

AM fungi – suitable taxa for soil ecotoxicological tests & risk assessment of plant protection products (PPP) and their active substances (AS)

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Objectives

We aimed to summarize advantages and disadvantages of specific vesicular-arbuscular (VAM) & arbuscular mycorrhizal (AM) fungi of the Glomeromycota for use in laboratory tests with PPP or AS. Our criteria is based on fungal structures, life cycles, cultivability and significance as non-target organisms.

Materials and Methods

Morphological structures of VAM and AM fungi were analyzed from species maintained in mono-species pot cultures on AM plants, mainly *Sorghum* sp., *Plantago lanceolata* and *Hieracium pilosella*. The principal results were obtained from our studies in Switzerland, Spain, Perú, Benin (IITA), Colombia (CIAT), and Germany over the last 20-40 years (Table 1).

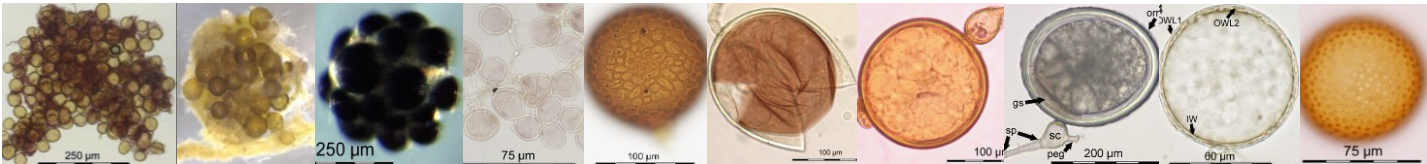


Fig. 1 Spore variety of AM fungal species belonging to ten of the twenty-eight AMF families currently attributed to the phylum Glomeromycota.

Table 1 Major characteristics of the current 12 Glomeromycota orders

AM fungal orders	Mycorrhizal formation & staining	Spore sizes (µm)	Hyphal diameters (µm)	Velocity of spore formation (months)	General Cultivability on plants
Glomerales	VAM & blue	20-450	4-12	2-24	Good
Entrophosporales	VAM & blue	50-200	4-12	2-12	Good
Diversisporales	VAM & blue	35-150	4-12	4-24	Good
Acaulosporales	VAM & blue	50-500	3-12	4-10	Species-specific
Sacculosporales	VAM & blue	90-200	4-12	6-24	Difficult
Pacisporales	VAM & blue	40-300	4-12	4-10?	Difficult
Gigasporales	AM & blue	70-1060	4-20	4-10	Species-specific
Ambisporales	VAM & pale blue	70-400	4-25	4-10	Species-specific
Archaeosporales	AM & faintly (to pale blue)	30-130	4-7	4-6	Good
Polonosporales	Unknown	60-150	4-10	4-10?	Difficult
Geosiphonales	Symbiosis with cyanobacteria	180-270	2-8	4-6	With moss and <i>Nostoc</i>
Paraglomerales	AM & faintly	50-220	4-12	5-12	Species-specific

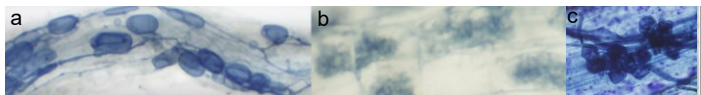


Fig. 2 Glomerales species form a) Vesicular b) Arbuscular Mycorrhiza (VAM), and all structures typically stain blue to dark blue in trypan blue or ink, while c) Gigasporales form AM, and instead of intraradical vesicles, c) extraradical auxiliary cells in the rhizosphere around the roots.



Fig. 3 Ambisporales species form Vesicular (a) Arbuscular (b) Mycorrhiza (VAM), but the structures stain only light, pale blue. c) Mycorrhizal structures of Archaeosporales do not or only faintly stain in trypan blue or ink.

Conclusions I

Just a few of the currently described 350 AM fungi can be considered in such tests which need to be identified to define the most suitable for such tests. AM fungi of seven orders form typical VAM, whose fungal structures stain blue to dark blue in conventional staining reagents. Ambisporales also form VAM, whose fungal structures stain significantly blue, but pale. Gigasporales form extraradical auxiliary cells instead of extraradical vesicles. Species of the more ancestral orders are not suitable for laboratory tests on AM colonisation, as their structures stain only insignificantly.

References

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Introduction

Glomeromycota comprises VAM & AM fungi (= AM fungi), which occur in all agricultural soils worldwide with varying abundance and richness depending largely on climate, soil, crop/vegetation and land use intensity. They are of major significance for ecosystems, as they improve plant growth, suppress pathogens and enhance soil fertility & stability and water infiltration. AM fungi comprise > 350 species divided into 3 classes, 12 orders, 28 families and > 70 genera. Some PPP's are known to have negative effects, while others can have positive or neutral effects on the development and growth of VAM fungi. We ask, which taxa are most appropriate for testing dose-response ecotoxicological laboratory experiments with PPP or AS.

Results

Different VAM/AM fungal taxa have specific life cycles, mycorrhizal structures, hyphal networks and spore formation characteristics (Tab. 1-2, Figs. 1-3). The spores, or 'fruit-bodies', are produced within weeks, only after months or years, or not at all. They are seasonal or not, formed singly, in clusters or huge agglomerations, in soils or preferably in plant roots, either perfectly mature, or as early aborted spores without any germination capacity or function. Estimations can be made about the beneficial performance of well-studied AM fungal taxa, or about their sensitivity in different soil-management or cropping systems and agricultural land use intensities. Glomeromycetes species have increased beneficial potentials, with respect to plant growth promotion, plant health, soil structure formation or soil health. Some species are commercially available, for bio-remediation, as bio-pesticides or bio-fertilizers. Genera with most positive ecological value, or highest benefits for plants or soils either belong to Glomerales, Entrophosporales, Diversisporales, Acaulosporales or Gigasporales. In contrast, Archaeosporales or Paraglomerales spp. rarely showed positive effects on plants or soils, while Pacisporales and Sacculosporales spp. have rarely been cultured. However, it is a black box, which of these taxa are most sensitive to herbicides, insecticides or even fungicides.

Table 2 Further ecological characteristics of the AMF orders most suitable for ecotoxicological laboratory tests

AM fungal orders	Seasonality of growth and sporulation	Spore formation on	Most beneficial AMF genera	Most beneficial AMF species
Glomerales	Rare	Hyphae (H)	<i>Rhizoglossus</i> , <i>Funnelliformis</i>	<i>Rhizoglossus</i> sp.
Entrophosporales	Rare	Hyphae	<i>Entrophospora</i>	<i>E. etunicata</i>
Diversisporales	Rare	Hyphae	<i>Diversispora</i>	<i>D. celata</i>
Acaulosporales	Yes	Sacculi necks (S)	<i>Acaulospora</i>	Species-specific
Gigasporales	Yes	Bulbous cells (B)	<i>Gigaspora</i> , <i>Fuscutata</i> , <i>Scutellospora</i>	Species-specific
Ambisporales	Yes	H & S, bi-morph	<i>Ambispora</i> , <i>Appendiculispora</i>	Not known

Conclusions II

Species of some orders are difficult or do not cultivate on plants in the greenhouse. Several orders have a strongly seasonal life cycle, which might also hamper the cultivability during timely exact laboratory tests. Thus, we first recommend species of those orders with a low seasonality, clear mycorrhizal structures, which are significantly stainable, and moreover, are known to be most beneficial for plants and/or soils. These are several *Rhizoglossus* sp., many other Glomerales species, and species such as *D. celata* and *E. etunicata*. For the selection of suitable test fungi not only quickly growing AM fungi should be considered, because their fungal structures can be easily identified and quantified at all development stages, such as some Glomerales species. For temperate conditions, some slower growing species should also be included, such as *Gigaspora margarita*, which are more sensitive species due to a slow initial development phase.