apiculate bases, rather than the curved ellipsoidal to fusiform conidia in P. inflatum. In addition, conidiophores of P. inflatum are unbranched or rarely branched, differed from other species in Paracremonium by its branched conidiophores and ellipsoidal conidia with apiculate bases.

Microascales Luttr. ex Benny & Kimbr.

The order is characterized by nonstromatic black perithecial ascomata with long necks or rarely with cleistothecial ascomata that lack paraphyses, and globose and evanescent asci, developing singly or in chains (Réblová et al. 2011). Currently, Microascales comprise four families, i.e. Ceratocystidaceae, Chadefaudiellaceae, Halosphaeraceae, and Microascaceae (Kirk et al. 2008; Réblová et al. 2011).

Fig. 36 Paracremonium ellipsoideum (from ex-holotype CGMCC3.19316). a–c Upper and reverse views of cultures on PDA, OA and SNA 15 days after inoculation; d sporulation on PDA under stereomicroscope; e–g conidiophores, phialides and conidia; h phialides borne on aerial hyphae and conidia in globose head. i conidia. Scale bars: e–i 10 µm
Microascaceae Luttr. ex Malloch

Microascaceae was established by Luttrel (Malloch 1970) to accommodate a morphologically heterogeneous group of fungi. Species of the family are characterized by the presence of mostly annelidic asexual morphs with dry aseptate conidia and by sexual morphs that form cleistothelial or perithecial, carbonaceous ascomata producing reniform, lunate or triangular ascospores with or without germ pores. Most species of Microascaceae are reported as saprobiont or plant pathogens, and others are opportunistic pathogens of humans and show intrinsic resistance to antifungal agents (Sandoval-Denis et al. 2016b).

Microascus Zukal

The genus Microascus was established by Zukal (1985) with M. longirostris Zukal as the type species, and the asexual morphs were traditionally included in Scopulariopsis Bainier. Several authors subsequently demonstrated by culturing, mating studies and molecular methods, that the sexual morphs of Scopulariopsis belong to the ascomycete genus Microascus (Morton and Smith 1963; Issakainen et al. 2003). Sandoval-Denis et al. (2016a) refined the generic delimitations in Microascaceae and updated their circumscriptions based on multi-locus phylogeny. Members of the newly refined Microascus were characterized by dark-coloured colonies, mostly brown to green-brown mycelia, solitary conidiogenous cells (annelides) with long and narrow annelated zone, smooth to roughened conidia, solitary ascocarps with or without germ pores. Most species of Microascaceae are reported as saprobiont or plant pathogens, and others are opportunistic pathogens of humans and show intrinsic resistance to antifungal agents (Sandoval-Denis et al. 2016b).

Microascus collaris Z.F. Zhang & L. Cai, sp. nov.

Index Fungorum number: 557744, Facesoffungi number: FoF 08453; Fig. 38

Etymology: Referring to its long neck of ascomata.

Holotype: HMAS 248018.

Hyphae hyaline to pale brown, septate, branched, thin- and smooth-walled 1.5–2.5 µm. Sexual morph Ascomata abundant, ostiolate, immersed or semi-immersed, subglobose or globose, black, 190–280 µm diam., 200–340 µm high, glabrous, with 1–2 cylindrical ostiolar neck, up to 250 µm, peridium with a textura angularis. Asci 8-spored, ovate to globose, hyaline, 9.0–13.5 × 8.5–12.5 µm. Ascospores triangular to lunate, smooth, thick-walled, pale yellow, 4.5–7.0 × 3.5–5.5 µm (x ± SD = 6.0 ± 0.59 × 4.4 ± 0.54 µm, n = 50). Asexual morph conidiophores indistinctive or simple, cylindrical, smooth-walled, pale yellow. Conidiogenous cells solitary on aerial hyphae, or clustered on conidiophores, cylindrical to ampulliform, slightly curved, smooth, pale yellow, 7.5–14.0 × 2.5–3.5 µm, with conspicuous collarette. Conidia aggregated in slimy head, ellipsoidal, smooth, hyaline to pale yellow, 4.0–6.0 × 3.0–4.0 µm (x ± SD = 4.9 ± 0.56 × 3.4 ± 0.32 µm, n = 50), with truncated base.

Culture characteristics—Colonies on PDA attaining 10–13 mm diam. after 4 weeks, compact, convex with papillate surface, margin dentate, black, aerial mycelia extremely sparse. Reverse crack, black. Colonies on OA attaining 25–26 mm diam. after 4 weeks, surface undulate, margin entire, dark brown (5A8) to black, with black ascomata scattered. Reverse cream-colored. Colonies on SNA attaining 18–22 mm diam. after 4 weeks, flat, margin entire with rhizoids, white to grey-yellow (4A2), with black ascomata scattered. Sporulation within 20 days.

Material examined: CHINA, Guangxi, Laibin, Sanshan Cave, N 23.41°, E 108.931°, on plant debris, May 2016, Z.F. Zhang, HMAS 248018 (holotype designated here), ex-type living culture CGMCC3.19321 = LC12598; ibid., LC12599.

Notes: Phylogenetically, our strains nested within the Microascus clade based on ITS, LSU, TUB and EF1-α sequences (Fig. 37) and its morphological characteristics fit well to this genus, i.e. ampulliform or lageniform conidiogenous cells and smooth- and thin-walled or finely rough- and thick-walled conidia (Sandoval-Denis et al. 2016a).

Microascus collaris is phylogenetically closely related to M. trautmannii Woudenb. & Samson (Fig. 37). However, M. collaris can be distinguished from M. trautmannii by the presence of sexual stage, shorter conidiogenous cells (7.5–14.0 µm vs. 16.0–22.0 µm) and wider conidia (3.0–4.0 µm vs. 2.5–3.0 µm). In morphology, M. pyramidus resembles M. collaris but can be differentiated by its longer asci (13.0–18.0 µm vs. 9.0–13.4 µm) and wider ascospores (5.0–6.5 µm vs. 3.5–5.5 µm).

Microascus levis Z.F. Zhang & L. Cai, sp. nov.

Index Fungorum number: 557745, Facesoffungi number: FoF 08454; Fig. 39

Etymology: Referring to its smooth conidia.

Holotype: HMAS 248002.

Microascus levis was described (Fig. 37). However, M. levis can be distinguished from M. trautmannii by the presence of sexual stage, shorter conidiogenous cells (7.5–14.0 µm vs. 16.0–22.0 µm) and wider conidia (3.0–4.0 µm vs. 2.5–3.0 µm). In morphology, M. pyramidus resembles M. levis but can be differentiated by its longer asci (13.0–18.0 µm vs. 9.0–13.4 µm) and wider ascospores (5.0–6.5 µm vs. 3.5–5.5 µm).
Hyphae pale brown to brown, septate, branched, smooth-or rough-walled, 1.5–3.5 μm diam. **Asexual morph** Conidiophores simple, cylindrical, smooth, hyaline to pale brown. **Conidiogenous cell** borne laterally on aerial hyphae, or lateral or at the apex of conidiophores, ampulliform or irregular shapes, sometimes curved, smooth-walled, pale brown, 6.0–12.5 × 2.5–5.0 μm. **Conidia** arranged in chains, sub-globose to globose, smooth-walled, pale brown, 5.5–8.5 (–9.5) × 5.0–8.5 μm (x ± SD = 6.8 ± 0.83 ± 6.2 ± 0.79 μm, n = 55). **Sexual morph** not observed.

**Culture characteristics**—Colonies on PDA attaining 23–25 mm diam. after 3 weeks, felt, compact, plicated, convex, margin entire to undulate, gray-yellow (4A2) to dark green (28E2) from margin to center, with light-colored margin. Reverse plicated, sunken, gray-yellow (4A2) to dark green (28E2). Colonies on OA attaining 32–40 mm diam. after 3 weeks, flat, white to cream-colored, margin entire, aerial mycelia sparse. Reverse white to cream-colored. Colonies on SNA attaining 30–34 mm diam. after 3 weeks, flat, margin entire, pale grey (30B2) to grey-yellow (30B3). Reverse pale grey (30B2) to grey-yellow (30B3). Sporulation within 15 days.

**Material examined:** CHINA, Guangxi, Guilin, Luotian Cave, N 24.94°, E 110.52°, on soil, May 2016, Z.F. Zhang, HMAS 248002 (holotype designated here), ex-type living culture CGMCC3.19308 = LC12495; ibid., LC12447.

**Notes:** *Microascoctus levis* is phylogenetically closely related to *M. cirrosus* Curzi. Whereas, the conidia of *M. levis* are subglobose to globose, rather than subglobose to obovate in *M. cirrosus*. In addition, the sexual stage of *M. levis* is absent. In morphology, *M. levis* is similar to *M. restrictus* Sand.-Den., Gené & Deanna A. Sutton and *M. verrucosus* Sand.-Den., Gené & Cano. While *M. levis* has larger conidia than *M. restrictus* (5.5–8.5 (–9.5) × 5.0–8.5 vs. 4.5–6.0 × 4.0–5.5) and the conidiogenous cell of *M. levis* is smooth-walled rather than typically warty in *M. verrucosus*. Meanwhile, colonies of these three closely related species on OA are obviously different (white to cream-colored with entire and flat margin for *M. levis*, olive brown to brown with an irregular undulate margin for *M. restrictus*, olive grey with an immersed and slightly undulated margin for *M. verrucosus*).

*Microascoctus sparsimycelialis* Z.F. Zhang & L. Cai, sp. nov.

**Index Fungorum number:** 557746, **Facesoffungi number:** FoF 08455; Fig. 40

**Etymology:** Referring to its sparse aerial mycelia on media.

**Holotype:** HMAS 248006.

Hyphae pale brown to brown, septate, branched, thick-walled, 1.5–3.5 μm diam, swollen to globose sometimes, up to 10 μm diam., aerial hyphae becoming dark brown and clustered when aging. **Asexual morph** Conidiophores simple, cylindrical to ellipsoidal, smooth, pale brown to brown. **Conidiogenous cells** solitary on aerial hyphae, or in whorls of 2–3 at apex of conidiophores, ellipsoidal, ampulliform or irregular shapes, straight or slightly curved, smooth or finely roughened, pale brown to brown, 5.0–10.0 (–14.0) × 3.0–5.0 μm, with conspicuous collar. **Conidia** in long chains, ovoid to globose, smooth or finely roughened, thick-walled, pale brown, 3.5–6.0 × 3.0–5.5 μm (x ± SD = 4.8 ± 0.58 × 4.31 ± 0.55 μm, n = 60), with apical base. **Sexual morph** not observed.

**Culture characteristics**—Colonies on PDA attaining 9–13 mm diam. after 3 weeks, compact, convex with crack surface, margin crenate, cream-white to grey-yellow (29D3), aerial mycelia sparse. Reverse crack, pale yellow-green (29A2) with dark green (29B2) to grey-yellow (29B3). Colonies on OA are obviously different (white to cream-colored with entire and flat margin for *M. levis*, olive brown to brown with an irregular undulate margin for *M. restrictus*, olive grey with an immersed and slightly undulated margin for *M. verrucosus*).

*Microascoctus sparsimycelialis* is phylogenetically and morphologically closely related to *M. restrictus* and *M. verrucosus* (Fig. 37). Colonies of *M. sparsimycelialis* on OA are dark green with entire margin, while these of *M. restrictus* are olive green with irregular margin. *M. sparsimycelialis* differs from *M. verrucosus* by its smooth conidiogenous
cells, rather than sparsely warted in *M. verrucosus*. Moreover, conidia of *M. sparsimycelialis* are pale brown with apical base, comparing to that being dark brown with truncate base in *M. restrictus* and *M. verrucosus*. In addition, both of *M. restrictus* and *M. verrucosus* produce solitary conidia laterally from vegetative hyphae, which is not the case in *M. sparsimycelialis*.

**Microascus superficialis** Z.F. Zhang & L. Cai, sp. nov.

*Index Fungorum number*: 557747, *Facesoffungi number*: FoF 08456; Fig. 41

**Etymology**: Referring to its superficial ascomata.

**Holotype**: HMAS 248005.

*Hyphae* hyaline to pale brown, septate, branched, smooth. **Sexual morph** *Ascomata* black, superficial or semi-immersed, glabrous, ostiolate, subglobose to globose, 215–350 µm diam., with a short cylindrical ostiolar neck, peridium with a textura angularis. *Asci* hyaline, 8-spored, irregularly ellipsoidal to subglobose, 12.0–15.0 × 9.0–11.5 µm. *Ascospores* triangular, yellow-brown, smooth, thick-walled, 5.5–7.0 × 4.0–5.5 µm (\(\bar{x} \pm SD = 6.4 \pm 0.41 \times 4.8 \pm 0.34 \mu m, n = 50\)). **Asexual morph** not observed.

**Culture characteristics**—Colonies on PDA attaining 12–17 mm diam. after 4 weeks, compact, rugged, margin undulate, cream-yellow (5A2) to red-brown (6C8), aerial mycelia sparse. Reverse crack, cream-yellow (5A2) to pale red-brown (6B5). Colonies on OA attaining 30–32 mm diam. after 4 weeks, plicated, margin undulate, white to beige (4A1) with dark-grey (7C1) circle, aerial mycelia sparse. Reverse white to pale salmon (5A2). Colonies on SNA attaining 17–19 mm diam. after 4 weeks, flat, compact, margin fimbriate, beige (30A2) to pale grey (30C4). Reverse beige to pale grey. Sporulation within 20 days on OA and SNA.

**Material examined**: CHINA, Guangxi, Laibin, Sanshan Cave, N 23.41°, E 108.931°, on animal faeces, May 2016, Z.F. Zhang, HMAS 248005 (holotype designated here), ex-type living culture CGMCC3.19638 = LC12597; ibid., LC12600; ibid., LC12601.

**Notes**: *Microascus superficialis* is phylogenetically closely related to *M. croci* (J.F.H. Beyma) Sand.-Den., Gené & Guarro (Fig. 37), while in contrast to *M. superficialis*, no sexual morph was observed in *M. croci*. Morphologically, *M. superficialis* shares similar sexual morph with *M. pyramidus* G.L. Barron & J.C. Gilman. However, ascospores of *M. pyramidus* have attenuated ends and often acquire a nearly square shape (Sandoval-Denis et al. 2016a). Meanwhile, *M. pyramidus* grows faster (40–50 mm in 4 weeks) than our new species on PDA (Barron et al. 1961).

**Microascus trigonus** Z.F. Zhang & L. Cai, sp. nov.

*Index Fungorum number*: 557748, *Facesoffungi number*: FoF 08457; Fig. 42

**Etymology**: Referring the shape of the ascospores.

**Holotype**: HMAS 248001.

*Hyphae* hyaline, septate, branched, smooth, thin-walled, 1.5–3.0 µm diam. **Sexual morph** *Ascomata* abundant, black, superficial, glabrous, subglobose to globose, 182–294 µm diam, with a short cylindrical ostiolar neck; peridium with a textura angularis. *Asci* short clavate, subglobose to globose, hyaline, 8-spored, 9.0–17 × 8.0–12 µm. *Ascospores* triangular, smooth, thick-walled, pale brown, 4.5–6.0 × 3.5–5.5 µm (\(\bar{x} \pm SD = 5.7 \pm 0.43 \times 4.3 \pm 0.53 \mu m, n = 50\)). **Asexual morph** conidiophores simple, straight, septate, occasionally branched, hyaline. *Conidiogenous cells* solitary on aerial hyphae, or in whorls of 2–3 on apex of conidiophores, lageniform to ampulliform, straight or slightly curved, pale brown, 4.5–10.0 (–14.5) × 2.5–4.5 µm. *Conidia* in long chains, ellipsoidal to globose, smooth, thick-walled, hyaline to pale brown, 3.5–5.5 × 3.0–4.5 µm (\(\bar{x} \pm SD = 4.5 \pm 0.47 \times 3.8 \pm 0.29 \mu m, n = 70\)).

**Culture characteristics**—Colonies on PDA attaining 26–30 mm diam after 3 weeks, felty, compact, plicated, convex, margin undulate, beige (30A2) to whitesmoke (4A2) with lightgrey (1C4) ring. Reverse plicated, crack, beige (30A2) to oldlace (5A2) with lightgray ring (1C4). Colonies on OA attaining 34–36 mm diam after 3 weeks, flat, margin entire, white to dark brown (5F8). Reverse white to pale brown (5B3). Colonies on SNA attaining 28–36 mm diam after 3 weeks, flat, margin fimbriate, floralwhite (1A2) to yellow-green (2A2). Reverse floralwhite (1A2) to pale yellow-green (2A2). Sporulation within 15 days.

**Material examined**: CHINA, Guangxi, Guilin, Luotian Cave, N 24.948°, E 110.524°, on soil, May 2016, Z.F. Zhang, HMAS 248001 (holotype designated here), ex-type living culture CGMCC3.19636 = LC12520; ibid., LC12600; ibid., LC12601.

**Notes**: *Microascus superficialis* is phylogenetically closely related to *M. croci* (J.F.H. Beyma) Sand.-Den., Gené & Guarro. **Microascus superficialis** shares similar sexual morph with *M. pyramidus* G.L. Barron & J.C. Gilman.
faeces, May 2016, Z.F. Zhang, LC12559; ibid., LC12586; ibid., LC12631.

Notes: *Microascus trigonus* is phylogenetically closely allied to *M. chartarus* (G. Sm.) Sand.-Den. (Fig. 37), but can be distinguished by the absence of sexual morph with ovate, green-brown, and frequently pointed conidia. Morphologically, *M. alveolaris* resembles *M. trigonus*. However, the conidia in *M. alveolaris* are ellipsoidal, navicular or bullet-shaped rather than ellipsoidal to globose in *M. trigonus*.

*Pseudoscopulariopsis* Sand.-Den., Gené & Guarro

*Pseudoscopulariopsis* was established to accommodate species that are generally similar to *Scopulariopsis*, but differs in the gray or olivaceous colonies, ampulliform annelides and navicular to fusiform ascospores without germ
pores (Sandoval-Denis et al. 2016a). Currently, this genus contains only two species. *Pseudoscopulariopsis asperispora* sp. nov. is described below (Fig. 37).

**Pseudoscopulariopsis asperispora** Z.F. Zhang & L. Cai, *sp. nov.*

Index Fungorum number: 557749, Facesoffungi number: FoF 08458; Fig. 43

**Etymology:** Referring to its rough-walled conidia.

**Holotype:** HMAS 247989.

**Hyphae** pale brown to brown, septate, branched, rough-and thick-walled, 1.5–3.5 µm diam. **Asexual morph** **Conidiophores** arising from hyphae, irregularly cylindrical,
branched 1–3 times, smooth or slightly rough, thick-walled, hyaline to pale brown, 2.0–4.0 µm diam. at base, swollen at apex, up to 6.5 µm diam. Conidiogenous cells in whorls of 2–6 at apex of conidiophores, ampulliform or cylindrical, straight or slightly curved, smooth, thin-walled, pale brown, 5.5–10.0 (−12.0) × 2.5–4.5 µm, with inconspicuous annelidic. Conidia in long chains, subglobose to globose, rough, thick-walled, brown, 4.5–7.5 × 4.5–7.0 µm (̄x ± SD = 6.0 ± 0.67 × 5.6 ± 0.66 µm, n = 60), with truncated base. Sexual morph not observed.

Culture characteristics—Colonies on PDA attaining 21–25 mm diam. after 3 weeks, low convex, margin erose, pale yellow-green (29D5) to olive (29F4), with ivory (29A2) margin. Reverse yellow-green (29D5) to olive (29F4) with ivory (29A2) margin. Colonies on OA attaining 42–45 mm diam. after 3 weeks, flat, slightly raised

Fig. 40 Microascus sparsimycelialis (from ex-holotype CGMCC3.19307). a–e Upper and reverse views of cultures on PDA, OA and SNA 3 weeks after inoculation; d–g conidiogenous cells and conidia in chains; h conidia; i swollen hyphae. Scale bars: d–i 10 µm
at center, margin erose, dark-brown (5F8) to black, aerial mycelia sparse. Reverse yellow-green (29A5). Colonies on SNA attaining 18–22 mm diam. after 3 weeks, flat, margin radially striate with lobate edge, dark olive with yellow-green (29C4) margin. Reverse dark olive (29E5) with yellow-green (29C4) margin. Sporulation within 15 days.

Material examined: CHINA, Guangxi, Guilin, Luotian Cave, N 24.948°, E 110.524°, on animal faeces, May 2016, Z.F. Zhang, HMAS 247989 (holotype designated here), ex-type living culture CGMCC3.19302 = LC12445; ibid., LC12446.

Notes: Pseudoscopulariopsis asperispora clustered within Pseudoscopulariopsis in a distinct clade with high support value based on the ITS, LSU, TUB, and EF1-α sequence analysis (Fig. 37). P. asperispora can be easily distinguished from P. schumacheri (E.C. Hansen) Sand.-Den., Gené & Guarro by its subglobose to globose conidia rather than obovate or short clavate in P. schumacheri; from P.

![Fig. 41 Microascus superficialis](from ex-holotype CGMCC3.19638). a–e Upper and reverse views of cultures on PDA, OA and SNA 3 weeks after inoculation; d, e ascoma; f peridium; g–i asci; j ascospores. Scale bars: e 100 µm; f–j 10 µm
**Wardomycopsis** Udagawa & Furuya

Wardomycopsis was introduced as one of the anamorph-typified genera related to *Microascus*, characterised by dark, globose, thick-walled conidia with germ slits that form short chains on annellidic conidiogenous cells (Udagawa and Furuya 1978; Silvera-Simón et al. 2008). Recent phylogenetic analyses demonstrated that *Wardomycopsis* is monophyletic (Sandoval-Denis et al. 2016a; Zhang et al. 2017). Currently, *Wardomycopsis* comprises five species and we herein add three new species named as *W. dolichi*, *W. ellipsoconidiophora* and *W. fusca* (Fig. 37).

**Wardomycopsis dolichi** Z.F. Zhang & L. Cai, sp. nov.

*Index Fungorum number:* 557750, *Facesoffungi number:* FoF 08459; Fig. 44

*Etymology:* Referring to its long conidiophore.

*Holotype:* HMAS 247998.

*Hyphae* hyaline to pale olive, septate, smooth or finely verrucose, thick-walled, 1.5–3.5 µm diam., sometimes swollen, up to 7.0 µm diam. *Asexual morph* Conidiophores cylindrical or long ellipsoidal, septate, branched 1–3 times, smooth, hyaline. Conidiogenous cells solitary on aerial hyphae, or in whorls of 1–3 at apex of conidiophores, ellipsoidal or clavate, thick-walled, olive-brown, 4.0–6.0 × 2.5–3.0 µm. *Conidia* mostly borne from conidiogenous cells, occasionally observed on aerial hyphae directly, ellipsoidal or clavate, thick-walled, olive-brown, 4.0–6.0 (− 7.5) × 2.5–4.0 µm (̅ ± SD = 5.1 ± 0.68 × 3.3 ± 0.30 µm, n = 30), with truncated base and median longitudinal germ slit. *Sexual morph* not observed.

*Culture characteristics*—Colonies on PDA attaining 24–28 mm diam. after 3 weeks, compact, slightly plicated, margin entire, white at margin, black at center. Reverse cream-yellow (4A2) to pale yellow (2A1) from middle to center. *Conidia* mainly borne from conidiogenous cells, occasionally observed on aerial hyphae directly, ellipsoidal or clavate, thick-walled, brown, 4.5–7.0 × 2.5–4.0 µm (̅ ± SD = 5.7 ± 0.72 × 3.3 ± 0.33 µm, n = 50), with truncated base and median longitudinal germ slit.

*Material examined:* CHINA, Guangxi, Guilin, E’gu Cave, N 23.41°, E 108.931°, on animal faeces, May 2016, Z.F. Zhang, HMAS 248004 (holotype designated here), ex-type living culture CGMCC3.19322 = LC12606; ibid., LC12607.

*Notes:* Our strains clustered within *Wardomycopsis* and formed a distinct clade with high support value based on the multi-locus analysis (Fig. 37). *W. dolichi* is phylogenetically closely allied to *W. fusca* and *W. humicola* (Fig. 37), while they are morphologically distinguishable. Conidiophores of *W. ellipsoconidiophora* are ellipsoidal and branched, comparing to ellipsoidal to globose and unbranched in *W. fusca*. *W. ellipsoconidiophora* differs from *W. fusca* (G.L. Barron) Udagawa & Furuya in its slightly wider conidium (2.5–3.0 µm vs. 1.5–2.5 µm) and conidia (2.5–4.0 µm vs. 1.5–2.5 µm), color on PDA and SNA media, and the absence of sexual morph, which is observed in *W. longicatena*.

**Wardomycopsis ellipsoconidiophora** Z.F. Zhang & L. Cai, sp. nov.

*Index Fungorum number:* 557751, *Facesoffungi number:* FoF 08460; Fig. 45

*Etymology:* Referring to its ellipsoidal conidiophores.

*Holotype:* HMAS 248004.

*Hyphae* hyaline, septate, smooth, thick-walled, 1.5–2.5 µm diam. *Asexual morph* Conidiophores arising from hyphae, ellipsoidal, septate, branched 1–3 times, smooth, thick-walled, hyaline to pale olive. Conidiogenous cells solitary on aerial hyphae, or in whorls of 1–5 at apex of conidiophores, ellipsoidal, smooth, thick-walled, pale olive, 3.0–6.0 × 2.5–3.0 µm. *Conidia* mostly borne from conidiogenous cells, occasionally observed on aerial hyphae, or in whorls of 1–5 at apex of conidiophores, ellipsoidal, smooth, thick-walled, olive-brown, 4.0–6.0 (− 7.5) × 2.5–4.0 µm (̅ ± SD = 5.1 ± 0.68 × 3.3 ± 0.30 µm, n = 30), with truncated base and median longitudinal germ slit.

*Material examined:* CHINA, Guangxi, Laibin, Sanshan Cave, N 23.41°, E 108.931°, on animal faeces, May 2016, Z.F. Zhang, HMAS 248004 (holotype designated here), ex-type living culture CGMCC3.19322 = LC12606; ibid., LC12588.

*Notes:* *Wardomycopsis ellipsoconidiophora* is phylogenetically closely allied to *W. fusca* and *W. humicola* (Fig. 37), while they are morphologically distinguishable. Conidiophores of *W. ellipsoconidiophora* are ellipsoidal and branched, comparing to ellipsoidal to globose and unbranched in *W. fusca*. *W. ellipsoconidiophora* differs from *W. fusca* (G.L. Barron) Udagawa & Furuya in its slightly wider conidium (2.5–3.0 µm vs. 1.5–2.5 µm) and low sequence similarities (98% similarity, 7 bp difference in 416 bp of ITS; 99% similarity, 5 bp difference in 842 bp of LSU; 96% similarity, 35 bp difference in 928 bp of EF1-α; 95% similarity, 22 bp difference in 475 bp of TUB).

**Wardomycopsis fusca** Z.F. Zhang, F. Liu & L. Cai, sp. nov.

*Index Fungorum number:* 557752, *Facesoffungi number:* FoF 08461; Fig. 46

*Hyphae* hyaline, septate, smooth, thick-walled, 1.5–2.5 µm diam. *Asexual morph* Conidiophores arising from hyphae, ellipsoidal, septate, branched 1–3 times, smooth, thick-walled, hyaline to pale olive. Conidiogenous cells solitary on aerial hyphae, or in whorls of 1–5 at apex of conidiophores, ellipsoidal, smooth, thick-walled, pale olive, 3.0–6.0 × 2.5–3.0 µm. *Conidia* mostly borne from conidiogenous cells, occasionally observed on aerial hyphae directly, ellipsoidal or clavate, thick-walled, olive-brown, 4.0–6.0 (− 7.5) × 2.5–4.0 µm (̅ ± SD = 5.1 ± 0.68 × 3.3 ± 0.30 µm, n = 30), with truncated base and median longitudinal germ slit.

*Material examined:* CHINA, Guangxi, Guilin, E’gu Cave, N 23.41°, E 108.931°, on animal faeces, May 2016, Z.F. Zhang, HMAS 248004 (holotype designated here), ex-type living culture CGMCC3.19322 = LC12606; ibid., LC12588.
Fig. 42 *Microascus trigonus* (from ex-holotype CGMCC3.19636). a–c Upper and reverse views of cultures on PDA, OA and SNA 3 weeks after inoculation; d, e ascoma; f peridium; g–i asci; j ascospore; k–n conidiogenous cells and conidia; o conidia. Scale bars: e 100 µm; h 20 µm; f, g, i–o 10 µm.


**Etymology**: Referring to the brown color of its conidia.

**Holotype**: HMAS 247997.

**Hyphae** hyaline to pale olive, septate, smooth, thin-walled, 1.5–2.5 µm diam. **Asexual morph** **Sporulation** abundant on SNA, brown, slimy. **Conidiophores** arising from hyphae, ellipsoidal to globose, occasionally branched one times, smooth, thick-walled, pale olive-brown, 3.0–7.5 × 2.5–5.0 µm. **Conidiogenous cells** solitary on aerial hyphae, ellipsoidal, or clustered on conidiophores, ampulliform, smooth, thick-walled, pale olive-brown, 3.0–5.0 (–6.0) × 2.5–3.5 µm. **Conidia** ellipsoidal, thick-walled, brown, 4.0–6.5 × 2.5–3.5 µm (× ± SD = 5.1 ± 0.62 × 3.0 ± 0.32 µm, n = 30), with truncated base and median longitudinal germ slit. **Sexual morph** not observed.

**Culture characteristics**—Colonies on PDA attaining 25–31 mm diam. after 3 weeks, felty, compact, convex,
margin entire, pale olive (29A3) to grey (28B3), with light colored margin. Reverse sunken in center, cream-yellow (29A3) to olive (29D4). Colonies on OA attaining 26–28 mm diam after 3 weeks, flat, margin entire, white to dark olive (29F5), with olive rings (29F5). Reverse white to pale olive (29B2). Colonies on SNA attaining 23–28 mm diam after 3 weeks, flat, slightly plicated, margin entire, beige (28A2) to pale olive (29D4). Reverse beige (28A2) to dark olive (29F6). Sporulation within 15 days.

Material examined: CHINA, Guangxi, Guilin, Luotian Cave, N 24.948°, E 110.524°, on soil, May 2016, Z.F. Zhang, HMAS 247997 (holotype designated here), ex-type living culture CGMCC3.19306 = LC12476; ibid., LC12526; Guangxi, Guilin, E’gu Cave, N 24.942°, E 110.511°, on animal faeces, May 2016, Z.F. Zhang, LC12636; Yunnan, Mengzi, Mingju old Cave, N 23.487°, E 103.619°, on animal faeces, May 2016, Z.F. Zhang, LC12607; ibid., LC12661; Yunnan, Yiliang, Sanjiao Cave, N 25.134°, E 103.383°, on soil, May 2016, Z.F. Zhang, LC12643.

Notes: Wardomyces fusca is phylogenetically and morphologically closely related to W. ellipsoconidiophora and W. humicola (Fig. 37), but differs in ellipsoidal or globose and mostly unbranched conidiophores. Contrast to W. fusca, W. ellipsoconidiophora and W. humicola have cylindrical to ellipsoidal and branched conidiophores.

Subclass Sordariomycetidae O.E. Erikss. & Winka

Calosphaeriales M.E. Barr

The Calosphaeriales is an order of perithecial ascomycetous fungi with allantoid to suballantoid ascospores and
characteristic ascogenous hyphae, ascogenous cells and centrum, considered unique among the ascomycetes (Réblová et al. 2015). The order traditionally comprises wood-inhabiting perithecial ascomycetes that occupy specialized habitats between wood and periderm (Réblová et al. 2015).

**Calosphaeriaceae** Munk

The family was introduced by Munk (1957), followed by several recent revisions (Damm et al. 2008). Members of the **Calosphaeriaceae** share a set of typical characters such as globose to subglobose dark ascomata with a central neck, hyaline, non-septate or one to several transverse septa, 8-spored, clavate, tapering, stipitate asci. The asci have a conspicuous, symmetrical thickening at the apex, which lacks a visible discharge mechanism (Réblová et al. 2015). **Calosphaeriaceae** members are typical inhabitants of wood and bark of a broad spectrum of trees and shrubs worldwide, including *Prunus* wood (Barr 1985).

**Jattaea** Berl.

Berlese (1900) introduced genus *Jattaea* with *J. algeriensis* Berl. as generic type. *Jattaea* was recently revised based on a five-locus phylogeny (Réblová et al. 2015) and 18 species are currently accepted (Réblová et al. 2015; Dayarathne et al. 2017). The members of *Jattaea* are characterized by non-stromatic perithecial ascomata, clavate and stipitate asci with a thickened apex and distinct sporiferous part, persistent paraphyses and allantoid, 1-septate, hyaline ascospores. Asexual morphs of *Jattaea* are phialophora-like, i.e. short-ampulliform to elongate-ampulliform phialides or adelophialides with funnel-shaped collarettes (Réblová et al. 2015; Dayarathne et al. 2017). In this study, one new species *Jattaea reniformis* is described (Fig. 47).

**Jattaea reniformis** Z.F. Zhang & L. Cai, sp. nov., Fig. 48

*Index Fungorum number*: 557753, *Facesoffungi number*: FoF 08462; *Fig. 48*

*Etymology*: Referring to its reniform conidia.

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**Fig. 45** *Wardomycopsis ellipsoconidiophora* (from ex-holotype CGMCC3.19322). a–c Upper and reverse views of cultures on PDA, OA and SNA 14 days after inoculation; d–f, h conidiophores and conidiogenous cells; g conidia borne on hyphae; i conidia. Scale bars: d–i 10 µm
Holotype: HMAS 247995.

Hyphae hyaline, septate, branched, smooth, 1.5–3.5 μm wide. Asexual morph Conidiophores micronematous, reduced to conidiogenous cells. Phialides arise from prostrate aerial hyphae solitary, lateral, monophialidic, long ampulliform to tapering, smooth to slightly granulate, hyaline, various in length, 4.5–11.5 μm long, 1.5–3.0 μm diam. at base, with conspicuous collarette, tapering to 1.0–1.5 μm below the collarette; adelophialides subcylindrical or ampulliform, 1.5–3.0 μm × 1.0–2.0 μm. Conidia aggregated in globose heads, cylindrical to reniform, unicellular, smooth, hyaline, various in size, 3.0–6.0 × 1.0–2.0 μm (\( \bar{x} \pm SD = 4.2 \pm 0.66 \times 1.5 \pm 0.21 \mu m, n = 60 \)). Sexual morph not observed.

Culture characteristics—Colonies on PDA attaining 32–38 mm diam. after 4 weeks, plicated, margin entire, pale linen (5A2), aerial mycelia sparse. Reverse plicated, cream-white to yellow (4A7). Colonies on OA attaining 32–36 mm diam. after 4 weeks, flat, margin entire, white at margin, light gray (4B2) at middle, gainsboro (4A2) in center, aerial mycelia sparse. Reverse white to gainsboro (4B2) with gray ring (4B2). Colonies on SNA attaining 35–38 mm diam. after 4 weeks, flat, margin erose, white, aerial mycelia extremely sparse. Reverse white. Sporulation within 3 weeks.

Material examined: CHINA, Yunnan, Yiliang, Sanjiao Cave, N 25.134°, E 103.383°, on soil, May 2016, Z.F. Zhang, HMAS 247995 (holotype designated here), ex-type living culture CGMCC3.19311 = LC12509; ibid., LC12510.

Notes: This species should be classified into genus Jattaea, because it fits well to the asexual morphs of Jattaea, i.e. short-ampulliform to elongate-ampulliform to cylindrical phialides or adelophialides, tapering, with a more or less conspicuous funnel-shaped collarette (Réblová 2011; Réblová et al. 2015). Meanwhile, our strains are phylogenetically allied with Jattaea species based on ITS, LSU and TUB sequences (Fig. 47). Jattaea reniformis is currently known only for its asexual morph and comparable with J.
aphanospora Rébluvá & J. Fourn., J. ribicola Rébluvá & Jaklitsch and J. tumidula (Sacc.) Rébluvá. While J. reniformis differs from J. aphanospora and J. ribicola by the presence of phialides and adelophialides, whereas only adelophialides are observed in J. aphanospora and J. ribicola. J. reniformis differs from J. tumidula by its subcylindrical or ampulliform adelophialides and wider conidia (1.0–2.0 µm vs. 1.0–1.2 µm); meanwhile only subcylindrical adelophialides was observed in J. tumidula. Generally J. reniformis is well distinguishable from other species in Jatteae by the absence of conidiophores.

Subclass Xylariomycetidae O.E. Erikss. & Winka

Xylariales Nannf.
The order Xylariales was established by Nannfeldt (1932), and have been revised in several recent studies (Daranagama et al. 2018; Voglmayr et al. 2018; Wendt et al. 2018), with three families Barrmaeliaceae Voglmayr & Jaklitsch, Graphostromataceae M.E. Barr, J.D. Rogers & Y.M. Ju and Hypoxylaceae DC. included and revised. Xylariales is one of the largest order of the subclass Xylariomycetidae, which currently comprises 22 families (Wijayawardene et al. 2020).

Apiosporaceae K.D. Hyde, J. Fröhl., Joanne E. Taylor & M.E. Barr

Apiosporaceae was introduced by Hyde et al. (1998) and confirmed as a family within Xylariales, closely related to Amphisphaeriaceae (Crous and Groenewald 2013).

Nigrospora Zimm.

Nigrospora was introduced by Zimmerman (1902) and most recently revised by Wang et al. (2017). Nigrospora is characterized by branched micronematous or semimacronematous conidiophores, monoblastic conidiogenous cells and black, shiny, aseptate conidia. Sexual morphs comprise perithecial ascomata, short-stalked asci with biseriated ascospores (Wang et al. 2017). Species of Nigrospora are cosmopolitans with wide host range, and reported as endophytes, saprobes, or pathogens on crops or humans (Wang et al. 2017; Raza et al. 2019). In this study, one new species Nigrospora globosa is described based on ITS, EF1-α and TUB phylogeny (Fig. 49).

Nigrospora globosa Z.F. Zhang & L. Cai, sp. nov.

Index Fungorum number: 557754, Facesoffungi number: FoF 08463; Fig. 50

Etymology: Referring to its globose conidia.

Holotype: HMAS 248000.

Hyphae hyaline to pale brown, septate, branched, smooth, 1.5–8.0 µm wide. Asexual morph Conidiophores reduced to conidiogenous cells. Conidiogenous cells arising from aerial hyphae solitary or aggregated in clusters, cylindrical, ampulliform, ellipsoidal or subglobose, straight or curved, smooth, hyaline to pale brown, 8.5–22.0 × 5.0–9.0 µm. Conidia solitary, unicellular, subglobose to globose, smooth, dark brown to black, shiny, 11.0–14.5 × 9.0–13.0 µm (̅x ± SD = 13.0 ± 0.84 × 11.3 ± 1.0 µm, n = 60). Sterile cells and Sexual morph not observed.

Culture characteristics—Colonies on PDA attaining 38–41 mm diam. after 6 days, flat, floccose, radially striate with lobate edge, white initially, becoming pale gray with age. Reverse white to light yellow (2A2) initially, becoming pink (5A2) to brown (5B3) with age. Colonies on OA attaining 50 mm diam. after 4 days, flat, aerial mycelia abundant, floccose, margin entire, white initially, becoming gray (4B2) with age. Reverse white initially, becoming pink (5A2) with age. Colonies on SNA attaining 38–41 mm diam. after 6 days, flat, margin entire, white to pale yellow (3A3) initially, then becoming pale gray with gray (4B2) sporulation patches. Reverse white to pale yellow (4A1–4A2). Sporulation within 7 days.

Material examined: CHINA, Guangxi, Guilin, Luotian Cave, N 24.948°, E 110.524°, on soil, May 2016, Z.F. Zhang, HMAS 248000 (holotype designated here), ex-type living culture CGMCC3.19633 = LC12440; ibid., LC12441.

Notes: Our two strains representing N. globosa clustered with N. chinensis Mei Wang & L. Cai in a distinct clade (Fig. 49). Morphologically, N. globosa differs from N. chinensis by its larger conidiogenous cells (8.5–22.0 × 5.0–9.0 µm vs. 5.0–9.5 × 4.0–7.0 µm), and the absence of sterile cells in N. globosa.

Discussion

Karst area covers ca. 20% of the terrestrial area on the earth (Ford and Williams 2013), and there are more than a half million karst caves in China (Chen 2006; Zhang and Zhu 2012). According to Hawksworth and Lücking (2017), there are more than 120,000 hitherto described fungal species, but the estimation of global fungal diversity on the earth is 2.2 to 3.8 million. However, only 1626 fungal species were documented from caves and mines worldwide. Our study revealed that karst caves encompass a high fungal diversity, with a number of undescribed species.

Up to now, nine phyla have been reported in cave environments, and five phyla were obtained in this study. The proportion of species of Ascomycota, 88.0 % in this study, and 75.8 % in caves worldwide, is much higher than other phyla including Basidiomycota (Fig. 3a, e). In addition, the majority of genera with high species diverse (> 10 species) in caves are Ascomycota (Fig. 3f). In cave Basidiomycota is rare possibly because they are difficult to culture and often need to be associated with nutrient rich substrates such as
wood and dung (Vanderwolf et al. 2013), while these organic matters are much exiguous compared to a regular terrestrial environment. Glomeromycota, a phylum of arbuscular mycorrhizal (AM) fungi (Schüßler et al. 2001) never reported from caves in previous studies, was obtained in this study from soil sample of Sanjiao Cave (Table S1). Meanwhile, in our another study on fungal community based on high-throughput sequencing (HTS), Glomeromycota accounts for ca. 0.3% of all fungal OTUs in caves, and soil and water samples encompass more abundant reads of Glomeromycota than air and rock samples (Zhang and Cai 2019), which might due to the higher nutrient concentrations in soils (Vanderwolf et al. 2013) and a better link of water sample inside caves and the forest reservoir outside the caves (Voříšková and Baldrian 2013).

The most commonly recorded fungal genera in worldwide caves are cosmopolitan ones, especially *Penicillium* and *Aspergillus*, two genera discovered in all the caves investigated (Fig. 3c, f). Due to their diverse physiological features, species of *Penicillium* and *Aspergillus* are ubiquitous and can grow on almost all types of habitat, including the subsurface environments (Houbraken et al. 2014). Although *Mortierella* and *Mucor* had been reported from many caves, Vanderwolf et al. (2013) suggested that the incidence of *Zygomycota*, mainly *Mortierella* and *Mucor*, in caves might be overestimated due to the bias of detecting method. However, several studies using metabarcoding method did detect high relative abundance of *Zygomycota* (up to 49.8% when endogenous carbon available) in tourism caves and pristine caves (Cloutier et al. 2017; Pfendler et al. 2019; Zhang and Cai 2019). Therefore, the culture-based method may not be as biased as previously speculated (Zhang and Cai 2019). Several studies demonstrated that fungi in caves with fast growth and abundant spore production, including...
Penicillium, Aspergillus, Mortierella and Mucor, were sensitive to the changes of organic matters or human activates (Min 1988; Docampo et al. 2010, 2011; Jurado et al. 2010; Vanderwolf et al. 2013), indicating a predominantly saprobic lifestyle and potentially exogenous origin. According to the summary of Vanderwolf et al. (2013), Rhachomyces was widespread and thirty-two species, as insect coloniners, had been reported in caves, which was however, not recorded here possibly because only very few insect samples were collected in this study.

Cave systems were suggested to be a good harbour for the development and preservation of allochthonous microorganisms, such as mycorrhizal and pathogenic fungi (Kuzmina et al. 2012; Vanderwolf et al. 2013; Zhang et al. 2017; Zhang and Cai 2019). Many fungi obtained in this study are plant endophytic or pathogenic. For example, Entrophospora R.N. Ames & R.W. Schneid., isolated from soil in Sanjiao Cave, was reported as an AM fungi (Schüßler et al. 2001; Palenzuela et al. 2010). Fusarium graminearum Schwabe, a plant pathogen that causes head blight of wheat (Bai and Shaner 2004), was isolated from soil and water samples of Mingjiu Old Cave and Tianliang Cave. Many species of Colletotrichum Corda, Diaporthe Nitschke, Fusarium and Phoma Sacc. complexes obtained in this study.

**Fig. 48** Jattaea reniformis (from ex-holotype CGMCC3.19311). a–c Upper and reverse views of cultures on PDA, OA and SNA 4 weeks after inoculation; d–j phialides and conidia in globose heads; k conidia. Scale bars: d–k 10 μm
Fig. 49 Maximum likelihood (ML) tree of Nigrospora based on ITS, EF1-α and TUB sequences. Twenty-three strains are used. The tree is rooted with Arthrinium vietnamense (IMI 99670). Tree topology of Nigrospora is indicated along branches (ML/PP). Novel species are in bold font and “T” indicates type derived sequences

are also known as plant pathogenic fungi. Myriodontium keratinophilum, an occasional human and animal pathogen widely spread in nature (Maran et al. 1985; Domsch et al. 2007), was isolated not only in this study, but also from several other caves in previous studies (Man et al. 2015; Zhang et al. 2017; Nováková et al. 2018). Many of these fungi may not grow in the cave environment, but are present rarely or regularly as spores, carried in by water, air currents, or animals (Vanderwolf et al. 2013; Zhang et al. 2017).

Studies had revealed that fungi in caves might be originated from outside environments, since the majority of fungi documented in caves have been reported from other environments such as soil and forest (Vanderwolf et al. 2013; Zhang et al. 2017). All genera and most species recorded in this study have also been reported from other environments. Although there are several suspected obligate troglobitic fungi exist in caves, and several were also observed in this study, such as Aspergillus spelunceus (Vanderwolf et al. 2013; Zhang et al. 2017, 2018). Although a number of new species have been discovered in caves, no new genera or families were reported (Zhang et al. 2017). Zhang et al. (2018) estimated the divergence time of suspected obligate troglobitic fungi and found that they were obviously much older than the cave formation geologic age. In other words, the geologic age of caves is too short for fungal speciation and these fungi are unlikely troglobitic fungi but travelers from other environments.

Caves are special environments with a number of potentially highly valuable fungal species that have been the targets for drug discovery (Cheeptham 2012; Rawat et al. 2017). According to Vanderwolf et al. (2013), there are still 14 potential troglobitic cave fungi. Four new oligotrophic fungi using carbon free silica gel medium (SGM) and 20 new fungal taxa from two caves in Guizhou, China were published by Jiang et al. (2017a, b) and Zhang et al. (2017), respectively. Amphinecta felina (syn. Beauveria felina (DC.) J.W. Carmich., Isaria felina (DC.) Fr.), a species known in producing insecticidal cyclodepsipeptide (Baute et al. 1981; Langenfeld et al. 2011; Seifert et al. 2011) and Cyclosporin C (Xu et al. 2018), is widely distributed in caves (Vanderwolf et al. 2013; Zhang et al. 2017; Belyagoubi et al. 2018), as well as this study. Meanwhile, the other two coprophilous species in Amphinecta were isolated in this study, and they may have good potential for the investigation of bioactive natural products. Trichoderma harzianum, a species that has been used as biocontrol agents against fungal diseases of plants (Elad et al. 1982; Felse and Panda 1999), was isolated from soil and organic matters. Another example is Beauveria bassiana (Bals.-Criv.) Vuill. isolated from four caves in this study and several times in other studies (Ogórek et al. 2013, 2014b, Vanderwolf et al. 2013; Zhang et al. 2014; Yoder et al. 2015), is a species widely used as insecticide (Feng et al. 1994; Zimmermann 2007; Xiao et al. 2012).

Conclusions

Our investigation reveals that karst caves from southwest China encompass a high fungal diversity, with a number of previously undescribed species. Most species identified in this study have been reported from other environments, indicating that the outside environment is likely a major source of mycobiota in caves. Based on morphological and phylogenetic distinctions, 33 new species scattered in seven different orders were identified and described. One new genus is proposed. This study significantly improved our understanding on fungal species diversity in caves. Further studies incorporating metagenomics and culture method could possibly provide broader and more comprehensive overview on fungal communities and their ecological roles in caves.
Acknowledgements This study was financially supported by NSFC (31725001), the Science and Technology Partnership Program, MOST (KY201701011), Gansu Foundation of Ecological Conservation & Remediation (No. 2018-20) and Gansu Foundation of Inducing Scientific Innovation for Development (No. 2017zx-10). Prof. Yuan-Hai Zhang in Institute of Karst Geology, Chinese Academy of Geological Sciences is thanked for providing caves’ information in Southwest China. Dr. Ya-Li Xi in Gansu Engineering Laboratory of Applied Mycology, Hexi University is thanked for help with sample collection. We also thank other members who provided technical support, valuable and constructive suggestions in our lab.

Author contributions ZFZ: Designed the work, conducted the experiment, and drafted the manuscript; SYZ: Part of the fungal isolation, and data submission; LE, SI, MR, and FL: Revised the manuscript; PZ, and QC: Help for the sample collection; LC: Conceived the work, and revised manuscript.

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