

## A checklist of Egyptian fungi: II. Glomeromycota

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### Abstract

Information about arbuscular mycorrhizal fungi (AMF) was abstracted based on an intensive search of publications, thesis, and preliminary annotated checklists and compilations. By screening all available sources of information, it was possible to report forty-eight taxa belonging to one class (Glomeromycetes), four orders (Archaeosporales, Diversisporales, Glomerales and Paraglomerales) and six families (Acaulosporaceae, Archaeosporaceae, Entrophosporaceae, Gigasporaceae, Glomeraceae and Pacisporaceae). Order Glomerales accommodates the greatest range of species (28 species), the order Archaeosporales and Paraglomerales accommodate the lowest range (one species each).

**Key words** – AM fungi – checklist – Egypt – *Glomus* – mycorrhiza – Saint Katherine

### Introduction

The arbuscular mycorrhizal (AM) symbiosis is the most widespread on earth and is defined as the association between the fungi of the phylum Glomeromycota (Schüßler *et al.* 2001) and most of the terrestrial species ranging from thallophytes to Angiosperms. The morphology of the fungus colonizing plant root tissues is highly elaborated in AM symbiosis. In natural communities, approximately 80% of higher plants were obligately dependent upon fungal associates. AM fungi are believed to be disseminated intercontinentally prior to continental drift, as supported by fossil records of earlier plants (Berch 1986; Stubblefield *et al.* 1987; Remy *et al.* 1994).

Molecular data used by Schüßler *et al.* (2001) to establish the relationships among arbuscular mycorrhizal fungi and between arbuscular mycorrhizal fungi and other fungi. The group of arbuscular mycorrhizal fungi was elevated to the level of phylum Glomeromycota, which was shown to be as distinct from other fungi as the Ascomycota or from the Basidiomycota.

Eight genera include approximately 150 species of arbuscular mycorrhizal fungi have been recognized based mainly on morphological characteristics of asexual spores, although molecular methods and various biochemical parameters are now being used in systematic studies (Schüßler & Walker 2010).

In Egypt, the pioneering work of Mostafa (1938) and Sabet (1939, 1940, 1945) is now accepted as the starting point of research on Egyptian Glomeromycota. These studies were followed by many other investigations concerned mainly with the ecology and physiology of

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endomycorrhizas in Egypt. However, taxonomic studies on Egyptian Glomeromycota are limited, and had never been the sole target of any study until Fares (1986) conducted a survey of AM, followed by Agwa (1990) and Nafady (2011) on mycorrhizas and nodulation in some Egyptian plants.

Checklists are important tools in biodiversity, taxonomy, systematics and conservation (Söderström *et al.* 2007, 2008; Abdel-Azeem and Salem 2013). In spite of that, several important areas lack recent checklists, including Egypt. For Egypt, only very few comprehensive assessments of local fungi have been published (e.g. El-Abyad and Abu-Taleb 1993; El-Abyad 1997; Abdel-Azeem 2010; Moustafa & Abdel-Azeem 2011; Abdel-Azeem and Salem 2013).

Values of relative species richness of different systematic and ecological groups in Egypt compared to values of the same groups worldwide, show that our knowledge of Egyptian Glomeromycota is fragmentary very rare and limited because may be Egyptian mycologists are not interested to study the taxonomy of Glomeromycota and this group overlooked during their studies (Abdel-Azeem 2010).

Following a recent publication on the assessment of total fungi in Egypt (Abdel-Azeem 2010, Abdel-Azeem and Salem 2013), this paper continues to close the gaps in knowledge on the fungal diversity of Egypt by providing a comprehensive checklist of Glomeromycotan fungi.

## Materials and methods

Egypt is located in the extreme Northeast of Africa. The desert covers more than 90 percent of Egypt and can be divided into 4 major regions: The Nile Valley and Delta, Western Desert, Eastern Desert and Sinai Peninsula (Zahran and Willis 2009). The Nile River flows north through Egypt and into the Mediterranean Sea. The country has no effective rainfall except in a narrow band along the northern coast. Consequently, Egypt has only one main source of water supply, the Nile. The climate in Egypt is generally moderate; it is mostly hot or warm during the day, and cool at night. In the coastal regions, daytime average temperatures range between a minimum 14<sup>0</sup>C in winter and maximum 30<sup>0</sup>C in summer. In deserts the temperatures vary considerably, especially in summer; when they may range from 7<sup>0</sup>C at night, to 52 °C during the day (Zahran and Willis 2009).

This study has undergone to report the most arbuscular mycorrhizal fungi in Egypt. So, this checklist has been compiled based on an intensive search of literatures and thesis. Nomenclature and authors names are according to the Schüßler's (<http://www.amf-phylogeny.com/>) and Blaszkowski' (<http://www.zor.zut.edu.pl/Glomeromycota/index.html>) websites which reports a continually updated listing of species, genera, families, and orders in the phylum.

## Data Collection

The species listed here were compiled mainly from the studies of Fares (1986), Mankarios and Abdel-Fattah (1994), Agwa (1990, 2000), Agwa and AbdelFatah (2002), Agwa and Al-Sodani (2003), Abdel-Azeem *et al.* (2007), El-Zayat *et al.* (2007), Abdel-Moneim and Abdel-Azeem (2009), Abdel-Azeem (2010), Mansour (2010), Nafady (2011) and Blaszkowski *et al.* (2008, 2010, 2015).

## Results

Forty-eight species of arbuscular mycorrhizal fungi including 12 genera, 6 families, 4 orders and 1 class are reported in this list of which AM fungi isolated from different localities in Egypt (Table 1).

**Table 1** Taxonomic ranks of Egyptian Glomeromycota

Orders	Families	Genera
Glomerales	Glomeraceae	<i>Dominikia</i> (1)
		<i>Funneliformis</i> (7)
		<i>Glomus</i> (14)
		<i>Rhizophagus</i> (4)
		<i>Sclerocystis</i> (2)
Diversisporales	Gigasporaceae	<i>Gigaspora</i> (2)
		<i>Scutellospora</i> (5)
	Acaulosporaceae	<i>Acaulospora</i> (8)
		<i>Entrophospora</i> (1)
Paraglomerales	Pacisporaceae	<i>Pacispora</i> (2)
	Paraglomeraceae	<i>Paraglomus</i> (1)
Archaeosporales	Archaeosporaceae	<i>Archaeospora</i> (1)

**Checklist of Glomeromycotan fungi reported in Egypt**

The genera and species are given in alphabetical order, with information on the area of Egypt where these the former were reported.

**Kingdom: Fungi****Phylum: Glomeromycota****Class: Glomeromycetes****Order 1: Glomerales****Family 1: Glomeraceae** (Figure 1)

1. *Dominikia duoreactiva* Błaszk., Goralska & Chwat,  
Reported from sand dunes of Giftung Island by Blaszkowski *et al.* (2015).
2. *Funneliformis africanum* (Błaszk. & Kovács) C. Walker & A. Schüßler  
Synonym: *Glomus africanum* Błaszk. & Kovács  
Reported from sand dunes of Giftung Island by Blaszkowski *et al.* (2010).
3. *Funneliformis caledonium* (Nicolson & Gerd.) Walker & Schüßler  
Synonym: *Glomus caledonium* (Nicolson & Gerd.) Trappe & Gerd.  
Reported from three deltaic Governorates by Mankarios and Abdel-Fattah (1994).
4. *Funneliformis coronatum* (Giovann.) C. Walker & Schuessler  
Synonym: *Glomus coronatum* Giovann.  
Reported from Wadi Al-Alaqi protected area by El-Zayat *et al.* (2007), Ismailia Governorate by Baraka *et al.* (2012) and El-Menofia Governorate by Sabet *et al.* (2013).
5. *Funneliformis geosporum* (Nicolson & Gerd.) Walker & Schuessler  
Synonym: *Glomus geosporum* (Nicol. & Gerd.) Walker  
Reported from desert soil of Wadi Al-Assuity Protected area and reclaimed soil of Al-Ghoryb at Assiut Governorate by Nafady (2011).
6. *Funneliformis mosseae* (Nicolson & Gerd.) Walker & Schüßler  
Synonym: *Glomus mosseae* (Nicol. & Gerd.) Gerd. & Trappe

Reported from three deltaic Governorates by Mankarios and Abdel-Fattah (1994), cultivated soil, Bahr El-Baqar at Port Said Governorate by Abdel-Azeem *et al.* (2007), cultivated soil of Al-Wasta, reclaimed soil of Al-Ghoryb and desert soil of Wadi Al-Assuity Protected area at Assiut Governorate by Nafady (2011).

**7. *Funneliformis verruculosum*** (Błaszk.) Walker & Schüßler  
Synonym: *Glomus verruculosum* Błaszk.  
Reported from desert soil at North Sinai by Mansour (2010).

**8. *Funneliformis xanthium*** (Błaszk., Blanke, Renker & Buscot) C. Walker & Schuessler  
Synonym: *Glomus xanthium* Błaszk., Blanke, Renker & Buscot  
Reported from cultivated soil of Al-Wasta at Assiut Governorate by Nafady (2011).

**9. *Glomus aggregatum*** Schenck & Smith emend. Koske  
Reported from desert soil of Wadi Al-Assuity Protected area at Assiut Governorate by Nafady (2011).

**10. *Glomus antarcticum*** Cabello  
Reported from cultivated soil of Al-Wasta at Assiut Governorate by Nafady (2011).

**11. *Glomus caesaris*** Sieverd. & Oehl  
Reported from cultivated soil of Al-Wasta at Assiut Governorate by Nafady (2011).

**12. *Glomus constrictum*** Trappe  
Reported from desert soil of Wadi Al-Assuity Protected area and reclaimed soil of Al-Ghoryb at Assiut Governorate by Nafady (2011).

**13. *Glomus diaphanum*** Morton & Walker  
Reported from Ismailia Governorate by Sabet *et al.* (2013).

**14. *Glomus etunicatum*** Becker & Gerd  
Reported from cultivated soil, Bahr El-Baqar at Port Said Governorate by Abdel-Azeem *et al.* (2007) and at Ismailia Governorate by Baraka *et al.* (2012).

**15. *Glomus fuegianum*** (Speg.) Trappe & Gerd.  
Reported from cultivated soil of Al-Wasta at Assiut Governorate by Nafady (2011).

**16. *Glomus invermaium*** Hall  
Reported from Saint Katherine protected area by Abdel-Moneim and Abdel-Azeem (2009) and from Ismailia Governorate by Baraka *et al.* (2012).

**17. *Glomus lamellosum*** Dalpé, Koske & Tews  
Reported from reclaimed soil of Al-Ghoryb at Assiut Governorate by Nafady (2011).

**18. *Glomus monosporum*** Gerd. & Trappe  
Reported from three deltaic Governorates by Mankarios and Abdel-Fattah (1994) and cultivated soil at Dakhliya Governorate by Abdel-Fattah (2001).

**19. *Glomus sinosum*** (Gerd. & B.K. Bakshi) R.T. Almeida & N.C. Schenck  
Reported from cultivated soil, Bahr El-Baqar at Port Said Governorate by Abdel-Azeem *et al.* (2007).

**20. *Glomus trimurales*** Koske & Halvorson  
Reported from cultivated soil of Al-Wasta and reclaimed soil of Al-Ghoryb at Assiut Governorate by Nafady (2011).

**21. *Glomus versiforme*** (Karsten) Berch  
Reported from cultivated soil of Al-Wasta and reclaimed soil of Al-Ghoryb at Assiut Governorate by Nafady (2011).

**22. *Glomus viscosum*** Nicolson  
Reported from Ismailia Governorate by Baraka *et al.* 2012.

**23. *Rhizophagus clarus*** (Nicolson & Schenck) Walker & Schüßler  
Synonym: *Glomus clarum* Nicolson & Schenck  
Reported from cultivated soil, Bahr El-Baqar cultivated area at Port Said Governorate by Abdel-Azeem *et al.* (2007), desert soil of Wadi Al-Assuity Protected area and cultivated soil of Al-Wasta at Assiut Governorate by Nafady (2011).

**24. *Rhizophagus fasciculatus*** (Thaxt.) Walker & Schüßler  
Synonym: *Glomus fasciculatum* Thaxt.  
Reported from from three deltaic Governorates by Mankarios and Abdel-Fattah (1994), cultivated soil at Dakhlia Governorate by Abdel-Fattah (2001).

**25. *Rhizophagus intraradices*** (Schenck & Sm.) Walker & Schüßler  
Synonym: *Glomus intraradices* Schenck & Sm.  
Reported from cultivated soil of Al-Wasta at Assiut Governorate by Nafady (2011), Ismailia Governorate by Baraka *et al.* 2012 and Behira Governorate by Sabet *et al.* 2013.

**26. *Rhizophagus irregularis*** (Błaszk., Wubet, Renker & Buscot) C. Walker & A. Schüßler  
Synonym: *Glomus irregulare*  
Reported from sand dunes of Giftung Island by Blaszkowski *et al.* (2008).

**27. *Sclerocystis clavispora*** Trappe  
Synonym: *Glomus clavisporum* Almeida & N.C. Schenck )  
Reported from Saint Katherine protected area by Abdel-Moneim and Abdel-Azeem (2009).

**28. *Sclerocystis sinuosa*** Gerd. & Bakshi  
Synonym: *Glomus sinuosum* (Gerd. & Bakshi) Almeida & Schenck  
Reported from cultivated soil, Bahr El-Baqar cultivated area at Port Said Governorate by Abdel-Azeem *et al.* (2007).

**Order 2 : Diversisporales**  
**Family 2: Gigasporaceae**

**29. *Gigaspora gigantean*** (Nicol. & Gerd.) Gerd. & Trappe  
Basionym: *Endogone gigantea* Nicolson & Gerd.  
Reported from cultivated soil of Al-Wasta at Assiut Governorate by Nafady (2011).



**Fig. 1-** Mature spores of *Funneliformis geosporum* (A), *Glomus constrictum* (B), *Funneliformis mosseae* (C) and *Rhizophagus clarus* (D).

**30. *Gigaspora margarita*** Becker & Hall

Reported from cultivated soil, Bahr El-Baqar cultivated area at Port Said Governorate by Abdel-Azeem *et al.* (2007), desert soil of Wadi Al-Assuity Protected area at Assiut Governorate by Nafady (2011).

**31. *Scutellospora armeniaca*** Blaszk.

Synonym: *Cetraspora armeniaca* Oehl, Souza & Sieverd.

Reported from cultivated soil of Al-Wasta at Assiut Governorate by Nafady (2011).

**32. *Scutellospora calospora*** (Nicolson & Gerd.) Walker & Sanders

Synonym: *Gigaspora calospora* Nicolson & Gerd.

Reported from cultivated soil of Al-Wasta at Assiut Governorate by Nafady (2011).

**33. *Scutellospora fulgida*** Koske & Walker  
Reported from cultivated soil of Al-Wasta at Assiut Governorate by Nafady (2011).

**34. *Scutellospora persica*** (Koske & Walker) Walker & Sanders  
Reported from reclaimed soil of Al-Ghoryb at Assiut Governorate by Nafady (2011).

**35. *Scutellospora reticulata*** (Koske, Mill. & Walker) Walker & Sanders  
Reported from cultivated soil of Al-Wasta at Assiut Governorate by Nafady (2011).

**Family 3: Acaulosporaceae** (Figure 2)

**36. *Acaulospora laevis*** Gerd. & Trappe  
Reported from three deltaic Governorates by Mankarios and Abdel-Fattah (1994), cultivated soil of Al-Wasta and reclaimed soil of Al-Ghoryb at Assiut Governorate by Nafady (2011).

**37. *Acaulospora bireticulata*** Rothwell & Trappe  
Reported from desert soil of Wadi Al-Assuity Protected area at Assiut Governorate by Nafady (2011).

**38. *Acaulospora capsicula*** Blaszk.  
Reported from reclaimed soil of Al-Ghoryb and desert soil of Wadi Al-Assuity Protected area at Assiut Governorate by Nafady (2011).

**39. *Acaulospora koskei*** Blaszk.  
Reported from reclaimed soil of Al-Ghoryb at Assiut Governorate by Nafady (2011).

**40. *Acaulospora rehmi*** Sieverd. & Toro  
Reported from cultivated soil of Al-Wasta at Assiut Governorate by Nafady (2011).

**41. *Acaulospora splendid*** Sieverd., Chaverri & Rojas  
Reported from reclaimed soil of Al-Ghoryb and cultivated soil of Al-Wasta at Assiut Governorate by Nafady (2011).

**42. *Acaulospora thomii*** Blaszk.  
Reported from reclaimed soil of Al-Ghoryb and cultivated soil of Al-Wasta at Assiut Governorate by Nafady (2011).

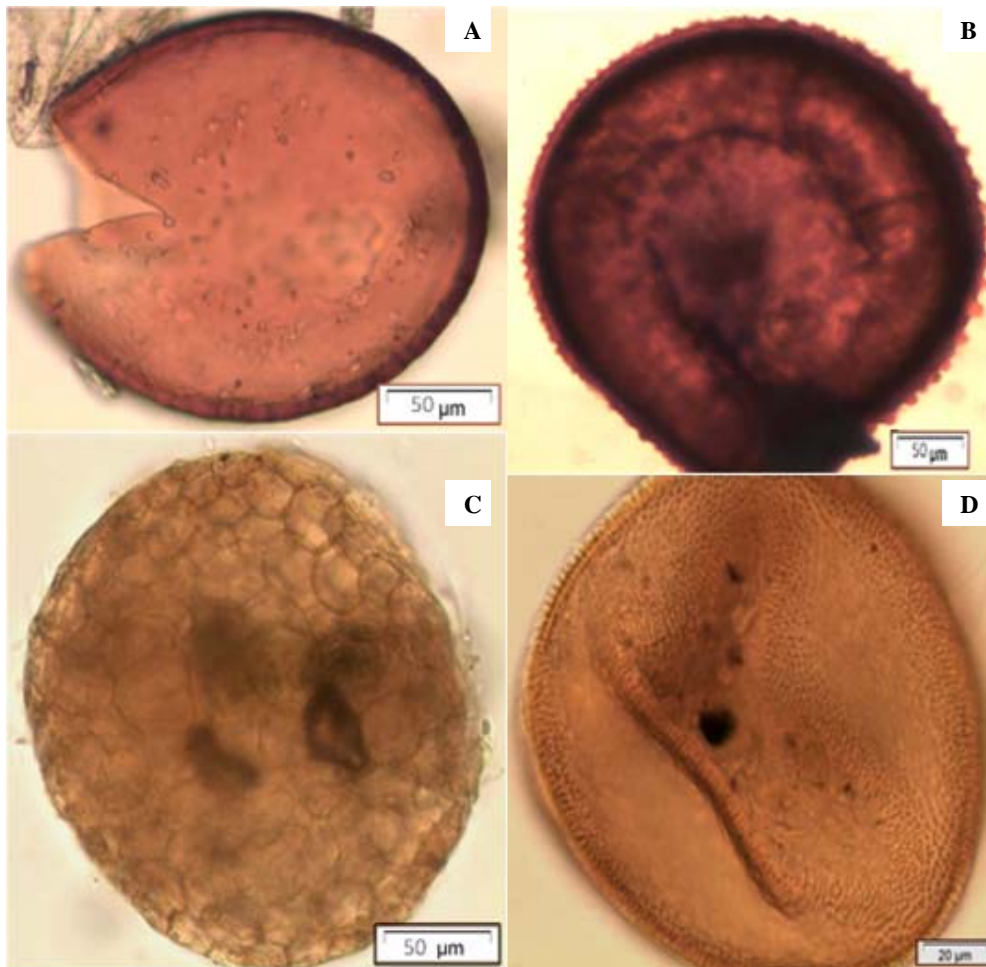
**43. *Acaulospora tuberculata*** Janos & Trappe  
Reported from cultivated soil of Al-Wasta, reclaimed soil of Al-Ghoryb and desert soil of Wadi Al-Assuity Protected area at Assiut Governorate by Nafady (2011).

**44. *Entrophospora infrequens*** (I.R. Hall) R.N. Ames & R.W. Schneid.  
Reported from cultivated soil of Al-Wasta and reclaimed soil of Al-Ghoryb at Assiut Governorate by Nafady (2011).

**Family 4: Pacisporaceae**

**45. *Pacispora boliviana*** Sieverd. & Oehl  
Reported from cultivated soil of Al-Wasta at Assiut Governorate by Nafady (2011).

**46. *Pacispora franciscana*** Sieverd. & Oehl  
Reported from cultivated soil of Al-Wasta and reclaimed soil of Al-Ghoryb at Assiut Governorate by Nafady (2011).



**Fig. 2-** Mature spores of *Acaulospora capsicula* (A), *Acaulospora tuberculata* (B), *Acaulospora bireticulata* (C) and *Entrophospora infrequens* (D).

### Order 3: Paraglomerales

#### Family 5: Paraglomeraceae

47. *Paraglomus occultum* (Walker) Morton & Redecker collected by Hamdy Agwa from unknown location in Egypt as mentioned by Morton & Redecker (2001).

### Order 4 : Archaeosporales

#### Family 6: Archaeosporaceae

48. *Archaeospora trappei* (Ames & Linderman). Morton & Redecker  
Reported from cultivated soil of Al-Wasta and reclaimed soil of Al-Ghoryb at Assiut Governorate by Nafady (2011).

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