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Three new orders and five new families in the vesicular-arbuscular mycorrhizal (VAM) fungi of the Glomeromycetes class in the phylum Glomeromycota

Fritz Oehl[1,*], Ewald Sieverding[2], Viviane Monique Santos[3], Daniele Magna Azevedo de Assis[3], Thays Gabrielle Lins de Oliveira[3], Mike Anderson Corazon-Guivin[4] & Gladstone Alves da Silva[3]

[1]Agroscope, Competence Division for Plants and Plant Products, Plant Protection Products – Impact and Assessment, Müller-Thurgau-Strasse 29, CH-8820 Wädenswil, Switzerland
[2]Institute of Agricultural Sciences in the Tropics (Hans-Ruthenberg Institute), University of Hohenheim, Garbenstr. 13, D-70599 Stuttgart-Hohenheim, Germany
[3]Departamento de Micologia, CB, Universidade Federal de Pernambuco, Cidade Universitária, Av. da Engenharia s/n, Recife 50740-600, PE, Brazil
[4]Laboratorio de Biología y Genética Molecular, Universidad Nacional de San Martín, Jr. Amorarca N 315, Morales 22201, Peru

* e-mail fritz.Oehl@agroscope.admin.ch

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The objective was to analyze the phylogeny and morphology of the Glomeromycetes on the order level hitherto consisting of Glomerales, Entrophosporales, Diversisporales and Gigasporales. The updated data sets show that Pacisporaceae is near to Gigasporales, but without support to place this family in Gigasporales or Diversisporales, while the Acaulosporaceae and Sacculosporaceae clades clearly separate from Diversisporaceae. The phylogeny indicates the transfer of Pacisporaceae from the Diversisporales to the new order Pacisporales. Pacisporales differ from all families in Gigasporales by type of spore formation, as forming spores on subtending hyphae instead on suspensors, by formation of vesicular-arbuscular mycorrhiza, and by germination characteristics. The phylogenetic analysis supports the separation of Acaulosporaceae and Sacculosporaceae from Diversisporales, from each other, and from all other Glomeromycetes orders. These two families are transferred to Acaulosporales and Sacculosporales. Acaulosporales are characterized by spore formation in a clear distance from globose termini of sporiferous saccules, three spore walls and generally by the diagnostic, 'beaded' inner wall. In Sacculosporales, there is no distance between the bi-walled spores and saccule termini, and the inner wall is never 'beaded'. Additionally, four new families are separated within Glomerales, and one new family within Diversisporales.

Key words: molecular phylogeny, systematics, classification, arbuscular mycorrhiza, AM fungi, Rhizoglomeraceae.

The Glomeromycetes Caval.-Sm. was the first class described in the arbuscular mycorrhizal fungi (AMF) (Cavalier-Smith 1998). The most ancestral AM fungal clades (e.g. Morton & Redecker 2001), however, were separated from the Glomeromycetes and have been counted within the Archaeosporomycetes Sieverd., G.A. Silva, B.T. Goto & Oehl and Paraglomeromycetes Oehl, G.A. Silva, B.T. Goto & Sieverd. (Oehl et al. 2011a, Hyde et al. 2024). These three fungal classes constitute together the subphylum Glomeromycotina Spatafora & Stajich (Spatafora et al. 2016) and the phylum Glomeromycota C. Walker & A. Schüssler (Schüßler et al. 2001) of the Mucoromyceta (Tedersoo et al. 2018). The Glomeromycetes currently comprise six fungal orders: Glomerales J.B. Morton & Benny (Morton & Benny 1990, Schwarzott et al. 2001), Entrophosporales Błaszk., Sánchez-García, B.T. Goto & Magurno (Błaszkowski et al. 2022), Diversisporales C. Walker & A. Schüssler (Walker & Schüßler 2004), Gigasporales Sieverd., G.A. Silva, B.T. Goto & Oehl (Oehl et al. 2011a), Archaeosporales C. Walker & A. Schüssler (Oehl et al. 2011a, Hyde et al. 2024), and Paraglomerales C. Walker & A. Schüssler (Oehl et al. 2011a, Schüßler et al. 2001). Furthermore, the Glomerales currently comprise five fungal families: Glomeraceae (Pirozynski & Dalpé 1989), Septoglomeraceae, Sclerocystaceae, Kamienskiaceae and Dominikiaceae (Silva et al. 2024). Entrophosporales comprises the single family Entrophosporaceae (Błaszkowski et al. 2022, Silva et al. 2025), Gigasporales comprise the families Gigasporaceae, Intraornatosporaceae,

Dentiscutataceae, Scutellosporaceae and Racocetraceae (Oehl et al. 2011a, Hyde et al. 2024), and Diversisporales the families Diversisporaceae, Acaulosporaceae, Sacculosporaceae and Pacisporaceae (Schüßler et al. 2001, Hyde et al. 2024). Finally, the order Archaeosporales comprises the families Archaeosporaceae, Ambisporaceae, Geosiphonaceae and Polonosporaceae (Morton & Redecker 2001, Schüßler 2002, Błaszkowski et al. 2021), while Paraglomerales comprise the two families Paraglomeraceae and Pervetustaceae (Morton & Redecker 2001, Błaszkowski et al. 2017).

So far, the greatest diversity of morphological characters in the Glomeromycetes were described within the Diversisporales of all six described AMF orders (e.g, Schüßler et al. 2001, Hyde et al. 2024), which was initially also expressed in the name of the order. On the one hand, these great differences were clearest for AM fungi forming spores on sporogeneous cells (Nicolson & Gerdemann 1968, Gerdemann & Trappe 1974, Morton & Benny 1990). Phylogenetic dissimilarities have been the most prominent argument to firstly separate this fungal group from the Diversisporales (Oehl et al. 2011a). On the other hand, several other, i.e. glomoid, acaulosporoid and entrophosporoid AM fungal clades have hitherto continued within the Diversisporales, on various phylogenetic positions. However, for a few of these clades major phylogenetic dissimilarities are well known, which have become more evident in the recent past with the increasing number of species and sequences included in the public data bases. Key morphological characters can be named for specific AM fungal groups, such as the spore formation in Sacculosporaceae, the diagnostic beaded germinal wall in Acaulosporaceae or the typical subtending hyphal features of *Pacispora* Sieverd. & Oehl, *Diversispora* C. Walker & A. Schüßler and *Redeckera* C. Walker & A. Schüßler (Gerdemann & Trappe 1974; Błaszkowski et al. 1998; Oehl & Sieverding 2004; Oehl et al. 2006, 2011b; c, 2012; Willis et al. 2016; Velazquez et al. 2008; Corazon-Guivin et al. 2022).

The aim of this study was to double-check the data bases and the different major phylogeny clades, in order to investigate, if there is enough substance i) to separate Acaulosporaceae, Sacculosporaceae and Pacisporaceae from the Diversisporales, and ii) to continue within this order with multiple families originating from the type family Diversisporaceae. Therefore, we reviewed the phylogeny and the major morphological characters of all these taxa. Hereafter, firstly the phylogenetic differences are presented between all major clades of the Glomeromycetes. Secondly, the morphological characters and major differences are highlighted for all the major clades within this fungal class. Finally, new families are described in the taxonomic section, because the molecular phylogenetic analyses support these new families, and because additionally, these taxa are also well supported by morphological arguments.

Material and methods

Phylogenetic analyses

The phylogeny was reconstructed using an alignment (dataset) generated with AM fungal sequences from species of Glomeromycetes (Suppl. Tab. S1). The dataset was used to reconstruct the Glomeromycetes phylogeny based on partial SSU, 5.8S, and partial LSU nrDNA (SSU-5.8S-LSU). *Paraglomus brasilianum* (Spain & J. Miranda) J.B. Morton & D. Redecker was included as outgroup. Short sequences without at least the 5.8S, and partial LSU nrDNA were not used in the analyses. The dataset was aligned in Mafft (Katoh et al. 2019), using the default parameters. Prior to phylogenetic analyses, the model of nucleotide substitution was estimated using ModelTest-NG (Darriba et al. 2020). The best model for both analyses was GTR + I + G. Bayesian (BI) analysis (two runs over 1×10^7 generations, with a sample frequency of 1,000 and a burnin value of 25 %) was performed in MrBayes 3.2.7a (Ronquist et al. 2012), launched from Cipres Science Gateway portal (Miller et al. 2010). Maximum likelihood (ML) analysis (1000 bootstrap) was performed in RAxML-NG, using the raxmlGUI 2.0.16 (Kozlov et al. 2019, Edler et al. 2021).

Morphological analyses

We morphologically analyzed all species belonging to Glomeromycetes deposited in those mycological herbaria, which harbor the majority of the type material of AM fungi, i.e. OSC (types deposited between 1968 to 2005), Z + ZT (types deposited between 2002 and 2024), and URM (types deposited between 2008 and 2024); additionally, AM fungal type materials were analyzed from private collections generated by Sieverding, Oehl, Trappe, Błaszkowski and McGee. The Hall and Abbott (1979) photographic slide collection was also reviewed. Older specimens (mounted on microscopic slides prior to 1990) were mostly mounted in lactophenol, while others were fixed with polyvinyl alcohol–lactic acid–glycerol (PVLG) or in a mixture of PVLG + Melzer's reagent, which after 1990 are the

principal fixing media (Brundrett et al. 1994). Newly mounted spores and sporocarps from collections or from cultures were fixed using the latter two fixing media or occasionally also in a mixture of 1:1 lactic acid to water, in Melzer's reagent and in water (Spain 2003). When available, spores freshly isolated from soils or bait cultures were also mounted and analyzed. All spore observations and all information on spore characteristics are based on spores extracted from soil, from trap cultures or from single or multiple spore-derived pure cultures. No information is provided from in vitro cultured materials. Spore wall terminology follows the nomenclature of Walker (Walker 1983), Stürmer and Morton (1997), and Błaszkowski (2012). Analyses of the spore walls, germination structures and all other mycorrhizal structures were performed using compound microscopes at 100–1000× magnification (Zeiss Axioplan, Oberkochen, Germany; Leika DFC 295; Wetzlar, Germany). For this paper, all original species descriptions and published species emendations were also considered and thoroughly studied.

Results

Molecular phylogeny

The dataset was generated with 251 sequences and 1406 sites; of which 556 were constant, 172 variables (but not parsimony informative), and 678 were parsimony informative.

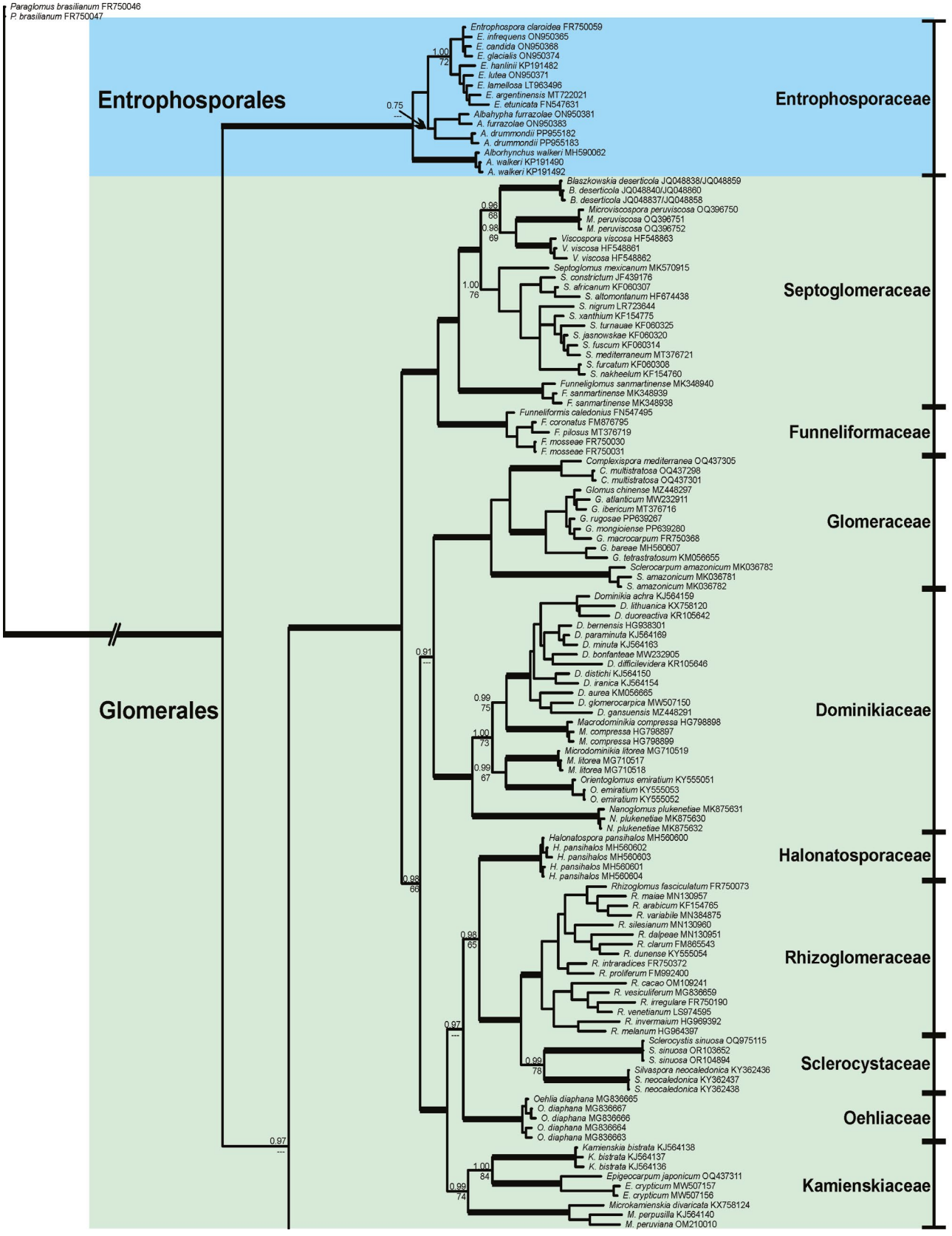
The phylogeny generated by RAxML-NG and Bayesian analysis showed similar topology. The phylogenetic tree for the Glomeromycetes showed seven different clades (Fig. 1) with full support from BI and ML analyses for the four well-established orders: Diversisporales, Entrophosporales, Gigasporales, and Glomerales, and three new orders, Acaulosporales, Pacisporales, and Sacculosporales. From these orders, three have just a single monogeneric family (Acaulosporales – Acaulosporaceae – *Acaulospora*; Pacisporales – Pacisporaceae – *Pacispora*; and Sacculosporales – Sacculosporaceae - *Sacculospora*).

Our results confirm Entrophosporales with a single family (Entrophosporaceae), and three genera (*Albahypha*, *Alborhynchus*, and *Entrophospora*). However, there was just a low BI support to maintain *Albahypha drummondii* (Błaszk. & Renker) Sieverd., Oehl, B.T. Goto & G.A. Silva and *A. furrazolae* (Magurno, P. Niezgoda, B.T. Goto & Błaszk.) G.A. Silva, B.T. Goto, Corazon-Guivin, Sieverd. & Oehl together. The families and genera from Gigasporales, represented in our tree, were confirmed phylogenetically by our results with strong support (≥0.95 for BI and ≥90 % for ML analyses), except for ML analysis to Dentiscutataceae and *Fuscutata*, with just 65 % of support. Two well supported clades, representing family level, were found in Diversisporales (Diversisporaceae and a new family, Corymbiglomeraceae). Diversisporaceae has a single genus (*Diversispora*), and showed full support in our phylogenetic analysis. Corymbiglomeraceae was fully supported by BI and presented a ML support of 94 %. The phylogeny recovered five genera in Corymbiglomeraceae (*Corymbiglomus* Błaszk. & Chwat, *Desertispora* Błaszk., Kozłowska, Ryszka, Al-Yahya'ei & Symanczik, *Paracorymbiglomus* Błaszk., P. Niezgoda & B.T. Goto, *Redeckera* C. Walker & A. Schüßler, and *Sieverdingia* Błaszk., P. Niezgoda & B.T. Goto) with full support in all phylogenetic analyses. Glomerales showed nine clades strongly supported on the family level (Dominikiaceae, Glomeraceae, Kamienskiaceae, Sclerocystaceae, Septoglomeraceae, and four new families, Funneliformaceae, Halonatosporaceae, Rhizoglomeraceae, and Oehliaceae). All families and all genera in Glomerales, represented in our tree, presented support ≥0.99 for BI and ≥90 % for ML analyses, except for ML analysis in Kamienskiaceae (74 %), Sclerocystaceae (78 %), and *Septoglomus* (76 %). Considering our phylogenetic findings, three new orders and five new families needed to be described in Glomeromycetes.

Morphological analyses

In this study, no new morphological findings are reported in the Glomeromycetes, since all described genera and families have been well defined in the last two decades during their first descriptions already or, when their descriptions were emended, based on the current knowledge and state-of-the-art. Here, some outstanding characters of genera, families or orders are highlighted.

The phylogenetic analyses suggested seven AM fungal orders in Glomeromycetes. Three of them form exclusively (Glomerales and Pacisporales) or almost exclusively (Entrophosporales) spores on subtending hyphae. Glomerales and Entrophosporales differentiate mono-walled, so-called glomoid spores (SW), while *Pacispora* form bi-walled spores, an outer spore wall and an inner germinal wall (OW & IW). Glomerales form spores, which generally are in same or similar color as the terminal or intercalary formed spores, while the subtending hyphae in Entrophosporales are always hyaline, subhyaline or white independently of the spore color. In En-


Paraglomus brasilianum FR750046
P. brasilianum FR750047
Entrophosporales
Glomerales
Entrophosporaceae
Septoglomeraceae
Funneliformaceae
Glomeraceae
Dominikiaceae
Halonatosporaceae
Rhizoglomeraceae
Sclerocystaceae
Oehliaceae
Kamienskiaceae
Entrophospora claroidea FR750059
E. infrequens ON950365
E. candida ON950368
E. glacialis ON950374
E. hanlinii KP191482
E. lutea ON950371
E. lamellosa LT963496
E. argentinensis MT722021
E. etunicata FN547631
Albahypha furrazolae ON950381
A. furrazolae ON950383
A. drummondii PP955182
A. drummondii PP955183
Alborhynchus walkeri MH590062
A. walkeri KP191490
A. walkeri KP191492
Blaszkowskia deserticola JQ048838/JQ048859
B. deserticola JQ048840/JQ048860
B. deserticola JQ048837/JQ048858
Microvisospora peruviscosa OQ396750
M. peruviscosa OQ396751
M. peruviscosa OQ396752
Viscospora viscosa HF548883
V. viscosa HF548861
V. viscosa HF548862
Septoglomus mexicanum MK570915
S. constrictum JF439176
S. africanum KF060307
S. altomontanum HF674438
S. nigrum LR723644
S. xanthium KF154775
S. turnauae KF060325
S. jasnowskae KF060320
S. fuscum KF060314
S. mediterraneum MT376721
S. furcatum KF060308
S. nakheelum KF154760
Funneliglomus sanmartinense MK348940
F. sanmartinense MK348939
F. sanmartinense MK348938
Funneliformis caledonius FN547495
F. coronatus FM876795
F. pilosus MT376719
F. mosseae FR750030
F. mosseae FR750031
Complexispora mediterranea OQ437305
C. multistratosa OQ437298
C. multistratosa OQ437301
Glomus chinense MZ448297
G. atlanticum MW232911
G. ibericum MT376716
G. rugosae PP639267
G. mongioiense PP639280
G. macrocarpum FR750368
G. bareae MH560607
G. tetrastratosum KM056655
Sclerocarpum amazonicum MK036783
S. amazonicum MK036781
S. amazonicum MK036782
Dominikia achra KJ564159
D. lithuanica KX758120
D. duoreactiva KR105642
D. bernensis HG938301
D. paraminuta KJ564169
D. minuta KJ564163
D. bonfanteae MW232905
D. difficilevidera KR105646
D. distichi KJ564150
D. iranica KJ564154
D. aurea KM056665
D. glomerocarpica MW507150
D. gansuensis MZ448291
Macrodominikia compressa HG798898
M. compressa HG798897
M. compressa HG798899
Microdominikia litorea MG710519
M. litorea MG710517
M. litorea MG710518
Orientoglomus emiratium KY555051
O. emiratium KY555053
O. emiratium KY555052
Nanoglomus plukenetiae MK875631
N. plukenetiae MK875630
N. plukenetiae MK875632
Halonatospora pansihalos MH560600
H. pansihalos MH560602
H. pansihalos MH560603
H. pansihalos MH560601
H. pansihalos MH560604
Rhizoglomus fasciculatum FR750073
R. maiae MN130957
R. arabicum KF154765
R. variabile MN384875
R. silesianum MN130960
R. dalpeae MN130951
R. clarum FM865543
R. dunense KY555054
R. intraradices FR750372
R. proliferum FM992400
R. cacao OM109241
R. vesiculiferum MG836659
R. irregulare FR750190
R. venetianum LS974595
R. invermaium HG969392
R. melanum HG964397
Sclerocystis sinuosa OQ975115
S. sinuosa OR103652
S. sinuosa OR104894
Silvaspora neocaledonica KY362436
S. neocaledonica KY362437
S. neocaledonica KY362438
Oehlia diaphana MG836665
O. diaphana MG836667
O. diaphana MG836666
O. diaphana MG836664
O. diaphana MG836663
Kamienskia bistrata KJ564138
K. bistrata KJ564137
K. bistrata KJ564136
Epigeocarpum japonicum OQ437311
E. crypticum MW507157
E. crypticum MW507156
Microkamienskia divaricata KX758124
M. perpusilla KJ564140
M. peruviana OM210010

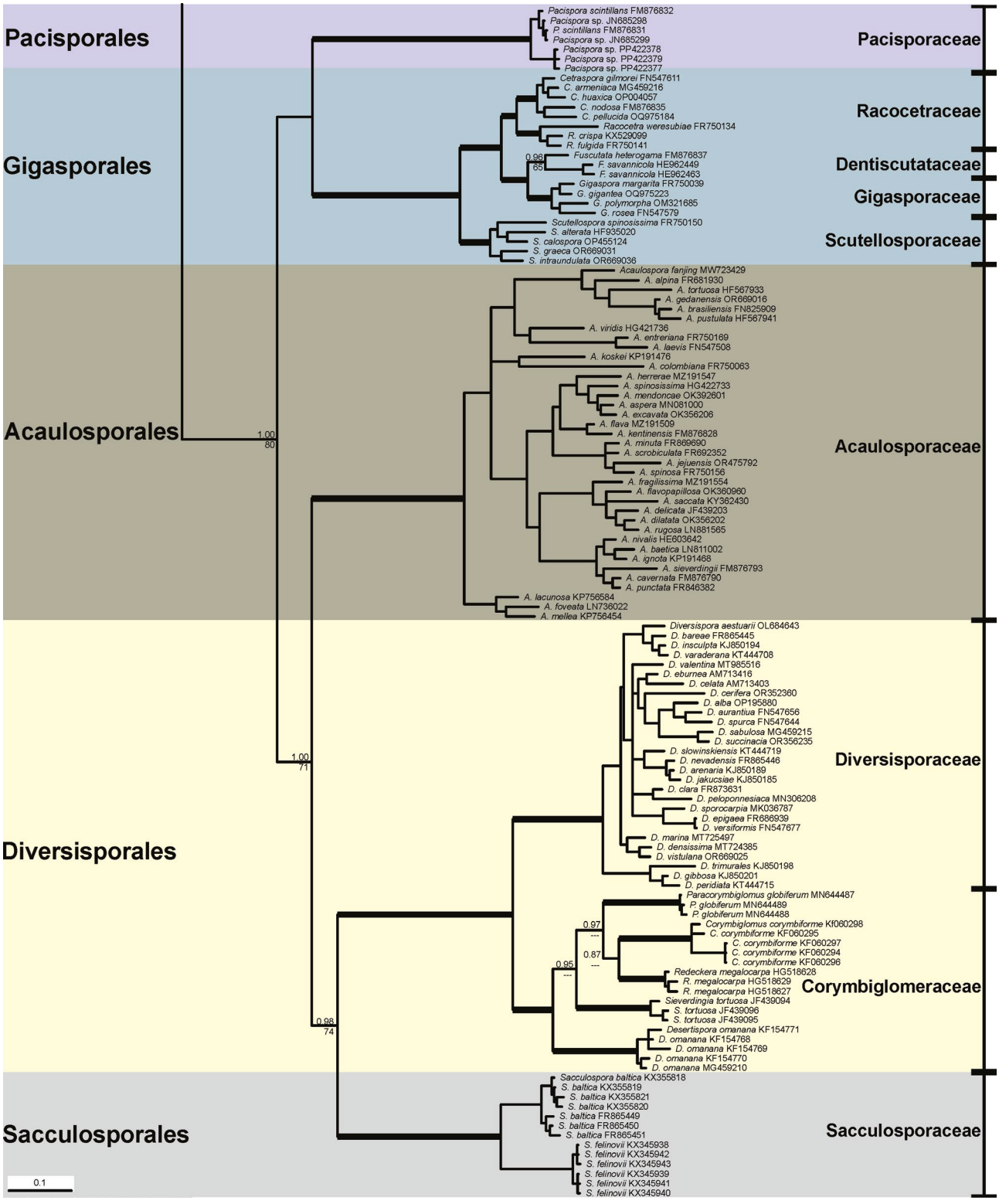


Fig. 1. Phylogenetic tree from partial SSU, 5.8S and partial LSU nrDNA sequences of Glomeromycetes. Sequences are labeled with their database accession numbers. Support values from Bayesian inference (BI) and maximum likelihood (ML) are shown only at the genera level or above. Only support values of at least 65 % are shown. Thick branches represent clades with more than 90 % support in all analyses. The tree was rooted by *Paraglomus brasilianum*.

trophosporales, so far only the type species has been known to form not only glomoid, but within the neck of sporiferous saccules also so-called entrophosporoid, bi-walled spores, with OW & IW (Tab. 1).

Two orders differentiate exclusively spores on or within the neck of sporiferous saccules, with two or three walls (Sacculosporales and Acaulosporales, respectively). Acaulosporales species form spores on or within the neck of sporiferous saccules, in more or less variable distance, which are ca. 1–2 fold as long as the spores size formed in/on the neck. Acaulosporales species have three spore walls (OW & IW, and an additional middle wall, MW), of which generally IW differentiate a typical, granular, so-called 'beaded' wall layer on its outer surface. This beaded appearance might be missing, or becoming invisible in acid lactic based mountants, only in very small-spored species of this order (e.g. in *A. gedanensis* (Niezgoda et al. 2024). Sacculosporales species exclusively form spores within sporiferous saccules, but without distance directly beneath the saccule terminus, and the bi-walled spores (with OW & IW) lack the granular, beaded wall layer on IW.

Gigasporales differentiate spores exclusively on sporogenous cells. Species of this order differentiate genus-specifically 1–4 spore walls (OW, MW, (rarely MW2) & IW), and genus-specifically germinate through germ warts (if solely mono-walled) or through prominent, pigment-less to light-yellow or well-pigmented brown germination shields, consisting of one, two, a few or multiple germination lobes/compartments (if > one spore wall). Pacisporales and Gigasporales share one important morphological character, which they do not share with any of the other glomeromycotan orders, i.e. the formation of extraradical and, more rarely, also intraradical auxiliary cells (e.g., Błaszkowski 2012). This is one outstanding argument to separate the Pacisporaceae from the Diversisporales. Pacisporales and Gigasporales mainly separate by spore formation type on subtending hyphae or on sporogenous cells, by spore germination through the germination shield center (perm pore) or through visible germ tube initiations in the periphery of prominent germination shields, respectively, if germination is not very different as through germ warts direct from the spore wall in the special case of *Gigaspora*. Moreo-

Tab. 1. Selected key morphological characteristics of the seven orders in Glomeromycetes.

Order	Mycorrhiza formation	Auxilliary cells	Spore formation on SH/bulbus/ saccule	Number of spore walls (SW)	SH/Saccule-spore distance/bulbus
Glomerales	Vesicular-arbuscular	No	Yes/No/No	1	SH concolorous with spore
Entrophosporales	Vesicular-arbuscular	No	Yes/No/Yes	1, rarely 2[1]	SH always (sub-)hyaline
Diversisporales	Vesicular-arbuscular	No	Yes/No/Yes	1-2	When one SW: SH hyaline and fragile below the septum, when two walls: SH concolorous with spore; when with sporiferous saccule either no distance (*Tricispora*[2]) or broad connection (*Otospora*[3]) between spores and sporiferous saccule
Acaulosporales	Vesicular-arbuscular	No	No/No/Yes[4]	3[5]	Spores formed 50-250 µm distant from sporiferous saccule
Sacculosporales	Vesicular-arbuscular	No	No/No/Yes[6]	2[7]	Spores directly connected to sporiferous saccule no distance
Pacisporales	Vesicular-arbuscular	Yes	Yes/No/No	2	2 SW, SH concolorous with spore
Gigasporales	Arbuscular	Yes	No/Yes/No	1-4[8]	Sporogenous hyphae (bulbus), genus-specifically bulbus concolorous with spore, or more pigmented than spores

[1] Two walls only in entrophosporoid spores, formed in the neck of sporiferous saccules. [2] Saccule terminus maximum half in size, when compared to attached spore; exclusively entrophosporoid spore formation known so far. [3] Saccule terminus of similar size as spore; spore formation acaulosporoid; IW never is granular-beaded. [4] Globose saccule terminus of similar size as spore; spore formation acaulosporoid, rarely entrophosporoid. [5] Three spore walls, and generally with characteristic granular-beaded inner spore wall (IW). [6] Saccule terminus generally smaller than spore; exclusively entrophosporoid spore formation known so far. [7] Ttwo spore walls, of which IW never is granular-beaded. [8] Genus-specifically 1-3(to rarely 4) spore walls.

Tab. 2. Selected key morphological characteristics of the new and newly emended families of the Glomeromycetes, described within the present study

Order	Mycorrhiza formation	Auxilliary cells	Spore formation on SH/bulbus/ saccule	Number of spore walls (SW)	Morphological key characters of sporocarps, spores and subtending hyphae (SH)
Funneliformaceae fam. nova.	Vesicular-arbuscular	No	Yes/No/No	1	Spores formed single, in clusters and non-organized compact sporocarps. SH funnel-shaped to rarely cylindrical. Wall differentiation and pigmentation may continue in SH over long distances from the spore base; pore regularly closed by a conspicuous septum in some distance from spore base
Septoglomeraceae emended	Vesicular-arbuscular	No	Yes/No/No	1	Spores formed in soil and sometimes in roots, either singly, in spore clusters, rarely in sporocarps. SH genus-specifically dominantly constricted, cylindrical or funnel-shaped, rarely inflated; straight, curved or flared; pore genus-specifically dominantly closed by a broad, thick, or even plug-like septum
Sclerocystaceae emended	Vesicular-arbuscular	No	Yes/No/No	1	Spores formed in compact sporocarps, or singly in soil and frequently in roots. When formed in sporocarps, spores generally organized around a central hyphal plexus; SH cylindrical or seldom slightly funnel-shaped, with a rather small pore channel. Pore at spore base regularly closed by a septum.
Rhizoglomeraceae fam. nova.	Vesicular-arbuscular	No	Yes/No/No	1	Spores formed in loose sporocarps (lumps), in clusters or singly in soil and frequently also in roots singly or in loose sporocarps and clusters. Pore at spore base regularly open, rarely closed by a septum. SW shows more than one, generally two to three (and up to five) distinct layers, of which one or several of the outermost layers may easily separate when pressure is applied to spores.
Oehliaceae fam. nova.	Vesicular-arbuscular	No	Yes/No/No	1	Spores formed in loose sporocarps (lumps), in clusters or singly in soil and frequently also in roots singly or in loose sporocarps and clusters. Pore at spore base regularly closed by a septum.
Halonatosporaceae fam. nova.	Vesicular-arbuscular	No	Yes/No/No	1	Outer SW layer strongly swells in PVLG, forming a halo with radiate columns.
Diversisporaceae emended	Vesicular-arbuscular	No	Yes/No/Yes	1	Diversisporoid spores formed singly, in clusters or in disorganized sporocarps with up to hundreds of spores), with 1–3 wall layers. Even in pigmented spores, SH hyaline to white behind the septum; SH cylindrical or inflated, in some species slightly constricted. Pore closed with a septum, rarely open. Otosporoid & tricisporoid spores with 2 walls (OW, IW); otosporoid spores laterally on persistent necks of sporiferous saccules at some distance from the terminus; spore pore closed by a septum at spore base. Tricisporoid spores in the neck of tightly attached saccules, smaller than the spores attached, rarely equal in size.
Corymbiglomeraceae fam. nova.	Vesicular-arbuscular	No	Yes/No/Yes	1-2	This new family includes 5 genera with diverse spore formation like mono-to-bi-walled spores on cylindrical SH, in clusters, sporocarps or singly in soil, often corymbiforme and with different types of hyphal mantles, or forming glomoid-diversisporoid-like spores staining purple in Melzer´s on the spore wall, which is not known for *Diversispora* spp., or forming mono-walled spores in large, disorganized sporocarps, containing up to thousands of spores per sporocarp.

ver, according to Błaszkowski (2012), Pacisporales form typical versicular-arbuscular mycorrhiza, while Gigasporales solely have arbuscular mycorrhiza, but intraradical vesicle formation is not (yet) known.

Lastly, Diversisporales continue to be the most diverse order forming glomoid spores (glomoid = on subtending hyphae) with genus-specifically one or two walls, or rarely acaulosporoid or entrophosporoid spores with two walls. Importantly, the specific characteristics of all the genera within this order can be easily distinguished from all other genera within the Glomeromycota (Oehl et al. 2011b; Błaszkowski et al. 2025a, b; Silva et al. 2024, 2025).

Within the Glomerales, Halonatosporaceae, Oehliaceae and Rhizoglomeraceae were already suggested as possible new families by Silva et al. (2024), based on the phylogenetic findings. This further separation of four new families is supported also by morphology. In Tab. 2, selected key morphological characteristics are shown for the five new and three newly emended families of the Glomeromycetes, described within the present study. Shortly, Oehliaceae and Rhizoglomeraceae frequently form spore agglomerations within the roots. Oehliaceae species generally form a septum closing the spore base, while in Rhizoglomeraceae the spore pores are not closed at the base, but often have several septa within long subtending hyphae in rather long distance from the spore base (> 25 µm). Halonatosporaceae can be characterized by spores forming a halo with radiate columns. Finally, Funneliformaceae separate easily from all other species in the Septoglomeraceae and other families in the Glomerales and Glomeromycetes by i) their spore formation on funnel-shaped subtending hyphae, thus ii) wide pores at the spore bases, iii) and wide, broad septa positioned within a short distance from the spore base or rarely also at the spore base, and iv) spore formation in sporocarps, which is not known for the morphologically and phylogenetically most closely related family (Septoglomeraceae), especially to the morphologically most closely related genus *Funneliglomus*.

The phylogenetic advances suggested a separation of the Diversisporales into two families, based on the two major clades recognized within this order (Fig. 1). The newly revised family Diversisporaceae comprises now solely the diversisporoid species sensu stricto, and two species with formation of bi-walled spores on or within the neck of sporiferous saccules, similar, but different to those of *Sacculospora* and *Entrophospora infrequens* (Oehl et al. 2011c, Hyde et al. 2024). In the new family Corymbiglomeraceae, besides the type genus *Corymbiglomus*, also *Paracorymbiglomus*, *Desertispora*, *Redeckera*, and *Sieverdingia* are included (Błaszkowski et al. 2025b; Tab. 2). However, the phylogenetic and morphological data bases of these taxa are still exiguous, so that a clearer separation of these AMF genera hitherto is not yet feasible.

Glomeromycetes now comprise twenty families of which nine belong to the Glomerales and five to the Gigasporales (Tab. 3). Two families are separat-

Tab. 3. Current orders, families and genera in the Glomeromycetes and in the whole phylum Glomeromycota

Classes					
	Orders		Families		Genera
Glomeromycetes					
1	Glomerales	1	Glomeraceae	1	*Glomus*
				2	*Complexispora*
				3	*Sclerocarpum*
				4	*Simiglomus*
		2	Funneliformaceae	5	*Funneliformis*
		3	Septoglomeraceae	6	*Septoglomus*
				7	*Funneliglomus*
				8	*Melanoglomus*
				9	*Blaszkowskia*
				10	*Viscospora*
				11	*Microviscospora*
		4	Sclerocystaceae	12	*Sclerocystis*
				13	*Parvocarpum*
				14	*Silvaspora*
		5	Rhizoglomeraceae	15	*Rhizoglomus*
		6	Oehliaceae	16	*Oehlia*

Classes / Orders		Families		Genera	
		7	Halonatosporaceae	17	*Halonatospora*
		8	Dominikiaceae	18	*Dominikia*
				19	*Delicatispora*
				20	*Macrodominikia*
				21	*Microdominikia*
				22	*Nanoglomus*
				23	*Orientoglomus*
		9	Kamienskiaceae	24	*Kamienskia*
				25	*Microkamienskia*
				26	*Epigeocarpum*
2	Entrophosporales	10	Entrophosporaceae	27	*Entrophospora*
				28	*Alborhynchus*
				29	*Albahypha*
3	Diversisporales	11	Diversisporaceae	30	*Diversispora*
				31[a]	*Otospora*
				32[a]	*Tricispora*
		12	Corymbiglomeraceae	33	*Corymbiglomus*
				34	*Desertispora*
				35	*Paracorymbiglomus*
				36	*Redeckera*
				37	*Sieverdingia*
4	Acaulosporales	13	Acaulosporaceae	38	*Acaulospora*
				39[b]	*Kuklospora*
5	Sacculosporales	14	Sacculosporaceae	40	*Sacculospora*
6	Gigasporales	15	Gigasporaceae	41	*Gigaspora*
		16	Intraornatosporaceae	42	*Intraornatospora*
				43	*Paradentiscutata*
		17	Dentiscutataceae	44	*Dentiscutata*
				45	*Fuscutata*
				46	*Quatunica*
		18	Racocetraceae	47	*Racocetra*
				48	*Cetraspora*
		19	Scutellosporaceae	49	*Scutellospora*
				50	*Orbispora*
				51	*Bulbospora*
7	Pacisporales	20	Pacisporaceae	52	*Pacispora*
Archaeosporomycetes					
8	Archaeosporales	21	Archaeosporaceae	53	*Archaeospora*
				54	*Andinospora*
				55	*Antiquispora*
				56[c]	*Intraspora*
				57	*Palaeospora*
		22	Ambisporaceae	58	*Ambispora*
		23	Geosiphanceae	59	*Geosiphon*
		24	Polonosporaceae	60	*Polonospora*
Paraglomeromycetes					
9	Paraglomerales	25	Paraglomeraceae	61	*Paraglomus*
				62	*Innospora*
		26	Pervetustaceae	63	*Pervestustus*

[a] currently suggested as synonym of *Diversispora* (Hyde et al. 2024); [b] currently suggested as synonym of *Acaulospora* (Hyde et al. 2024); [c] currently suggested as synonym of *Archaeospora* (Esmaeilzadeh-Salestani et al. 2025).

ed within the Diversisporales, while the lasting four orders are represented each by one family. Selected key morphological characters of all 26 genera within the largest order Glomerales, including the variability of their spore and sporocarp sizes, are given in Suppl. Tab. S2.

Taxonomy

With respect to the organization of this extensive section, we decided to organize the taxa as follows i) first the taxonomic orders with dominant glomoid spore formation (Glomerales, Entrophosporales & Diversisporales, ii) the orders with dominant acaulosporoid spore formation (Acaulosporales & Saccculosporales), and finally iii) the orders with extraradical formation of auxilliars cells (Gigasporales & Pacisporales). With exception of Gigasporales, all other orders can be called typical vesicular-arbuscular mycorrhizal (VAM) fungi, whose intraradical fungal structures stain blue to dark blue in trypan blue or ink procedures. Gigasporales form arbuscular mycorrhiza as they do not form vesicles in roots. Within Glomerales, we organize the families according to their outstanding type genera (*Glomus*, *Funneliformis*, *Septoglomus*, *Sclerocystis*, *Rhizoglomus*, *Dominikia* and *Kamienskia*), and report the other, mono-generic and mono-specific, and thus rather small families (based on *Halonatospora* & *Oehlia*) directly below their most closely related taxa. The organization of taxa is also reflected in the Tabs. 1–3 and Supp. Tab. S2.

Glomeromycetes Caval.-Sm., Biol. Rev. Cambridge Philos. Soc. 73: 246. 1998.
MycoBank no.: MB 90168

Emended description: see Oehl et al. (2011a).

Type order: Glomerales J.B. Morton and Benny, emend. Błaszk., B.T. Goto, and Magurno.

Other orders:
Diversisporales C. Walker & A. Schüßler,
Entrophosporales Błaszk., Sánchez-García, B.T. Goto & Magurno,
Acaulosporales Sieverd., Silva G.A. & Oehl,
Sacculosporales Silva G.A., Sieverd. & Oehl,
Gigasporales Sieverd., G.A. Silva, B.T. Goto & Oehl,
Pacisporales Oehl, Sieverd., G.A. Silva.

Glomerales J.B. Morton and Benny, Mycotaxon 37: 473. 1990.
MycoBank no.: MB 90425

Emended description: see Błaszkowski et al. (2022) and Silva et al. (2024).

Type family: Glomeraceae Piroz. & Dalpé emend. Oehl, G.A. Silva & Sieverd.

Other families:
Funneliformaceae Oehl, Sieverd. & G.A. Silva,
Septoglomeraceae Oehl, G.A. Silva & Sieverd.,
Halonatosporaceae Oehl, Sieverd. & G.A. Silva,
Sclerocystaceae Oehl, G.A. Silva & Sieverd.,
Rhizoglomeraceae Sieverd., G.A. Silva & Oehl,
Oehliaceae Sieverd. & G.A. Silva,
Dominikiaceae G.A. Silva, Sieverd. & Oehl,
Kamienskiaceae G.A. Silva, Sieverd. & Oehl.

Glomeraceae Piroz. & Dalpé, Symbiosis 7: 19. 1989.
MycoBank no.: MB 82026

Emended description: see Oehl et al. (2011a) and Silva et al. (2024).

Type genus: *Glomus* Tul. & C. Tul.

Other genera:
Complexispora Błaszk., B.T. Goto, Niezgoda & Magurno,
Sclerocarpum B.T. Goto, Błaszk., Niezgoda, Kozłowska & Jobim,
Simiglomus Sieverd., G.A. Silva & Oehl.

Glomus Tul. & C. Tul., G. bot. ital. 2(1): 63. 1845. [1844].
MycoBank no.: MB 20244

Description: see Silva et al. (2024).

Type species: *Glomus macrocarpum* Tul & C. Tul., G. bot. ital. 2(1): 63. 1845. [1844].
MycoBank no.: MB 240247

≡ *Endogone macrocarpa* (Tul. & C. Tul.) Tul. & C. Tul., Fungi Hypog.: 182. 1851.
MycoBank no.: MB 218537

≡ *Endogone guttulata* E. Fisch., Ber. Schweiz. Bot. Ges. 32: 13. 1923.
MycoBank no.: MB 266684

≡ *Endogone nuda* Petch., Ann. R. Bot. Gdns Peradeniya 9: 322. 1925.
MycoBank no.: MB 223365

≡ *Endogone pampaloniana* Bacc., Nuovo Giorn. Bot. Ital., n.s. 10: 90. 1903.
MycoBank no.: MB 223215

≡ *Paurocotylis fulva* var. *zealandica* Cooke, Grevillea 8: 59. 1879.
MycoBank no.: MB 522257

Complexispora Błaszk., B.T. Goto, Niezgoda & Magurno, Mycol. Prog. 22(5, no. 34): 7. 2023.
MycoBank no.: MB 847607

Description: see Błaszkowski et al. (2023) and Silva et al. (2024).

Type species: *Complexispora multistratosa* Błaszk., B.T. Goto, Niezgoda & Magurno, Mycol. Prog. 22(5, no. 34): 6. 2023.

MycoBank no.: MB 847608

Sclerocarpum B.T. Goto, Błaszk., Niezgoda, Kozłowska & Jobim, Mycol. Prog. 18(3): 375. 2019.
MycoBank no.: MB 828316

Description: see Jobim et al. (2019) and Silva et al. (2024).

Type species: *Sclerocarpum amazonicum* B.T. Goto, Błaszk., Niezgoda, Kozłowska & Jobim, Mycol. Prog. 18: 377. 2019.

MycoBank no.: MB 828317

Simiglomus Sieverd., G.A. Silva & Oehl, Mycotaxon 116: 104. 2011.
MycoBank no.: MB 518435

Description: see Oehl et al. (2011a).

Type species: *Simiglomus hoi* (S.M. Berch & Trappe) G.A. Silva, Oehl & Sieverd., Mycotaxon 116: 104 (2011).

MycoBank no.: MB 518461

Basionym: *Glomus hoi* S.M. Berch & Trappe, Mycologia 77: 654. 1985.

MycoBank no.: MB 105333

Funneliformaceae Oehl, Sieverd. & G.A. Silva, fam. nov.
MycoBank no.: MB 860129

Description: Spores formed within soil or rarely in roots, singly or sometimes in sporocarps with one, a few to several spores per sporocarp only; the conspicuous SH is concolorous with spore wall color (or slightly lighter in color), SH is species-specific and generally funnel-shaped to rarely cylindrical. Wall differentiation and pigmentation may continue over long distances from the spore base (often > 50–250 µm), then mycelium generally is hyaline. Pore regularly closed by a conspicuous septum in some distance from spore base, or with some genera at spore base. Septum arises species-specifically from the structural wall layer, from an additional adherent innermost, (semi-)flexible lamina, or from both but not by introverted wall thickening, which is lacking. Forming typical vesicular-arbuscular mycorrhiza, with mycorrhizal structures that stain blue to dark blue with trypan blue.

Type genus: *Funneliformis* C. Walker & A. Schüssler, emend. Oehl, G.A. Silva & Sieverd.

Funneliformis C. Walker & A. Schüssler, The Glomeromycota—a species list with new families and genera: 13. 2010.
MycoBank no.: MB 542894

Description: see Oehl et al. (2011b) and Silva et al. (2024).

Type species: *Funneliformis mosseae* (T.H. Nicolson & Gerd.) C. Walker & A. Schüssler, The Glomeromycota—a species list with new families and genera: 13. 2010.

MycoBank no.: MB 542895

Basionym: *Endogone mosseae* T.H. Nicolson & Gerd., Mycologia 60: 314. 1968.

MycoBank no.: MB 330367

≡ *Glomus mosseae* (T.H. Nicolson & Gerd.) Gerd. & Trappe, Mycol. Mem. 5: 40. 1974.

MycoBank no.: MB 314604

Septoglomeraceae Oehl, G.A. Silva & Sieverd., Taxonomy 4: 768. 2024; emended here by Oehl, G.A. Silva & Sieverd.
MycoBank no.: MB 855466

Emended description: Spores formed in soil and sometimes in roots, terminally on or intercalarily in hyphae, either singly, in loose spore clusters or rarely in sporocarps. Spores with one mono- to multiple-layered wall. SH wall conspicuously continuous and concolorous with the SW or slightly lighter in color than the SW; SH genus-specifically dominantly constricted, cylindrical or funnel-shaped, rarely inflated; straight, curved or flared; pore genus-specifically dominantly closed by a broad, thick, or even plug-like septum; forming typical vesicular–arbuscular mycorrhiza with mycorrhizal structures that stain blue to dark blue with trypan blue.

Type genus: *Septoglomus* Sieverd., G.A. Silva & Oehl.

Other genera:
Blaszkowskia G.A. Silva & Oehl,
Funneliglomus Corazon-Guivin, G.A. Silva & Oehl,
Melanoglomus B.T. Goto, Błaszk., Sieverd., G.A. Silva & Oehl,
Microviscospora Oehl, Corazon-Guivin, Błaszk., B.T. Goto, Sieverd. & G.A. Silva,
Viscospora Sieverd., Oehl & G.A. Silva.

Septoglomus Sieverd., G.A. Silva & Oehl, Mycotaxon 116: 105. 2011.
MycoBank no.: MB 518436

Emended description: see Oehl et al. (2011b).

Type species: *Septoglomus constrictum* (Trappe) Sieverd., G.A. Silva & Oehl. Mycotaxon 116: 105. 2011.

MycoBank no.: MB 518462

Basionym: *Glomus constrictum* Trappe, Mycotaxon 6: 361. 1977.
MycoBank no.: MB 314589
≡ *Funneliformis constrictus* (Trappe) C. Walker & A. Schüssler, The Glomeromycota— a species list with new families and genera: 14. 2010.
MycoBank no.: MB 542904

Blaszkowskia G.A. Silva & Oehl, Mycol. Prog. 22(11, no. 74): 5. 2023.
MycoBank no.: MB 847414

Description: see Silva et al. (2024).
Type species: *Blaszkowskia deserticola* (Trappe, Bloss & J.A. Menge) Oehl & G.A. Silva. Mycol. Prog. 22(11, no. 74): 5. 2023.
MycoBank no.: MB 847415
Basionym: *Glomus deserticola* Trappe, Bloss & J.A. Menge, Mycotaxon 20: 123. 1984.
MycoBank no.: MB 106847
≡ *Septoglomus deserticola* (Trappe, Bloss & J.A. Menge) G.A. Silva, Oehl & Sieverd. Mycotaxon 116: 106. 2011.
MycoBank no.: MB 518463

Funneliglomus Corazon-Guivin, G.A. Silva & Oehl, Sydowia 71: 19. 2019.
MycoBank no.: MB 829266

Description: see Silva et al. (2024).
Type species: *Funneliglomus sanmartinense* Corazon-Guivin, G.A. Silva & Oehl, Sydowia 71: 21. 2019.
MycoBank no.: MB 830216

Melanoglomus B.T. Goto, Błaszk., Sieverd., G.A. Silva & Oehl, Mycol. Prog. 24: 73. 5. 2025.
MycoBank no.: MB 857542

Description: see Goto et al. (2025).
Type species: *Melanoglomus titan* (B.T. Goto & G.A. Silva) B.T. Goto, Błaszk., Sieverd., G.A. Silva & Oehl, Mycol. Prog. 24: 73. 5. 2025.
MycoBank no.: MB 857543
Basionym: *Septoglomus titan* B.T. Goto & G.A. Silva, Mycotaxon 124: 105. 2013.
MycoBank no.: MB564321

Microviscospora Oehl, Corazon-Guivin, Błaszk., B.T. Goto, Sieverd. & G.A. Silva, Mycol. Prog. 24: 73. 5. 2025.
MycoBank no.: MB 857544

Description: see Goto et al. (2025).
Type species: *Microviscospora peruviscosa* Oehl, Corazon-Guivin, Błaszk., B.T. Goto, Sieverd. & G.A. Silva, Mycol. Prog. 24: 73. 5. 2025.
MycoBank no.: MB 857544

Basionym: *Viscospora peruviscosa* Corazon-Guivin, G.A. Silva & Oehl, J. Appl. Bot. Food Quality – Angew. Botan. 96: 118. 2023.
MycoBank no.: MB 857545

Viscospora Sieverd., Oehl & G.A. Silva, Mycotaxon 116: 108. 2011.
MycoBank no.: MB 518439

Emended description: see Goto et al. (2025).
Type species: *Viscospora viscosa* (T.H Nicolson) Sieverd., Oehl & G.A. Silva, Mycotaxon 116: 108. 2011.
MycoBank no.: MB 518471
Basionym: *Glomus viscosum* T.H. Nicolson, Mycol. Res. 99: 1502. 1995.
MycoBank no.: MB 413125
≡ *Septoglomus viscosum* (T.H. Nicolson) C. Walker, D. Redecker, D. Stiller & A. Schüssler, Mycorrhiza 23: 524. 2013.
MycoBank no.: MB 550089

Sclerocystaceae Oehl, G.A. Silva & Sieverd., Taxonomy 4: 770. 2024; emended here by Oehl, G.A. Silva & Sieverd.
MycoBank no.: MB 855467

Emended description: Spores formed in compact sporocarps, or singly in soil and frequently in roots. When formed in sporocarps, spores generally organized around a central hyphal plexus; SH wall continuous with the SW and for a certain distance concolorous with the SW or slightly lighter in color. SH cylindrical or seldom slightly funnel-shaped, with a rather small pore channel. Pore at spore base regularly closed by a septum. Forming vesicular–arbuscular mycorrhizae, the fungal structures of which stain blue to dark blue in trypan blue.
Type genus: *Sclerocystis* Berk. & Broome.
Other genera:
Silvaspora Błaszk., Niezgoda, B.T. Goto, Crossay & Magurno,
Parvocarpum Magurno.

Sclerocystis Berk. & Broome, J. Linn. Soc., Bot. 14(no. 74): 137. 1873. [1875].
MycoBank no.: MB 20512

Emended description: see Silva et al. (2024).
Type species: *Sclerocystis coremioides* Berk. & Broome, J. Linn. Soc., Bot. 14(no. 74): 137. 1873. [1875].
MycoBank no.: MB 213141

≡ *Glomus coremioides* (Berk. & Broome) D. Redecker & J.B. Morton, Mycologia 92:
284. 2000.
MycoBank no.: MB 464612

Parvocarpum Magurno, MycoKeys 107: 283. 2024.

Emended description: see Silva et al. (2024).
Type species: *Parvocarpum badium* (Oehl, Redecker & Sieverd.) Magurno, MycoKeys 107: 284. 2024.
MycoBank no.: MB 853560
Basionym: *Glomus badium* Oehl, D. Redecker & Sieverd., J. Appl. Bot. Food Qual. 79: 39. 2005.
MycoBank no.: MB 341387
≡ *Funneliformis badius* (Oehl, D. Redecker & Sieverd.) C. Walker & A. Schüssler, The Glomeromycota—a species list with new families and genera: 13. 2010.
MycoBank no.: MB 541897

Silvaspora Błaszk., Niezgoda, B.T. Goto, Crossay & Magurno, Frontiers in Microbiology 12(no. 655910): 14. 2021.
MycoBank no.: 838881

Description: see Silva et al. (2024).
Type species: *Silvaspora neocaledonica* (D. Redecker, Crossay & Cilia) Błaszk., Niezgoda, B.T. Goto, Crossay & Magurno, Frontiers in Microbiology 12(no. 655910): 14 (2021)
MycoBank no.: MB 838882
Basionym: *Rhizophagus neocaledonicus* D. Redecker, Crossay & Cilia, Mycol. Prog. 17: 739. 2018.
MycoBank no.: MB 820537
≡ *Rhizoglomus neocaledonicum* (D. Redecker, Crossay & Cilia) Oehl, A. Turrini & Giovann., Mycol. Prog. 17: 1216 (2018).
MycoBank no.: MB 827095

Rhizoglomeraceae Sieverd., G.A. Silva & Oehl, fam. nov.
MycoBank no.: MB 860131

Description: Spores formed in loose sporocarps, in clusters or singly in soil and frequently also intraradical in loose sporocarps and clusters. When formed in compact sporocarps, they are not organized around a central plexus of hyphae. SH wall continuous with the SW and for a certain distance concolorous with the SW or slightly lighter in color. SH cylindrical or seldom slightly funnel-shaped at spore base. Pore at spore base regularly open, rarely closed by a septum. SW shows more than one, generally two to three (and up to five) distinct layers, of which one or several of the outermost layers may easily separate when pressure is applied to spores. Forming vesicular–arbuscular mycorrhizae, the fungal structures of which stain blue to dark blue in trypan blue.
Type genus: *Rhizoglomus* Sieverd., G.A. Silva & Oehl.

Rhizoglomus Sieverd., G.A. Silva & Oehl, Mycotaxon 129: 377. 2015 [2014].
MycoBank no.: MB 803191

Description: see Rhizoglomeraceae and Silva et al. (2024).
Type species: *Rhizoglomus intraradices* (N.C. Schenck & G.S. Sm.) Sieverd., G.A. Silva & Oehl, Mycotaxon 129(2): 380. 2015 [2014].
MycoBank no.: MB 803192
Basionym: *Glomus intraradices* N.C. Schenck & G.S. Sm., Mycologia 74: 78. 1982.
MycoBank no.: MB 110704
≡ *Rhizophagus intraradices* (N.C. Schenck & G.S. Sm.) C. Walker & A. Schüssler, The Glomeromycota—a species list with new families and genera: 19. 2010.
MycoBank no.: MB 542910

Oehliaceae Sieverd. & G.A. Silva, fam. nov.
MycoBank no.: MB 860132

Description: Spores formed in loose sporocarps, in clusters or singly in soil and frequently also intraradical singly or in loose sporocarps and clusters. When formed in sporocarps, they are not organized around a central plexus of hyphae. SH wall continuous with the SW and for a certain distance concolorous with the SW or slightly lighter in color. SH cylindrical or seldom slightly funnel-shaped at spore base. Pore at spore base regularly closed by a septum. SW shows more than one, generally two to three (and up to five) distinct layers. Forming vesicular–arbuscular mycorrhizae, fungal structures stain blue to dark blue with trypan blue.
Type genus: *Oehlia* Błaszk., Kozłowska & Dalpe.

Oehlia Błaszk., Kozłowska, Niezgoda, B.T. Goto & Dalpé, Nova Hedwigia 107(3–4): 507. 2018.
MycoBank no.: MB 824689

Description: see Oehliaceae, Błaszkowski et al. (2018a), and Silva et al. (2024).
Type species: *Oehlia diaphana* (J.B. Morton & C. Walker) Błaszk., Kozłowska & Dalpé, Nova Hedwigia 107(3–4): 507. 2018.

MycoBank no.: MB 824693

Basionym: *Glomus diaphanum* J.B. Morton & C. Walker, Mycotaxon 21: 433, 1984.

MycoBank no.: MB 106161

Halonatosporaceae G.A. Silva, Oehl & Sieverd., fam. nov.
MycoBank no.: MB 860134

Description: Spores formed in loose clusters or singly in soil and frequently in roots. SH wall continuous with the SW and for a certain distance concolorous with the SW or slightly lighter in color. Outer SW layer strongly swells in PVLG, forming a halo with radiate columns. SH cylindrical or slightly flared, sometimes slightly constricted at spore base, straight or slightly curved. Pore open or closed by a septum at spore base. SW shows more than one, generally two to three (and up to five) distinct layers. Forming vesicular–arbuscular mycorrhizae, whose fungal structures stain blue to dark blue with trypan blue.

Type genus: *Halonatospora* Błaszk., Niezgoda, B.T. Goto & Kozłowska.

Halonatospora Błaszk., Niezgoda, B.T. Goto & Kozłowska, Botany 96(11): 743. 2018.
MycoBank no.: MB 826963

Description: see Halonatosporaceae, Silva et al. (2024) and Błaszkowski et al. (2018b).

Type species: *Halonatospora pansihalos* (S.M. Berch & Koske) Błaszk., Niezgoda, B.T. Goto & Kozłowska, Botany 96(11): 743 (2018).

MycoBank no.: MB 826964

Basionym: *Glomus pansihalos* S.M. Berch & Koske. Mycologia 78: 832, 1986.

MycoBank no.: MB 358213

Dominikiaceae G.A. Silva, Sieverd. & Oehl, Taxonomy 4: 773. 2024.
MycoBank no.: MB 855469

Description: see Silva et al. (2024).

Type genus: *Dominikia* Błaszk., Chwat & Kovács.

Other genera:
Delicatispora Błaszk., Niezgoda & B.T. Goto,
Macrodominikia Oehl, Sieverd. & G.A. Silva,
Microdominikia Oehl, Corazon-Guivin & G.A. Silva,
Nanoglomus Corazon-Guivin, G.A. Silva & Oehl,
Orientoglomus G.A. Silva, Oehl & Corazon-Guivin.

Dominikia Błaszk., Chwat & Kovács, Nova Hedwigia 100(1–2): 228. 2014 [2015].
MycoBank no.: MB 808255

Emended description: see Silva et al. (2024).

Type species: *Dominikia minuta* (Błaszk., Tadych & Madej) Błaszk., Chwat & Kovács, Nova Hedwigia 100: 230. 2014 [2015].

MycoBank no.: MB 808256

Basionym: *Glomus minutum* Błaszk., Tadych & Madej. Mycotaxon 76: 189. 2000.

Delicatispora Błaszk., Niezgoda & B.T. Goto, MycoKeys 112: 261. 2025.
MycoBank no.: MB 856187

Description: see Błaszkowski et al. (2025a).

Type species: *Delicatispora indica* (Błaszk., Wubet & Harikumar) Błaszk., Niezgoda & B.T. Goto, MycoKeys 112: 261. 2025.

MycoBank no.: MB 856189

Basionym: *Glomus indicum* Błaszk., Wubet & Harikumar, Botany 88: 134. 2010.

MycoBank no.: MB 515245.

≡ *Dominikia indica* (Błaszk., Wubet & Harikumar) Błaszk., G.A. Silva & Oehl, Nova Hedwigia 101 (1–2): 71. 2014.

MycoBank no.: MB 808258

Macrodominikia Oehl, Sieverd. & G.A. Silva, Taxonomy 4: 774. 2024.
MycoBank no.: 855470

Description: see Silva et al. (2024) and Błaszkowski et al. (2025a).

Type species: *Macrodominikia compressa* (Sieverd., Oehl, Palenz., Sánchez-Castro & G.A. Silva) Oehl, Sieverd. & G.A. Silva, Taxonomy 4: 774. 2024.

MycoBank no.: MB 855471

Basionym: *Glomus compressum* Sieverd., Oehl, Palenz., Sánchez-Castro & G.A. Silva. Nova Hedwigia 99: 433. 2014.

MycoBank no.: MB 807530

≡ *Dominikia compressa* (Sieverd., Oehl, Palenz., Sánchez-Castro & G.A. Silva) Oehl, Palenz., Sánchez-Castro & G.A. Silva. Nova Hedwigia. 101: 71. 2014 [2015].

MycoBank no.: MB 809861

Microdominikia Oehl, Corazon-Guivin & G.A. Silva, Mycol. Prog. 18(12): 1400. 2019.
MycoBank no.: MB 831098

Description: see Silva et al. (2024).

Type species: *Microdominikia litorea* (Błaszk. & Kozłowska) Oehl, Corazon-Guivin & G.A. Silva, Mycol. Prog. 18(12): 1400. 2019.

MycoBank no.: MB 831099

Basionym: *Dominikia litorea* Błaszk. & Kozłowska, Phytotaxa 338(3): 246. 2018.

MycoBank no.: MB 823832

Nanoglomus Corazon-Guivin, G.A. Silva & Oehl, Mycol. Prog. 18(12): 1398. 2019.
MycoBank no.: MB 831096

Description: see Silva et al. (2024).

Type species: *Nanoglomus plukenetiae* Corazon-Guivin, G.A. Silva & Oehl, Mycol. Prog. 18(12): 1398. 2019.

MycoBank no.: MB 831097

Orientoglomus G.A. Silva, Oehl & Corazon-Guivin, Mycol. Prog. 18(12): 1400. 2019.
MycoBank no.: MB 831100

Description: see Silva et al. (2024).

Type species: *Orientoglomus emiratium* (Błaszk., Kozłowska, Mullath, AlDhaheri & Al-Yahya'ei) G.A. Silva, Oehl & Corazon-Guivin, Mycol. Prog. 18(12): 1403. 2019.

MycoBank no.: MB 831101

Basionym: *Dominikia emiratia* Błaszk., Kozłowska, Mullath, AlDhaheri & Al-Yahya'ei, Botany 95(7): 632. 2017.

MycoBank no.: MB 819815

Kamienskiaceae G.A. Silva, Sieverd. & Oehl, Taxonomy 4: 772. 2024.
MycoBank no.: MB 855468

Description: see Silva et al. (2024).

Type genus: *Kamienskia* Błaszk., Chwat & Kovács

Other genera:
Epigeocarpum Błaszk., B.T. Goto, Jobim, Niezgoda & Marguno,
Microkamienskia Corazon-Guivin, G.A. Silva & Oehl.

Kamienskia Błaszk., Chwat & Kovács, Nova Hedwigia 100(1–2): 230. 2014 [2015].
MycoBank no.: MB 808260

Description: see Silva et al. (2024).

Type species: *Kamienskia bistrata* (Błaszk., D. Redecker, Koegel, Symanczik, Oehl & Kovács) Błaszk., Chwat & Kovács, Nova Hedwigia 100(1–2): 230. 2014 [2015].

MycoBank no.: MB 808261

Basionym: *Glomus bistratum* Błaszk., D. Redecker, Koegel, Symanczik, Oehl & Kovács, Botany 87: 267. 2009.

MycoBank no.: MB 512540

Epigeocarpum Błaszk., B.T. Goto, Jobim, Niezgoda & Marguno, Frontiers in Microbiology 12(no. 655910): 10. 2021.
MycoBank no.: MB 838879

Description: see Błaszkowski et al. (2021b) and Silva et al. (2024).

Type species: *Epigeocarpum crypticum* Jobim, Błaszk., Niezgoda, Magurno & B.T. Goto, Frontiers in Microbiology 12(no. 655910): 14. 2021.

MycoBank no.: MB 838880

Microkamienskia Corazon-Guivin, G.A. Silva & Oehl, Nova Hedwigia 109: 359. 2019.
MycoBank no.: MB 830814

Description: see Silva et al. (2024).

Type species: *Microkamienskia perpusilla* (Błaszk. & Kovács) Corazon-Guivin, G.A. Silva & Oehl. Nova Hedwigia 109: 361. 2019.

MycoBank no.: MB 830815

Basionym: *Glomus perpusillum* Błaszk. & Kovács. Mycologia 101: 249. 2009.

MycoBank no.: MB 512346

≡ *Kamienskia perpusilla* (Błaszk. & Kovács) Błaszk., Chwat & Kovács. Nova Hedwigia 100: 231. 2015.

MycoBank no.: MB 808264

Entrophosporales Błaszk., Sánchez-García, B.T. Goto & Magurno, Frontiers in Microbiology 13 (no. 962856): 10. 2022.
MycoBank no.: MB 846043

Description: see Błaszkowski et al. (2022) and Silva et al. (2025).

Type family: Entrophosporaceae Oehl & Sieverd.

Entrophosporaceae Oehl & Sieverd., J. Appl. Bot. Food Qual. 80: 73. 2006.
MycoBank no.: MB 521877

Description: see Błaszkowski et al. (2022) and Silva et al. (2025).

Type genus: *Entrophospora* R.N. Ames & R.W. Schneid.

Other genera:
Albahypha Oehl, G.A. Silva, B.T. Goto & Sieverd.,
Alborhynchus Oehl, B.T. Goto, Corazon-Guivin, Sieverd. & G.A. Silva.

Entrophospora R.N. Ames & R.W. Schneid., Mycotaxon 8 (2): 347. 1979.
MycoBank no.: MB 20223

Emended description: see Silva et al. (2025).

Type species: *Entrophospora infrequens* (I.R. Hall) R.N. Ames & R.W. Schneid., Mycotaxon 8 (2): 348. 1979.

MycoBank no.: MB 313899

Basionym: *Glomus infrequens* I.R. Hall, Transactions of the British Mycological Society 68 (3): 345. 1977.

MB 314599

Albahypha Oehl, G.A. Silva, B.T. Goto & Sieverd., Mycotaxon 117: 308. 2011.
MycoBank no.: MB 561639

Emended description: see Silva et al. (2025).

Type species: *Albahypha drummondii* (Blaszk. & Renker) Sieverd., Oehl, B.T. Goto & G.A. Silva, Mycotaxon 117: 308. 2011.

MycoBank no.: MB 561640

Basionym: *Glomus drummondii* Blaszk. & Renker, Mycological Research 110 (5): 559. 2006.

MycoBank no.: MB 510049

≡ *Entrophospora drummondii* (Błaszk. & Renker) Błaszk., Niezgoda, B.T. Goto & Magurno, Frontiers in Microbiology 13 (no. 962856): 13. 2022.

MycoBank no.: MB 836247

Alborhynchus Oehl, B.T. Goto, Corazon-Guivin, Sieverd. & G.A. Silva, Journal of Fungi 11(2, no 97): 6. 2025.
MycoBank no.: MB 856948

Description: see Silva et al. (2025).

Type species: *Alborhynchus walkeri* (Blaszk. & Renker) Oehl, B.T. Goto, Corazon-Guivin, Sieverd. & G.A. Silva, Journal of Fungi 11(2, no 97): 7. 2025.

MycoBank no.: MB 856949

Basionym: *Glomus walkeri* Blaszk. & Renker, Mycological Research 110 (5): 563. 2006.

MycoBank no.: MB 510050

≡ *Entrophospora walkeri* (Błaszk. & Renker) Błaszk., Niezgoda, B.T. Goto & Magurno, Frontiers in Microbiology 13 (no. 962856): 13. 2022.

MycoBank no.: MB 836252

Diversisporales C. Walker & A. Schüssler, Mycological Research 108 (9): 981. 2004.
MycoBank no.: MB 90593

Emended description: Spore formation diversisporoid, otosporoid, or tricisporoid, redeckeroid or (para-)corymbiglomoid. Diversisporoid spores formed singly, in clusters, or in disorganized sporocarps with up to very high spore numbers (up to several hundreds). In pigmented spores, SH conspicuously change color, becoming hyaline to white behind the septum, (immediately beyond the septum, or at a very short distance from this septum); SH generally straight, cylindrical, in some species constricted or inflated. Spores with 1-3 wall layers; pore often closed with a septum that may arise from innermost wall lamina, an overlaying laminate layer, or from both; SH pore rarely open. Otosporoid and tricisporoid spores with two multiple-layered walls; otosporoid spores formed laterally on the persistent neck of a terminal or intercalary sporiferous saccule at some distance from the saccule terminus; spore pore generally closed by a septum at spore base. Tricisporoid spores formed within the evanescent neck of a tightly attached terminal or intercalary sporiferous saccule, closely attached to the saccule terminus which is often smaller in size than the mature spores attached, rarely equal in size; tricisporoid spores with two cicatrices formed by the outer wall pigmented structural layer. Corymbiglomoid and para-corymbiglomoid spores include several generic clades of Glomeromycetes fungi, such as *Corymbiglomus*, *Paracorymbiglomus* and *Sieverdingia* species forming on generally cylindrical SH i) mono-to-bi-walled spores with very specific features (e.g. (para-)corymbiforme or with a dense hyphal mantle), or ii) *Desertispora*, forming glomoid-diversisporoid-like spores staining purple in Melzer´s reagent on the spore wall, which is not known for *Diversispora* species, or iii) redeckeroid spores, which form mono-walled spores in large, disorganized and compact sporocarps, containing hundreds to thousands of spores per sporocarp; spores, with 2 to rarely 3 wall layers; SH generally broad at spore base and with a conspicuous, thick and broad septum that arises from the inner lamina of the structural wall layer; structural layer generally continue over very short distances into SH; SWL1 fragile, usually inflating in a short distance to the spore base where SWL2 becomes invisible in the SH (= characteristically 'redeckeroid').

Type family: Diversisporaceae C. Walker & A. Schüssler

Other family: Corymbiglomeraceae G.A. Silva, Sieverd. & Oehl.

Diversisporaceae C. Walker & A. Schüssler, Mycological Research 108 (9): 981. 2004; emended here by Oehl, G.A. Silva & Sieverd.
MycoBank no.: MB 82125

Emended description: Spore formation diversisporoid, otosporoid, or tricisporoid. Diver-

sisporoid spores formed singly, in clusters, or in disorganized sporocarps with up to very high spore numbers (up to several hundreds). In pigmented spores, SH conspicuously change color, becoming hyaline to white behind the septum, (immediately beyond the septum); SH often cylindrical or inflated, in some species constricted. Spores with 1–3 wall layers; pore often closed with a septum that may arise from innermost wall lamina, an overlaying laminate layer, or from both; SH pore rarely open. Otosporoid and tricisporoid spores with two multiple-layered walls; otosporoid spores formed laterally on the persistent neck of a sporiferous saccule at some distance from the saccule terminus; spore pore generally closed by a septum at spore base. Tricisporoid spores formed within the evanescent neck of a tightly attached sporiferous saccule, which is often smaller in size than the mature spores attached, rarely equal in size; tricisporoid spores with two cicatrices formed by the pigmented structural layer of the outer wall.

Type genus: *Diversispora* C. Walker & A. Schüssler

Other genera:
Otospora Oehl, Palenzuela & N. Ferrol, Mycologia 100(2): 297. 2008.

MycoBank no.: MB 506746, current synonym of *Diversispora,*
Tricispora Oehl, Sieverd., G.A. Silva & Palenz., Mycotaxon 117: 310. 2011.

MycoBank no.: MB 561642, current synonym of *Diversispora*

Diversispora C. Walker & A. Schüssler, Mycol. Res. 108 (9): 982. 2004.
MycoBank no.: MB 28884

Emended description: see description for the family Diversisporaceae here, directly above.

Type species: *Diversispora spurca* (C.M. Pfeiff., C. Walker & Bloss) C. Walker & A. Schüssler, Mycological Research 108 (9): 982. 2004.

MycoBank no.: MB 487795

Basionym: *Glomus spurcum* C.M. Pfeiff., C. Walker & Bloss, Mycotaxon 59: 374. 1996.

MycoBank no.: MB 415789

Corymbiglomeraceae G.A. Silva, Sieverd. & Oehl fam. nov.
MycoBank no.: MB 860135

Description: This new family includes several generic clades of Glomeromycetes fungi, such as i) *Corymbiglomus*, *Paracorymbiglomus* and *Sieverdingia* species forming mono-to-bi-walled spores on cylindrical SH, in clusters, sporocarps or singly in soil, often corymbiforme and with different types of hyphal mantles, or such as ii) *Desertispora*, forming glomoid-diversisporoid-like spores staining purple on the spore wall, which is not known for Diversispora species, or iii) such as *Redeckera* species, which form mono-walled spores in large, disorganized and compact sporocarps, containing hundreds to thousands of spores per sporocarp; spores, with 2 to rarely 3 wall layers; SH generally broad at spore base and with a conspicuous, thick and broad septum that arises from the inner lamina of the structural wall layer; structural layer generally continue over very short distances into SH; SWL1 fragile, usually inflating in a short distance to the spore base where SWL2 becomes invisible in the SH (= characteristically 'redeckeroid').

Type genus: *Corymbiglomus* (Błaszk. & Chwat) emend. Błaszk., Niezgoda & B.T. Goto

Other genera:
Desertispora Błaszk., Kozłowska, Ryszka, Al-Yahya'ei & Symanczik,
Paracorymbiglomus Błaszk., Niezgoda & B.T. Goto,
Redeckera C. Walker & A. Schüssler,
Sieverdingia Błaszk., Niezgoda & B.T. Goto.

Corymbiglomus Błaszk. & Chwat, Glomeromycota 1: 272. 2012.
MycoBank no.: MB 564566

Description: see Błaszkowski (1995).

Emended description: Błaszkowski et al. (2025b).

Type species: *Corymbiglomus corymbiforme* (Blaszk.) Błaszk. & Chwat, The Glomeromycota 1: 274. 2012.

MycoBank no.: MB 564567

Basionym: *Glomus corymbiforme* Blaszk., Mycologia 87(5): 732. 1995.

MycoBank no.: MB 413122

Desertispora Błaszk., Kozłowska, Ryszka, Al-Yahya'ei & Symanczik, Mycological Progress 17 (4): 444. 2018.
MycoBank no.: MB 823563

Description: see Symanczik et al. (2018).

Type species: *Desertispora omanana* (Symanczik, Błaszk. & Al-Yahya'ei) Symanczik, Błaszk., Kozłowska & Al-Yahya'ei, Mycological Progress 17 (4): 444. 2018.

MycoBank no.: MB 830800

Basionym: *Diversispora omanana* Symanczik, Błaszk. & Al-Yahya'ei, Mycologia 106 (2): 247. 2014.

MycoBank no.: MB 830799

Paracorymbiglomus Błaszk., Niezgoda & B.T. Goto, MycoKeys 117: 178. 2025.
MycoBank no.: MB 858391

Description: see Błaszkowski et al. (2025b).
Type species: *Paracorymbiglomus globiferum* (Koske & C. Walker) Błaszk., Niezgoda & B.T. Goto, MycoKeys 117: 178. 2025.
MycoBank no.: MB 858393
Basionym: *Glomus globiferum* Koske & C. Walker, Mycotaxon 26. 133. 1986.
Synonym: *Corymbiglomus globiferum* (Koske & C. Walker) Błaszk. & Chwat, Acta Mycol. 48 (1): 99. 2013.
MycoBank no.: MB 622179

Redeckera C. Walker & A. Schüssler, The Glomeromycota—a species list with new families and new genera: 44. 2010.
MycoBank no.: MB 542402

Description: see Oehl et al. (2011b).
Type species: *Redeckera megalocarpa* (D. Redecker) C. Walker & A. Schüssler, The Glomeromycota—a species list with new families and new genera: 44. 2010.
MycoBank no.: MB 542403
Basionym: *Glomus megalocarpum* D. Redecker, Mycological Progress 6 (1): 38. 2007.
MycoBank no.: MB 529715

Sieverdingia Błaszk., Niezgoda & B.T. Goto, Mycological Progress 18 (11): 1368. 2019.
MycoBank no.: MB 832298

Description: see Błaszkowski et al. (2019).
Type species: *Sieverdingia tortuosa* (N.C. Schenck & G.S. Sm.) Błaszk., Niezgoda & B.T. Goto, Mycol. Prog. 18 (11): 1369. 2019.
MycoBank no.: MB 832299
Basionym: *Glomus tortuosum* N.C. Schenck & G.S. Sm., Mycologia 74 (1): 83. 1982.
MycoBank no.: MB 110706

Acaulosporales Sieverd., Silva G.A. & Oehl, ord. nov.
MycoBank no.: MB 860126

Description: Spores formed laterally on or intrahyphally within hyphal stalk of a terminally or intercalary formed sporiferous saccule, in some distance to the sporiferous saccule termini, or rarely even within the inflated sporiferous saccule terminus; spores have three walls: an outer spore wall, a middle wall and an inner wall. One or a few layers of the outer spore wall are continuous with the wall of the stalk and the sporiferous saccule. The outer hyaline to subhyaline layers are often evanescent, the inner layers of the outer spore wall are permanent. When the connections of the hyphal stalk break off, the spore appears with one to two cicatrices which are closed by the permanent sublayers of the inner layers of the outer spore wall. The middle wall is thin and flexible. The inner wall consists of several thin layers of which the outer layer is generally granulated having a characteristic 'beaded' appearance. This beaded appearance might be missing in a few small-spored species, or becoming invisible in acid lactic based mountants, only in very small-spored species of this order. The second layer of the inner wall often stains deep purple in Melzer's reagent. The inner wall functions as germinal wall, a germination orb may be formed on the outer surface. Forming vesicular-arbuscular mycorrhizae whose fungal structures in the roots stain significantly blue with trypan blue.

Type family: **Acaulosporaceae** J.B. Morton & Benny, Mycotaxon 37: 479. 1990.
MycoBank no.: MB 82037

Emended description; see description for the order here, directly above.
Type genus: *Acaulospora* Gerd. & Trappe
Other genus:
Kuklospora Oehl & Sieverd., J. Appl. Bot. Food Qual. 80: 74. 2006.
MycoBank no.: MB 29042, current synonym of *Acaulospora*

Acaulospora Gerd. & Trappe, Mycol. Mem. 5: 31. 1974.
MycoBank no.: MB 20003

Emended description; see description for the order here directly above.
Type species: *Acaulospora laevis* Gerd. & Trappe, Mycol. Mem. 5: 33. 1974.
MycoBank no.: MB 308078

Sacculosporales Silva G.A., Sieverd. & Oehl, ord. nov
MycoBank no.: MB 860127

Description: Sporocarps unknown. Spores formed within the hyphal neck of closely adherent terminal or intercalary formed sporiferous saccules. Spores have two walls: OW and IW. At least two layers (including the outer wall structural layer) are continuous with the sporiferous saccule wall. After the hyphal neck connections break off, spores show two, often opposite, cicatrices that are closed by the permanent sublayers of the outer wall structural

layer. Inner wall forms de novo. Inner wall consists of several layers, none of which has a granular, 'beaded' appearance, and does not stain in Melzer's reagent.

Type family: **Sacculosporaceae** Oehl, Sieverd., G.A. Silva, B.T. Goto, I.C. Sánchez & Palenz., Mycotaxon 117: 310. 2011.
MycoBank no.: MB 561645

Emended description: see above for the order Sacculosporales and Willis et al. (2016).

Type genus: *Sacculospora* Oehl, Sieverd., G.A. Silva, B.T. Goto, I.C. Sánchez & Palenz.

Sacculospora Oehl, Sieverd., G.A. Silva, B.T. Goto, I.C. Sánchez & Palenz., Mycotaxon 117: 311. 2011.
MycoBank no.: MB 561646

Description: see above for the order Sacculosporales and Willis et al. (2016).

Type species: *Sacculospora baltica* (Blaszk., Madej & Tadych) Oehl, Palenz., I.C. Sánchez, B.T. Goto, G.A. Silva & Sieverd., Mycotaxon 117: 311. 2011.

MycoBank no.: MB 561647

Basionym: *Entrophospora baltica* Blaszk., Madej & Tadych, Mycotaxon 68: 167. 1998.

MycoBank no.: MB 444868

Gigasporales Sieverd., G.A. Silva, B.T. Goto & Oehl, Mycotaxon 116: 373. 2011.
MycoBank no.: MB 519688

Description: see Oehl et al. (2011a).

Type family: Gigasporaceae Morton & Benny

Other families:
Dentiscutataceae F.A. Souza, Oehl & Sieverd.,
Intraornatosporaceae B.T. Goto & Oehl,
Racocetraceae Oehl, Sieverd. & F.A. Souza,
Scutellosporaceae Sieverd., F.A. Souza & Oehl.

Gigasporaceae Morton & Benny, Mycotaxon 37: 483. 1990.
MycoBank no.: MB 82038

Emended description: see Oehl et al. (2008).

Type genus: ***Gigaspora*** Gerd. & Trappe, Mycologia Memoirs 5: 25. 1974.

MycoBank no.: MB 20239

Description: e.g. see for Gigasporaceae

Type species: *Gigaspora gigantea* (T.H. Nicolson & Gerd.) Gerd. & Trappe, Mycologia Memoirs 5: 29. 1974.

MycoBank no.: MB 314484

Basionym: *Endogone gigantea* T.H. Nicolson & Gerd., Mycologia 60 (2): 321. 1968.

MycoBank no.: MB 330364

Scutellosporaceae Sieverd., F.A. Souza & Oehl, Mycotaxon 106. 330. 2009 [2008]; emended here by Oehl, G.A. Silva, Sieverd.
MycoBank no.: MB 511945

Emended description: Sporocarps are unknown. Spores generally singly formed on bulbous sporogenous cells that are formed terminally on subtending hyphae (= sporogenous hyphae; SH) that arise from mycelia hyphae in soil. Spores have 3 walls, an outer, a middle and an inner germinal wall (OW, MW, IW). OW with 3 or several layers, MW with 1–2 layers, and IW with 2–4 layers. A single germination shield, rarely two shields, are formed on the outer surface or between the outer and the subsequent layer of the inner wall. Germination shields are transparent, or hyaline to subhyaline, seldom light yellow, generally bi-lobed, sometimes mono-lobed; often violin-shaped or oval to ovoid, rarely cardioid, circular or coiled; only a few folds cover the shield surface where in general one germ tube initiation (gti) is formed per lobe. Sometimes one to a few so-called false lobes are visible, which never bear a gti, and usually develop artificially by pressure on the spore, e.g., through pressure on the cover slides under the microscope. Generally from one gti, seldom from both gti, a germ tube arises and penetrates the outer spore walls. SH form one to several septa in some distance to the sporogenous cells. Forming typical arbuscular mycorrhizae without vesicle formation in roots; knobby extraradical auxiliary cells branching from the hyphal mycelium without spines on the surface.

Type genus: *Scutellospora* C. Walker & F.E. Sanders

Other genera:
Bulbospora Oehl & G.A. Silva,
Orbispora Oehl, G.A. Silva & D.K. Silva.

Scutellospora C. Walker & F.E. Sanders, Mycotaxon 27: 179. 1986; emended here by Oehl, G.A. Silva & Sieverd.
MycoBank no.: MB 25074

Emended description: Sporocarps unknown. Spores formed on sporogenous cells that form terminally on a hypha which arises from mycelia hyphae in soil. Outer spore wall generally is three-layered and continuous with the wall of the sporogenous cell. Outer layer of the outer spore wall generally rigid, second layer laminate and third lay-

er thin, often membranous, tightly adherent to the laminate layer and thus, often difficult to observe. Pore between the spore and sporogenous cell is narrow and usually closed by a plug formed by spore wall material. Two hyaline walls ('MW' and 'IW') form de novo during spore formation and have 1–2 and 2–3 layers, respectively. IW is two to three-layered forming a germination shield on its outer surface or between the outer and the subsequent layer of IW. The shield is transparent, or hyaline to subhyaline, seldom light yellow, bi-lobed; often violin-shaped to oval to ovoid to more rarely cardioids or coiled and then, either circular or apparently broad ellipsoid to irregular; only a few folds cover the shield surface where 1–2 rounded germ tube initiations ('gti', about 2–4 µm in diam) are visible from where the germ tubes arise which penetrate the outer spore wall layers. Sometimes one to a few so-called false lobes are visible, which never bear a gti, and usually develop artificially by pressure on the spore, e.g., through pressure on the cover slides under the microscope; mycelia hyphae form one to several septa in some distance to the sporogenous cells. Auxiliary cells in the hyphal mycelium, as far as known, are knobby without spines on the surface. Forming typical arbuscular mycorrhizae without vesicle formation in roots; knobby extraradical auxiliary cells branching from the hyphal mycelium without spines on the surface.

Type species: *Scutellospora calospora* (T.H. Nicolson & Gerd.) C. Walker & F.E. Sanders Mycotaxon 27: 180. 1986.

MycoBank no.: MB 128413

Basionym: *Endogone calospora* T.H. Nicolson & Gerd., Mycologia 60 (2): 322. 1968.

MycoBank no.: MB MB 330363

≡ *Gigaspora calospora* (T.H. Nicolson & Gerd.) Gerd. & Trappe, Mycologia Memoirs 5: 28. 1974.

MycoBank no.: MB 314482

Bulbospora Oehl & G.A. Silva, Sydowia 66. 315. 2014.
MycoBank no.: MB 809231

Description: see Marinho et al. (2014).

Type species: *Bulbospora minima* Oehl, Marinho, B.T. Goto & G.A. Silva, Sydowia 66. 315. 2014.

MycoBank no.: MB 809232

Orbispora Oehl, G.A. Silva & D.K. Silva, Mycotaxon 116. 163. 2011; emended here by Oehl, G.A. Silva, Sieverd.
MycoBank no.: MB 519533

Emended description: Sporocarps unknown. Spores 100-300 µm, formed on sporogenous cells that form terminally on hyphae arising from mycelia in soil. Outer spore wall (OW) generally (2–)3-layered and continuous with the wall of the sporogenous cell. Two hyaline walls ('MW' and 'IW') form de novo during spore formation and have 1–2 and 2–3 layers, respectively. A germination orb is formed on the outer IW surface or between the outer and the subsequent layer of IW. Germination orb is transparent, or hyaline to subhyaline, seldom light yellow, mono-lobed; coiled and then, either circular or apparently broad ellipsoid to rarely irregular; with one rounded germ tube initiation in the outer periphery of the lobe. One (rarely two) germ tube arises from this gti to penetrate the outer spore wall layers.

Type species: *Orbispora pernambucana* (Oehl, D.K. Silva, N. Freitas & L.C. Maia) Oehl, G.A. Silva & D.K. Silva, Mycotaxon 116. 166. 2011.

MycoBank no.: MB 519535

Basionym: *Scutellospora pernambucana* Oehl, D.K. Silva, N. Freitas & L.C. Maia, Mycotaxon 106: 363. 2009 [2008].

MycoBank no.: MB 512130

Racocetraceae Oehl, Sieverd. & F.A. Souza, Mycotaxon 106: 333. 2009 [2008].
MycoBank no.: MB 511946

Description: see Oehl et al. (2008).

Type genus: *Racocetra* Oehl, F.A. Souza & Sieverd.

Other genus: *Cetraspora* Oehl, F.A. Souza & Sieverd.

Racocetra Oehl, F.A. Souza & Sieverd., Mycotaxon 106: 334. 2009 [2008].
MycoBank no.: MB 511947

Description: see Oehl et al. (2008).

Type species: *Racocetra coralloidea* (Trappe, Gerd. & I. Ho) Oehl, F.A. Souza & Sieverd., Mycotaxon 106: 336. 2009 [2008].

MycoBank no.: MB 511948

Basionym: *Gigaspora coralloidea* Trappe, Gerd. & I. Ho, Mycologia Memoir No. 5: 30. 1974.

≡ *Scutellospora coralloidea* (Trappe, Gerd. & I. Ho) C. Walker & F.E. Sanders, Mycotaxon 27: 181. 1986.

MycoBank no.: MB 128414

Cetraspora Oehl, F.A. Souza & Sieverd., Mycotaxon 106: 337. 2009 [2008].
MycoBank no.: MB 511957

Description: see Oehl et al. (2008).

Type species: *Cetraspora gilmorei* (Trappe & Gerd.) Oehl, F.A. Souza & Sieverd., Mycotaxon 106: 338. 2009 [2008].

MycoBank no.: MB 511958

Basionym: *Gigaspora gilmorei* Trappe & Gerd., Mycologia Memoir No. 5: 27. 1974.

≡ *Scutellospora gilmorei* (Trappe & Gerd.) C. Walker & F.E. Sanders, Mycotaxon 27: 181. 1986.

MycoBank no.: MB 128417

Dentiscutataceae F.A. Souza, Oehl & Sieverd., Mycotaxon 106. 340. 2009 [2008].
MycoBank no.: MB 511962

Description: see Oehl et al. (2008)

Type genus: *Dentiscutata* Sieverd., F.A. Souza & Oehl

Other genera:
Fuscutata Oehl, F.A. Souza & Sieverd.,
Quatunica F.A. Souza, Sieverd. & Oehl.

Dentiscutata Sieverd., F.A. Souza & Oehl, Mycotaxon 106. 340. 2009 [2008].
MycoBank no.: MB 511968

Description: see Oehl et al. (2008).

Type species: *Dentiscutata nigra* (J.F. Redhead) Sieverd., F.A. Souza & Oehl, Mycotaxon 106. 342. 2009 [2008].

MycoBank no.: MB 511969

Basionym: *Gigaspora nigra* J.F. Redhead, Mycologia 71: 187. 1979.

MycoBank no.: MB 314489

≡ *Scutellospora nigra* (J.F. Redhead) C. Walker & F.E. Sanders, Mycotaxon 27: 181. 1986.

MycoBank no.: MB 128421

Fuscutata Oehl, F.A. Souza & Sieverd., Mycotaxon 106. 342. 2009 [2008].
MycoBank no.: MB 511963

Description: see Oehl et al. (2008).

Type species: *Fuscutata heterogama* Oehl, F.A. Souza, L.C. Maia & Sieverd., Mycotaxon 106. 342. 2009 [2008].

MycoBank no.: MB 511964

Quatunica F.A. Souza, Sieverd. & Oehl, Mycotaxon 106. 347. 2009 [2008].
MycoBank no.: MB 511976

Description: see Oehl et al. (2008).

Type species: *Quatunica erythropus* (Koske & C. Walker) F.A. Souza, Sieverd. & Oehl, Mycotaxon 106. 348. 2009 [2008].

MycoBank no.: MB 511977

Basionym: *Gigaspora erythropus* Koske & C. Walker, Mycologia 76: 250. 1984.

MycoBank no.: MB 318956

≡ *Scutellospora erythropus* (Koske & C. Walker) C. Walker & F.E. Sanders, Mycotaxon 27: 181. 1986.

MycoBank no.: MB318960

Intraornatosporaceae B.T. Goto & Oehl, Mycotaxon 119: 121. 2012.
MycoBank no.: MB 563599

Description: see Goto et al. (2012).

Type genus: *Intraornatospora* B.T. Goto, Oehl & G.A. Silva, Mycotaxon 119: 122. 2012.

Other genus: *Paradentiscutata* B.T. Goto, Oehl & G.A. Silva.

Intraornatospora B.T. Goto, Oehl & G.A. Silva, Mycotaxon 119: 122. 2012.
MycoBank no.: MB 563600

Description: see Goto et al. (2012).

Type species: *Intraornatospora intraornata* (B.T. Goto & Oehl) B.T. Goto, Oehl & G.A. Silva, Mycotaxon 119: 122. 2012.

MycoBank no.: MB 563601

Basionym: *Racocetra intraornata* B.T. Goto & Oehl, Mycotaxon 109: 485. 2009.

MycoBank no.: MB 513428

Paradentiscutata B.T. Goto, Oehl & G.A. Silva, Mycotaxon 119: 122. 2012.
MycoBank no.: MB 563602

Description: see Goto et al. (2012).

Type species: *Paradentiscutata bahiana* Oehl, Magna, B.T. Goto & G.A. Silva, Mycotaxon 119: 123. 2012.

MycoBank no.: MB 563603

Pacisporales Oehl, Sieverd. & G.A. Silva, ord. nov.
MycoBank no.: MB 860128

Description: Spores formed singly in soils or rarely in roots, terminally on SH, with two spore walls (OW & IW), while only the outer wall is continuous with the mycelia and SH, but the inner wall forms de novo during spore differentiation. Spore pore usually is closed by a septum at the spore base arising from the inner wall layers of the outer spore wall. IW functions as germinal wall; germ tubes emerge from the germinal wall directly or from the center of a multiple-lobed germination structure consisting of several lobes positioned around this center. Forming typical vesicular-arbuscular mycorrhizal fungi, whose fungal structures in the roots

stain intensively blue with trypan blue, and additionally extraradical auxiliary cells in the rhizosphere of mycorrhizal roots, rarely intraradically, as also known for Gigasporales.

Type family: **Pacisporaceae** C. Walker, Błaszk., A. Schüssler & Schwarzott, Mycological Research 108 (9): 981. 2004.
MycoBank no.: MB 82126

Emended description: see above for Pacisporales.

Type genus: *Pacispora* Sieverd. & Oehl.

Pacispora Sieverd. & Oehl, J. Appl. Bot. 78: 74. 2004.
MycoBank no.: MB 28842

Emended description: see above for Pacisporales.

Type species: *Pacispora scintillans* (S.L. Rose & Trappe) Sieverd. & Oehl ex C. Walker, Vestberg & A. Schüssler, Mycological Research 111 (3): 254. 2007.

MycoBank no.: MB 510506

Basionym: *Glomus scintillans* S.L. Rose & Trappe, Mycotaxon 10 (2): 417. 1980.

MycoBank no.: MB 113776

Discussion

Our results show seven major clades at order level in Glomeromycetes, sensu Oehl et al. (2011a), with full support in all analyses (Fig. 1). Tedersoo et al. (2024) and Silva et al. (2024) have obtained the same seven clades, fully supported for this class. Although the topology of our tree, considering the relationships among the orders, is relatively similar to that obtained by Silva et al. (2024), it is different from the tree obtained by Tedersoo et al. (2024). In Tedersoo et al. (2024), Sacculosporales is near to Pacisporales, but with low IQ-TREE support (88.1/78 %), while in our tree Sacculosporales is a sister group to Diversisporales (0.95 for BI and 90 % for ML), and Pacisporales is near to Gigasporales, but with no support. In our tree, Acaulosporales is a sister group to a clade with Sacculosporales and Diversisporales together (1.00 for BI and 71 % for ML), while the tree generated by Tedersoo et al. (2024) showed Acaulosporales as a sister group of Diversisporales (44.4/99 %). Considering the topology variation, in order level, found between different trees, and considering the low or no support to place the order Pacisporales with other clades, we are confident that it is not possible to put Pacisporales together with Gigasporales or Sacculosporales, nor Diversisporales together with Sacculosporales or Acaulosporales in a same taxon, respectively. Thus, it was necessary to describe three new orders.

Silva et al. (2024) described four new families in Glomerales. These authors suggested that future studies could describe new families in this order, citing specifically *Halonatospora*, *Oehlia*, and *Rhizoglomus* as three genera types for future new families. The nine family clades in Glomerales, here generated, are strongly supported (>0.99 for BI and >90 % for ML), except for ML analysis of Kamienskiaceae and Sclerocystaceae (74 and 78 %, respectively), justifying the erection of four new families. In our tree, Halonatosporaceae is close to Rhizoglomeraceae and Sclerocystaceae, and Oehliaceae is near to the clade composed by these three families. The studies from Tedersoo et al. (2024) show Halonatosporaceae near to Kamienskiaceae and Oehliaceae near to Sclerocystaceae and Rhizoglomeraceae, but with no good support to maintain these groups in any of these families. Our tree and that from Tedersoo et al. (2024) give support to erect Funneliformaceae in a new family. The data by Tedersoo et al. (2024) had no support to erect Rhizoglomeraceae, however our phylogenetic tree well separates this family. Considering our analysis and the morphology of the different groups, we are convinced that Rhizoglomeraceae represent a strong new family in Glomerales.

Entrophosporales present a single family with three genera (Silva et al. 2025), however there was no ML support in our tree to place *Albahypha drummondi* and *A. furrazolae* together, and the BI support, to group these species, was low (0.75). Acaulosporales, Pacisporales, and Sacculosporales possess monogeneric families. In relation to Gigasporales, the five families and eleven genera represented in our tree are well supported, and our findings are similar to that obtained by Silva et al. (2024), except for the ML analysis for Dentiscutataceae and *Fuscutata* (0.96 for BI and 65 % for ML).

Morphologically, no new data are created in this study but summarized from the most significant advances and literature in the past (Table 1). Several major clades have been well known as clearly distinct, such as the Acaulosporaceae, Sacculosporaceae and Pacisporaceae (e.g. Morton & Benny 1990, Oehl et al. 2011c, Błaszkowski 2012, Willis et al. 2016). Based on the advances in the phylogenetic analyses, these morphological clades are here separating on the order level.

The newly revised family Diversisporaceae comprise now solely the diversisporoid species sensu

stricto, and the recently recombined species, formerly attributed to *Otospora* and *Tricispora* (Hyde et al. 2024, Tedersoo et al. 2024, Błaszkowski et al. 2025b). In the new family Corymbiglomeraceae, besides the type genus *Corymbiglomus*, also *Paracorymbiglomus*, *Desertispora*, *Redeckera* and *Sieverdingia* are included. However, the phylogenetic and morphological data bases of these taxa are still scarce, so that a clearer separation of these AMF genera hitherto is not yet feasible. Concerning morphology, *Redeckera* is the next genus, which should be separated on the family level, as soon as more species are analyzed on the molecular-biological level. This clade of fungi seems to be as clearly separable morphologically, as for instance Acaulosporaceae, Gigasporaceae and Rhizoglomeraceae (e.g. Morton & Benny 1990, Oehl et al. 2011a, Sieverding et al. 2015).

Funneliformis, *Halonatospora*, *Oehlia* and *Rhizoglomus* are morphologically well-defined taxa, which were now presenting also taxa on the family level. The earlier described families are also separating readily (Silva et al. 2024), which recently was also used as a useful base to separate ecological groups within Glomerales (Buil et al. 2025). In Glomerales, one well-known family is still analyzed on a low level. This is Sclerocystaceae, in which only for a few species molecular analyses have been available. In this family, we expect a clearer separation on the genus level, when more sequences are available, for instance for early described species like *S. clavispora*, *S. rubiformis* and *S. taiwanensis* (e.g. Schenck & Perez 1990; Almeida & Schenck 1990; Wu 1993a, b). Interestingly, species of Sclerocystaceae were in earlier times recombined with the genus *Glomus* (Redecker et al. 2000).

In conclusion, the present revision of the Glomeromycetes is, to our opinion, a strong step forward in the taxonomy and phylogeny of the Glomeromycetes. There is now a strong correlation between phylogenetic and morphological clades, much more than ever before. It will be interesting, how this fungal class and the whole phylum will be further explored on the taxonomic, but also on the ecological level. Glomeromycetes now comprise seven orders, twenty families and fifty genera. The whole phylum, consisting of the three classes Glomeromycetes, Archaeosporomycetes and Paraglomeromycetes, now include nine orders, twenty-six families and about sixty genera (Tab. 3). The most ancestral clades have not anymore been included in Glomeromycetes since a while, also based on concomitant phylogenetic and morphological data. These ancestral clades of AM fungi in Archaeosporomycetes and Paraglomeromycetes currently remain the larger mystery, since hyphae and spores are often very short-lived and also the intraradical structures are not easily to detect in nature or even after staining procedures. However, when thinking about small-spored, hyaline and short-lived spores of *Viscospora*, *Kamienskia* or *Dominikia* (Walker et al. 1995, Błaszkowski et al. 2015), or even easily visible sporocarps of Sclerocystaceae (Berkeley & Broome 1873, Wu & Chen 1987, Goto et al. 2016) or big spores in Dentiscutataceae (Spain & Miranda 1996; de Souza et al. 2005) and Gigasporaceae (e.g., Manawasinghe et al. 2025), it becomes also clear again that much research work has still to be done even in Glomeromycetes.

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Tab. S1 Update on selected key morphological characters of the genera within the order Glomerales, as extended to Silva et al. (2024).

Family	Genus (spore sizes)	Sporocarp (sizes), cluster or single spore formation	Spores Solely un-pigmented to greyish or yellowish white	Pore closure - Introverted wall thickening at spore base	Pore closure - Introverted wall thickening in SH	Pore closure by a single septum at or close to spore base	Pore closure by multiple septa in SH	Dominating shape of subtending hyphae (SH)
Glomeraceae	*Glomus* (30–500 µm)	Sporocarps (80–900 µm), clusters or single spores	No	Yes	Species-specific	Yes	No	Cylindrical to variable
	Simiglomus (50–150 µm)	Clusters and single spores	No	No	No	No	Yes	Cylindrical
	Complexispora (60–230 µm)	Single spores	No	Yes	No	Yes	No	Cylindrical
	Sclerocarpum (35–65 µm)	Solely sporocarps (120–)950 × 1600(−2000)	Yes	Yes	No	Yes	No	Funnel-shaped, pronounced introverted thickening at the spore base
Funneliformaceae	*Funneliformis* (90–320 µm)	Sporocarps (150–700 µm) and single spores	No	No	No	Generally with wide pores and one large septum	Generally with wide pores and one large septum	Funnel-shaped
Septoglomeraceae	*Septoglomus* (50–200(−330) µm)	Clusters and single spores	No	No	No	Yes	Species-specific	Constricted
	Melanoglomus (250–400 µm)	Clusters and single spores	No	No	No	Yes	Species-specific	Constricted to cylindrical
	Funneliglomus (90–150 µm)	Single spores	No	No	No	Yes	Species-specific	Funnel-shaped
	Blaszkowskia (20–120 µm)	Clusters and single spores	No	No	No	Yes	Yes	Funnel-shaped
	Viscospora (44–97 × 46–94 µm)	Clusters and single spores	Yes	Slightly	Slightly	Yes	Yes	Cylindrical
	Microviscospora (30–56 × 25–54 µm)	Clusters and single spores	Yes	Slightly	Slightly	Yes	Yes	Cylindrical
Sclerocystaceae	*Sclerocystis* (50–350 × 30–150 µm)	Mainly sporocarps (120–800 µm), regular radial organization	No	Yes	No	Yes	No	Funnel-shaped & introverted wall-thickening
	Silvaspora (60–120 µm)	Single spores	No	Yes	No	Yes	No	Funnel-shaped

Family	Genus	Sporocarp, cluster or single spore formation	Solely un-pigmented to greyish or yellowish white spores	Pore closure - Introverted wall thickening at spore base	Pore closure - Introverted wall thickening in subtending hyphae	Pore closure by a single septum at or close to spore base	Pore closure by multiple septa at spore base	Dominating shape of the subtending hyphae
	Parvocarpum (50–120 µm)	Mainly sporocarps (150–300 µm), irregular radial organization	No	Yes	No	Yes	No	Cylindrical
Rhizoglomeraceae	*Rhizoglomus* (20–)30–450 × (15)–30–450 µm)	Formed frequently in roots, Sporocarps (150–750 × 120–600 µm), clusters and single spores	No	No	No	No	Yes	Cylindrical
Oehliaceae	*Oehlia* (50–130 µm)	Formed frequently in roots; Sporocarps (120–700 × 100–150 µm), clusters and single spores	Yes	Yes	No	Yes	No	Cylindrical
Halonatosporaceae	*Halonatospora* (100–200 µm)	Clusters and single spores	No	Yes	No	Yes	Yes	Cylindrical
Dominikiaceae	*Dominikia* (35-55 µm)	Sporocarps and single spores	No	Yes/No	Species-specific	Yes	Species-specific	Cylindrical
	Macrodominikia (60-100 µm)	Loose sporocarps, clusters and single spores	No	Yes	Yes	Yes	No	Cylindrical, Fine, long and irregular pore channel
	Microdominikia (11-33 µm)	Sporocarps and single spores	Yes	No	No	Yes	No	Cylindrical
	Delicatispora (20-45 µm)	Loose, small sporocarps (up to 25 spores), clusters and single spores	Yes	No	No	Yes, but not regularly	No	Cylindrical to funnel-shaped
	Nanoglomus (20-45 µm)	Sporocarps and single spores	Yes	No	No	Yes	No	Funnel-shaped
	Orientoglomus (40-)60-100 µm)	Clusters and single spores	No	Slightly	Slightly	Yes	No	Cylindrical

Family	Genus	Sporocarp, cluster or single spore formation	Solely un-pigmented to greyish or yellowish white spores	Pore closure - Introverted wall thickening at spore base	Pore closure - Introverted wall thickening in subtending hyphae	Pore closure by a single septum at or close to spore base	Pore closure by multiple septa at spore base	Dominating shape of the subtending hyphae
Kamienskiaceae	*Kamienskia* (35-55 µm)	Loose, fragile sporocarps to fragile clusters	Yes	No	No	No	No	Cylindrical
	Micro-kamienskia (15-33 µm)	Loose, fragile sporocarps to fragile clusters	Yes	No	No	No	No	Cylindrical
	Epigeocarpum (30-50 µm)	Described from 1 sporocarp 1600-1700 µm	Yes	Yes	No	Yes	No	Cylindrical, fine pore channel

An identification key for all 26 genera in the order Glomerales has been presented in Goto et al. (2025).

Tab. S2 GenBank accession numbers for the sequences used in the present study.

Species name	ID	Country	GenBank accession numbers (nrDNA)
Acaulospora alpina	sample 1518	UK	FR681930
Acaulospora aspera	3	Peru	MN081000
Acaulospora baetica	JP212	Spain	LN811002
Acaulospora brasiliensis	Att1211-0	UK	FN825909
Acaulospora cavernata	BEG33	UK	FM876790
Acaulospora colombiana	Att1476-8	Colombia	FR750063
Acaulospora delicata	G11_2	Not available	JF439203
Acaulospora dilatata	10	Peru	OK356202
Acaulospora entreriana	Att1541-1	Argentina	FR750169
Acaulospora excavata	12	Peru	OK356206
Acaulospora fanjing	P1	China	MW723429
Acaulospora flava	1	Peru	MZ191509
Acaulospora flavopapillosa	1	Peru	OK360960
Acaulospora foveata	FO-fov	Mexico	LN736022
Acaulospora fragilissima	5	Peru	MZ191554
Acaulospora gedanensis	Ag4	Poland	OR669016
Acaulospora herrerae	3	Peru	MZ191547
Acaulospora ignota	268-3	Brazil	KP191468
Acaulospora jejuensis	JJ18046	South Korea	OR475792
Acaulospora kentinensis	Att1499-9	Taiwan	FM876828
Acaulospora koskei	102-10	Not available	KP191476
Acaulospora lacunosa	TPX6	Portugal	KP756584
Acaulospora laevis	BEG13	New Zealand	FN547508
Acaulospora mellea	SR2	Portugal	KP756454
Acaulospora mendoncae	p054_002	Brazil	OK392601
Acaulospora minuta	FO378	Benin	FR869690
Acaulospora nivalis	DI2660	Switzerland	HE603642
Acaulospora punctata	70-2	Switzerland	FR846382
Acaulospora pustulata	JP-2012b	Spain	HF567941
Acaulospora rugosa	DRIVE-L-7	Norway	LN881565
Acaulospora saccata	ac3	New Caledonia - France	KY362430
Acaulospora scrobiculata	BR224	Brazil	FR692352

Acaulospora sieverdingii	Att869-3	Australia	FM876793
Acaulospora spinosa	Att165-9	USA	FR750156
Acaulospora spinosissima	FO438	Benin	HG422733
Acaulospora tortuosa	JP-2012a	Spain	HF567933
Acaulospora viridis	CP 100	Spain	HG421736
Albahyphae drummondii	ED_spore_1	China	PP955182
Albahyphae drummondii	ED_spore_2	China	PP955183
Albahyphae furrazolae	446	Poland	ON950381
Albahyphae furrazolae	E50	Poland	ON950383
Alborhynchus walkeri	162-22	Not available	KP191490
Alborhynchus walkeri	162-41	Not available	KP191492
Alborhynchus walkeri	USK_C8	Poland	MH590062
Blaszkowskia deserticola	BEG73	USA	JQ048837
Blaszkowskia deserticola	BEG73	USA	JQ048840
Blaszkowskia deserticola	BEG73	USA	JQ048858
Blaszkowskia deserticola	BEG73	USA	JQ048859
Blaszkowskia deserticola	BEG73	USA	JQ048860
Blaszkowskia deserticola	BEG73	USA	JQ048838
Cetraspora armeniaca	Ce-7	Poland	MG459216
Cetraspora huaxica	chx1	China	OP004057
Cetraspora gilmorei	Att590-16	USA	FN547611
Cetraspora nodosa	BEG4	UK	FM876835
Cetraspora pellucida	MN408A	USA	OQ975184
Complexispora mediterranea	461s2s3	Greece	OQ437305
Complexispora multirrostrata	455s1	Greece	OQ437298
Complexispora multirrostrata	455s5	Greece	OQ437301
Corymbiglomus corymbiforme	100-1	Poland	KF060294
Corymbiglomus corymbiforme	100-2	Poland	KF060295
Corymbiglomus corymbiforme	100-3	Poland	KF060296
Corymbiglomus corymbiforme	100-4	Poland	KF060297
Corymbiglomus corymbiforme	100-5	Poland	KF060298
Desertispora omanana	F69	Oman	KF154768
Desertispora omanana	D69	Oman	KF154769

Desertispora omanana	D73	Oman	KF154770
Desertispora omanana	D73	Oman	KF154771
Desertispora omanana	Do-F69-18	Oman	MG459210
Diversispora aestuarii	Dae_407_8	Poland	OL684643
Diversispora alba	1	Peru	OP195880
Diversispora arenaria	111-2-9	Poland	KJ850189
Diversispora aurantiua	Att1296-0	Israel	FN547656
Diversispora bareae	Dol Z2	Spain	FR865445
Diversispora celata	Att1278-2	Switzerland	AM713403
Diversispora cerifera	TC2	New Caledonia - France	OR352360
Diversispora clara	JP-2011	Spain	FR873631
Diversispora densissima	6	Poland	MT724385
Diversispora eburnea	AZ420A	USA	AM713416
Diversispora epigaea	Att475-22	USA	FR686939
Diversispora gibbosa	109-1-21	Poland	KJ850201
Diversispora insculpta	142-1-51	Poland	KJ850194
Diversispora jakucsiae	238-2-5	Hungary	KJ850185
Diversispora marina	16	Poland	MT725497
Diversispora nevadensis	SN Pl1	Spain	FR865446
Diversispora peloponnesiaca	dp9	Greece	MN306208
Diversispora sabulosa	336-4	Lithuania	MG459215
Diversispora slowinskiensis	gl14a4	Poland	KT444719
Diversispora peridiata	5	Poland	KT444715
Diversispora sporocarpia	Ds4	Poland	MK036787
Diversispora spurca	Att246-18	USA	FN547644
Diversispora succinacia	TC4	New Caledonia - France	OR356235
Diversispora trimurales	131-1-11	Not available	KJ850198
Diversispora valentina	P11_Con	Spain	MT985516
Diversispora varaderana	1	Cuba	KT444708
Diversispora versiformis	BEG47	USA	FN547677
Diversispora vistulana	Dv3cor	Poland	OR669025
Dominikia achra	146-1	Poland	KJ564159
Dominikia aurea	Da-33	Not available	KM056665

Dominikia bernensis	FO310	Switzerland	HG938301
Dominikia bonfanteae	Db_33	Poland	MW232905
Dominikia difficilevidera	279-13	Poland	KR105646
Dominikia disticha	237-1	South Africa	KJ564150
Dominikia duoreactiva	271-9	Egypt	KR105642
Dominikia gansuensis	DG_spore_3	China	MZ448291
Dominikia glomerocarpica	Dg_5	Brazil	MW507150
Dominikia paraminuta	211-1	Eritrea	KJ564169
Dominikia iranica	187-2-4	Iran	KJ564154
Dominikia lithuanica	331-8	Lithuania	KX758120
Dominikia minuta	137-2	Poland	KJ564163
Entrophospora argentinensis	clone 1	Argentina	MT722021
Entrophospora candida	NC172	USA	ON950368
Entrophospora claroidea	Att1063-4	Switzerland	FR750059
Entrophospora etunicata	Att1505-8	USA	FN547631
Entrophospora glacialis	442	Sweden	ON950374
Entrophospora hanlinii	251-101	Cuba	KP191482
Entrophospora infrequens	419	Spain	ON950365
Entrophospora lamellosa	ON393	Canada	LT963496
Entrophospora lutea	418	Canada	ON950371
Epigeocarpum crypticum	Ec_6	Brazil	MW507156
Epigeocarpum crypticum	Ec_5	Brazil	MW507157
Epigeocarpum japonicum	441s1	Japan	OQ437311
Funneliformis caledonius	BEG20	UK	FN547495
Funneliformis coronatus	BEG28	Italy	FM876795
Funneliformis mosseae	BEG12	UK	FR750030
Funneliformis mosseae	BEG12	UK	FR750031
Funneliformis pilosus	8P	Spain	MT376719
Funneliglomus sanmartinense	4a	Peru	MK348938
Funneliglomus sanmartinense	4b	Peru	MK348939
Funneliglomus sanmartinense	4c	Peru	MK348940
Fuscutata heterogama	Att334-16	USA	FM876837
Fuscutata savannicola	Att1455-2	Ecuador	HE962449

Fuscutata savannicola	Att1455-2	Ecuador	HE962463
Gigaspora gigantea	PA125	USA	OQ975223
Gigaspora margarita	BEG34	New Zealand	FR750039
Gigaspora polymorpha	HMAS255790	China	OM321685
Gigaspora rosea	DAOM194757	USA	FN547579
Glomus atlanticum	Ga_10	Portugal	MW232911
Glomus bareae	Gb6	Poland	MH560607
Glomus chinense	GS_spore_1	China	MZ448297
Glomus ibericum	P26	Spain	MT376716
Glomus macrocarpum	Att1495-0	UK	FR750368
Glomus mongioiense	422c6	Italy	PP639280
Glomus rugosae	Hel	Poland	PP639267
Glomus tetrastratosum	276-22	Poland	KM056655
Halonatospora pansihalos	Hp2	Poland	MH560600
Halonatospora pansihalos	Hp4	Poland	MH560601
Halonatospora pansihalos	Hp7	Poland	MH560602
Halonatospora pansihalos	Hp9	Poland	MH560603
Halonatospora pansihalos	Hp6	Poland	MH560604
Kamienskia bistrata	205-1	Poland	KJ564136
Kamienskia bistrata	205-1	Poland	KJ564137
Kamienskia bistrata	205-1	Poland	KJ564138
Macrodominikia compressa	FO352	Switzerland	HG798897
Macrodominikia compressa	FO352	Switzerland	HG798898
Macrodominikia compressa	FO352	Switzerland	HG798899
Microdominikia litorea	Dl-10	Greece	MG710517
Microdominikia litorea	Dl-6	Greece	MG710518
Microdominikia litorea	Dl-8	Greece	MG710519
Microkamienskia divaricata	240-7	South Africa	KX758124
Microkamienskia perpusilla	169-3	Italy	KJ564140
Microkamienskia peruviana	MACG4	Peru	OM210010
Microviscospora peruviscosa	5	Peru	OQ396750
Microviscospora peruviscosa	6	Peru	OQ396751
Microviscospora peruviscosa	7	Peru	OQ396752

Nanoglomus plukenetiae	clone 1	Peru	MK875630
Nanoglomus plukenetiae	clone 2	Peru	MK875631
Nanoglomus plukenetiae	clone 3	Peru	MK875632
Ohelia diaphana	DAOM745424	Canada	MG836663
Ohelia diaphana	DAOM745424	Canada	MG836664
Ohelia diaphana	DAOM227022	Canada	MG836665
Ohelia diaphana	DAOM227022	Canada	MG836666
Ohelia diaphana	DAOM227022	Canada	MG836667
Orientoglomus emiratium	344-3	United Arab Emirates	KY555051
Orientoglomus emiratium	344-4	United Arab Emirates	KY555052
Orientoglomus emiratium	344-5	United Arab Emirates	KY555053
Paracorymbiglomus globiferum	11	Brazil	MN644487
Paracorymbiglomus globiferum	12	Brazil	MN644488
Paracorymbiglomus globiferum	16	Brazil	MN644489
Pacispora scintillans	W4545	Germany	FM876831
Pacispora scintillans	W4545	Germany	FM876832
Pacispora sp.	BP2	Chile	PP422377
Pacispora sp.	BP4	Chile	PP422378
Pacispora sp.	BP6	Chile	PP422379
Pacispora sp.	87	Not available	JN685298
Pacispora sp.	88	Not available	JN685299
Paraglomus brasilianum	Att260-8	Brazil	FR750046
Paraglomus brasilianum	Att260-8	Brazil	FR750047
Racocetra crispa	CMPC739.12	Brazil	KX529099
Racocetar fulgida	W2993	Argentina	FR750141
Racocetra weresubiae	W2988	Argentina	FR750134
Redeckera megalocarpa	CL/Guad05-051	Guadeloupe - France	HG518627
Redeckera megalocarpa	CL/Guad05-051	Guadeloupe - France	HG518628
Redeckera megalocarpa	CL/Guad05-051	Guadeloupe - France	HG518629
Rhizoglomus arabicum	F84	Oman	KF154765
Rhizoglomus cacao	ZL-2022b	Peru	OM109241
Rhizoglomus clarum	Att894-7	Iceland	FM865543
Rhizoglomus dalpeae	rd10	Benin	MN130951

Rhizoglomus dunense	232-5	Greece	KY555054
Rhizoglomus fasciculatum	MUCL46100	Not available	FR750073
Rhizoglomus intraradices	FL208	USA	FR750372
Rhizoglomus invermaium	Att1646	Ecuador	HG969392
Rhizoglomus irregulare	Att857-12	Australia	FR750190
Rhizoglomus maiae	rm6	Brazil	MN130957
Rhizoglomus melanum	Dovre 6K	Norway	HG964397
Rhizoglomus proliferum	DAOM226389	Guadeloupe - France	FM992400
Rhizoglomus silesianum	rs4	Poland	MN130960
Rhizoglomus variabile	Rv6	Peru	MN384875
Rhizoglomus venetianum	AT-2018	Italy	LS974595
Rhizoglomus vesiculiferum	Rv_10	Lithuania	MG836659
Sacculospora baltica	E101-10	Poland	KX355818
Sacculospora baltica	E101-6	Poland	KX355819
Sacculospora baltica	E101-7	Poland	KX355820
Sacculospora baltica	E101-10	Poland	KX355821
Sacculospora baltica	SN Pa1	Spain	FR865449
Sacculospora baltica	SN Pa1	Spain	FR865450
Sacculospora baltica	SN Pa1	Spain	FR865451
Sacculospora felinovii	Gf1	India	KX345938
Sacculospora felinovii	Gf10	India	KX345939
Sacculospora felinovii	Gf2	India	KX345940
Sacculospora felinovii	Gf3	India	KX345941
Sacculospora felinovii	Gf5	India	KX345942
Sacculospora felinovii	Gf6	India	KX345943
Sclerocarpum amazonicum	Sa2	Brazil	MK036781
Sclerocarpum amazonicum	Sa5	Brazil	MK036782
Sclerocarpum amazonicum	Sa6	Brazil	MK036783
Sclerocystis sinuosa	MD126	USA	OQ975115
Sclerocystis sinuosa	MD126	USA	OR103652
Sclerocystis sinuosa	MD126	USA	OR104894
Scutellospora alterata	S.Alt	Brazil	HF935020
Scutellospora calospora	VRU21	Iran	OP455124

Scutellospora graeca	Sg8	Greece	OR669031
Scutellospora intraundulata	Su8	Greece	OR669036
Scutellospora spinosissima	Att664-1	Venezuela	FR750150
Septoglomus africanum	207-5	Not available	KF060307
Septoglomus altomontanum	Palenz_SN_33	Spain	HF674438
Septoglomus constrictum	08_48_17	Not available	JF439176
Septoglomus furcatum	254-4	Brazil	KF060308
Septoglomus fuscum	220-2	South Africa	KF060314
Septoglomus jasnowskae	206-2	Greece/Spain	KF060320
Septoglomus mediterraneum	P21	Spain	MT376721
Septoglomus mexicanum	CS01-16	Mexico	MK570915
Septoglomus nakheelum	G90	Oman	KF154760
Septoglomus nigrum	SAF86	Switzerland	LR723644
Septoglomus turnauae	243-1	Italy	KF060325
Septoglomus xanthium	6	Greece	KF154775
Sieverdingia tortuosa	G14-1	Not available	JF439094
Sieverdingia tortuosa	G14-8	Not available	JF439095
Sieverdingia tortuosa	G14-2	Not available	JF439096
Silvaspora neocaledonica	rh1	New Caledonia - France	KY362436
Silvaspora neocaledonica	rh2	New Caledonia - France	KY362437
Silvaspora neocaledonica	rh3	New Caledonia - France	KY362438
Viscospora viscosa	BEG27	Italy	HF548861
Viscospora viscosa	BEG27	Italy	HF548862
Viscospora viscosa	BEG27	Italy	HF548863