ARTICLE

The history, fungal biodiversity, conservation, and future perspectives for mycology in Egypt

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Abstract: Records of Egyptian fungi, including lichenized fungi, are scattered through a wide array of journals, books, and dissertations, but preliminary annotated checklists and compilations are not all readily available. This review documents the known available sources and compiles data for more than 197 years of Egyptian mycology. Species richness is analysed numerically with respect to the systematic position and ecology. 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 fungi is fragmentary, especially for certain systematic and ecological groups such as *Agaricales*, *Glomeromycota*, and lichenized, nematode-trapping, entomopathogenic, marine, aquatic and coprophilous fungi, and also yeasts. Certain groups have never been studied in Egypt, such as *Trichomycetes* and black yeasts. By screening available sources of information, it was possible to delineate 2281 taxa belonging to 755 genera of fungi, including 57 myxomycete species as known from Egypt. Only 105 taxa new to science have been described from Egypt, one belonging to *Chytridiomycota*, 47 to *Ascomycota*, 55 to anamorphic fungi and one to *Basidiomycota*.

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INTRODUCTION

Biological diversity (biodiversity) encompasses the variety of life forms occurring in nature, from the ecosystem to the genetic level, as a result of evolutionary history (Wilson 1992). The idea that fungi form a kingdom distinct from plants and animals gradually became accepted only after Whittaker (1969). Presently, the "fungi" as a mega-diverse group span three kingdoms, most belonging to the *Fungi* (*Eumycota*), while others are classified in the *Protozoa* and *Chromista* (*Straminipila*) (Cavalier-Smith 1998, James *et al.* 2006b). The word "fungi", lower case and not in italics, is commonly used as a collective term for organisms traditionally studied by mycologists from all three kingdoms (Hawksworth 1991). The myxomycetes have also been traditionally studied by mycologists (Everhart & Keller 2008, Rojas & Stephenson 2008), and are included here.

Estimates for the number of fungi in the world range up to ca. 13.5 M species (McNeely *et al.* 1990, Hawksworth 1991, 2001, Hawksworth & Kalin-Arroyo 1995, Hyde 1996, Hyde *et al.* 1997, Tangley 1997, Groombridge & Jenkins 2002, Brusca & Brusca 2003, Rossman 2003, Crous *et al.* 2006, Adl *et al.* 2007, Kirk *et al.* 2008). It might be expected that the predicted numbers of fungi on Earth would have been considerably greater than the 1.5 M suggested by Hawksworth (1991), which is currently accepted as a working figure although recognized as conservative (Hawksworth 2001).

The 10th edition of *Ainsworth & Bisby's Dictionary of the Fungi* (Kirk *et al.* 2008) provided a total of 98 998 for the number of fungal species accepted to date (excluding taxa treated under *Chromista* and *Protozoa*). Kirk *et al.* (2008) reported 1 039 species chromistan fungal analogues and 1 165 as protozoan in which 1 038 are regarded as protozoan fungal analogues: *Percolozoa* (*Acrasida*), *Amoebozoa* (*Dictyostelia, Myxogastria, Protostelia*), *Cercozoa* (*Plasmodiophorida*) which were previously treated as *Myxomycota* and *Plasmodiophoromycota*.

Egypt's geographical position at the junction between two large continents (Africa and Asia), and its inclusion as part of the Mediterranean basin, has indelibly influenced both the people and the biota of the country socially, economically and biologically. Egypt is part of the Sahara of North Africa, it has an area of about 1 M km^2, divided by the River Nile into a western part including the Libyan Desert (681 000 km^2) and an eastern part comprising the Eastern Desert (223 000 km^2), and the Sinai Peninsula (61 000 km^2). The Nile basin, comprising the valley in the south (Upper Egypt) and Nile delta in the north (Lower Egypt), forms a riparian oasis (40 000 km^2) that constitutes the densely inhabited farmlands of Egypt.

Kassas (2002) mentioned four gaps related to biodiversity knowledge: the number of species on Earth; the diversity of the less conspicuous organisms such as fungi, bacteria, algae, and protozoa; the role played by each species among biotic elements of ecosystems; and the human ability to assess and forecast bio-ecological degradation.

Documentation of the Egyptian fungi may be dated back to 4500 B.C., when ancient Egyptians produced a number of hieroglyphic depictions of plants (many of which are psychedelic) on walls and within texts throughout Egypt. Temples with countless pillars are shaped like huge mushrooms with tall stems, umbrella caps, and mushroom engravings distributed all over the country (Fig. 1). These are shaped like *Amanita* sporophores, and some like *Psilocybe*. Others look like bracket fungi and are decorated with pictures of an incredible variety of plants (Arthur 2000). In the Egyptian Book of the Dead, the Papyrus of Ani (Budge 1967), mushrooms are called "the food of the gods," or "celestial food" and "the flesh of the gods."

Studies on fungi in Egypt started at the beginning of the 19th century on lichens (e.g. Delile 1813a, b, Nylander 1864, 1876, Müller 1880a–c, 1884, Stizenberger 1890, 1891). In the early 20th century, Sickenberger (1901) and Steiner (1893, 1916) provided information for collections of lichens from Egypt in the 19th and early 20th Century. In the *Flore d'Egypte*, Delile (1813a) presented a scientific study of Egyptian fungi into the early19th century (Mouchacca 2008), in which he described the gastromycete now known as *Itajahya rosea* (syn. *Phallus roseus*; Fig. 1) which he had collected in Damietta and Assiut in 1798 and 1799, respectively. It should be noted that some early works repeat previous records, sometimes ambiguously as a result of the misinterpretation of synonyms and erratic use of infraspecific ranks; further, in the case of Sickenberger, misspellings of scientific names (Seaward & Sipman 2006).

By the beginning of the 20th century, special attention was being given to phytopathogenic fungi on wild and domesticated plants of economic importance (e.g. Fletcher 1902, Reichert 1921, Fahmy 1923, Shearer 1924, Briton-Jones 1922, 1923, 1925, Bishara 1928, Melchers 1931, Sirag El-Din 1931, Abdel-Salam 1933).

Fig. 1. A. Giant mushroom-like pillars (upper part), which are common in Egyptian temples. B. Description of *Phallus roseus* by Delile (1813a).

Both Reichert and Melchers are considered the pioneer scientists in the documentation of Egyptian fungi. Israel Reichert (1891–1975) went to study in Germany. Here he obtained his doctorate on *Die Pilzflora Ägypten* in which 237 species were recognized, of which 42 were new to science. Unfortunately, none of his specimens were retained in Egypt, or if they were, there is no record of their whereabouts today. However, earlier material collected before 1914 was present in the Botanisches Museum in Berlin-Dahlem, which Reichert used when compiling his list of 1921, but it is not known if these specimens survived World War II.

In 1927 Leo E. Melchers went to Egypt at the invitation of the Egyptian Minister of Agriculture as chief mycologist for 18 months. He met a series of difficulties such as there being no records available on the occurrence, distribution, or dates of any mycological observations conducted previously by any investigator in Egypt, and no mycological reference collection existing in the country. His checklist, however, included 345 species of fungi, especially those causing plant diseases (Melchers 1931).

No studies were carried out on the soil fungi until the 1930s, yet it was to be expected that, in such a country with rich agricultural traditions, knowledge of these fungi should have attracted considerable interest. Research on Egyptian soil fungi was probably commenced by Younis Salem Sabet (1898–1977). Sabet graduated in 1921 from the High School of Agriculture (now the Faculty of Agriculture of Cairo University), and soon after was sent to England to study botany at the University of London, where he obtained a BSc (Hons) in 1925. After his return, he joined the Ministry of Agriculture in the Plant Breeding Section. In 1927 he was appointed lecturer in Botany in the faculty of Science of the newly established Egyptian University, and in 1935 published his pioneering study, which was followed by many other publications (Sabet 1936, 1938, 1939a). His exploration led to the discovery of three taxa which were described later as new to science.

Sabet took the initiative in the establishment of some scientific organisations, and served as a member and president for several years in some others. Particularly of note were the Egyptian Academy of Sciences, Egyptian Botanical Society, Egyptian Science Union, Egyptian Association for Scientific Culture, Society of Applied Microbiology, Egyptian Phytopathological Society, Society for the History of Science, and Society of Atomic Energy.

Near the end of the 1930s, new aspects of mycological research were introduced into Egypt by several investigators such as mycorrhizal fungi (Mostafa 1938, Sabet 1939b, 1940, 1945, Yousef 1946); biocontrol (Mostafa & Gayed 1953), rhizosphere (Montasir *et al.* 1956, Naim *et al.* 1957), air (Saad 1958, Zaki 1960), and stored seeds and grains (Assawah & El-Arosi 1960).

In 1956 late Magdy A. Ragab (Department of Botany, Faculty of Agriculture, University of Cairo) isolated 16 new species for the first time from soil, water and some plant hosts (Ragab 1956).

However, the credit for initiating real research concerned with Egyptian fungi must be given to Abdel-Al H. Moubasher

Fig. 2. A selection of prominent mycologists who have contributed greatly to our knowledge of mycology in Egypt. **A.** Abdel-Al H. Moubasher. **B.** Samy M. El-Abyad. **C.** Jean Mouchacca. **D.** Abdul-Wahid F. Moustafa. **E.** Farida T. El-Hissy. **F.** Younis S. Sabet. **G.** Israel Reichert. **H.** Youssef A. Youssef.

(Botany Department, Faculty of Science, Assiut University; Fig. 2). In the early 1960s, with colleagues and students, he broadened the scope of mycological research in Egypt by conducting many studies on fungi. These included aspects such as: cellulose-decomposition, thermophily, osmophily, seed and grain mycobiota, phylloplane fungi, mycotoxins, and aquatic fungi. Moubasher, with his colleagues and students, have published more than 150 scientific papers to date, and in 1993 he published his major contribution to mycology in the Arabic World, the lavishly illustrated *Soil fungi of Qatar and other Arab Countries* (Moubasher 1993). He also invited outside specialists to run courses from the 1980s and trained many PhDs students. Specialists included Colin Booth and David Hawksworth in the 1980s.

El-Abyad & Abu-Taleb (1993) summarized the habitat diversity of Egyptian fungi, and in 1997 the late Samy M. El-Abyad (Botany Department, Faculty of Science, Cairo University; Fig. 2) presented his pioneering attempt to update the checklist of Egyptian fungi: 1 246 species were recorded of which 173 were referred to *Mastigomycotina*, 41 to *Zygomycotina*, 222 to *Ascomycotina*, 143 to *Basidiomycotina,* and 667 to *Deuteromycotina*. Different ecological and taxonomic groups were not separated cited in the checklist, such as protozoan fungal analogues (*Myxomycota*, *Plasmodiophoromycota*), lichens, yeasts, aquatic and marine fungi, entomopathogenic fungi, nematophagous fungi, and mycorrhizal fungi. A large numbers of taxa, either reported in routine isolations or as novel taxa, are completely absent from this list. This may be due to his inability to trace the majority of references, which is actually the main reason why updated information documenting the fungi of Egypt was needed today. Amongst records lacking in the El-Abyad (1997) checklist are seven *Podaxis* species (Melchers 1931), *Chaetomium gelasinosporum* and *C. uniporum* (Aue & Müller 1967), *C. mareoticum* (Besada & Yusef 1969), *Zygopleurage faiyumensis* (Lundqvist 1969), *Podospora aegyptiaca* (Lundqvist 1970), *Thermoascus aegyptiacus* (Udagawa & Ueda 1983), and *Gelasinospora hippopotama* (Krug *et al.* 1994).

In addition to the previous efforts of Reichert (1921), Melchers (1931), El-Abyad & Abu-Taleb (1993), and El-Abyad (1997), several other studies have added to the documentation of Egyptian fungi: Moubasher (1993), Lado (1994), Mouchacca (1995, 1999, 2001a, b, 2003a, b, 2004, 2005, 2008, 2009a, b; Fig. 2), Moustafa & Abdel-Azeem (2005a, b, 2006, 2010), Moustafa (2006), and Seaward & Sipman (2006).

The late Abdel Razak Abo-Sedah organized the Second African Regional Mycological Congress, in Cairo in 1992, under the auspices of the IMA Committee for the

Development of Mycology in Africa. Then in 1993 he founded the Regional Center for Mycology and Biotechnology (RCMB) in Al-Azhar University, Cairo. The major tasks of this centre were the establishment of a fungal culture collection, the application of fungi in public health, agriculture, environment and industry, and supporting researchers as well as research projects. The centre actively participated in organizing further African regional and international conferences and meetings in Cairo in 1994, Vancouver in 1994, Zimbabwe in 1995, Cairo in 1996 on "Regulations of fungal activities", and again in Cairo in 1999 on "Fungi and the Environment". The center had collaborative agreements with the former International Mycological Institute (IMI) in the UK, and collaborative activities with Egyptian universities as well as with others in the UK, South Africa, Mauritius, Zimbabwe and Austria. The centre also initiated and published *The African Journal of Mycology and Biotechnology* from 1993 to 2001, which contained numerous contributions by Egyptian authors, and also a mycological newsletter in Arabic.

From the beginning of 2005 to the end of 2007, the Biodiversity Monitoring and Assessment Project (BioMap) had as its primary objective to develop and strengthen biodiversity research, monitoring and assessment across Egypt. In this project an extensive e-database was established to map the distribution of species across Egypt, and document up to 50 % of the Egyptian fungi (<biomapegypt.org>).

As mentioned above, the information concerning the fungi of Egypt is still incomplete and cannot be fully documented without an updated checklist of all taxa reported for the country. The present contribution assesses the diversity of fungi in Egypt. In addition, major groups of fungi are discussed briefly to highlight the extent of their diversity, followed by examples of habitats that are unique and deserve greater attention. These data show that the present contribution is a preliminary one concerning the diversity of Egyptian fungi, and therefore this summation is intended to enhance our knowledge of, and stimulate research into, the fungi of Egypt.

MATERIALS AND METHODS

The present contribution is based on an exhaustive revision of the available literature and sources of the Egyptian fungi reported from the 19th century to the present, including dissertations, published papers, compilations and checklists. Name corrections, authorities, and taxonomic assignments of all taxa reported in this article were checked against the *Index Fungorum* database (<indexfungorum.org>). In addition, websites of international mycological centres such as the ATCC (USA) (<atcc.org>), CABI (UK) (<194.203.77.76/grc/index.htm>), CBS (The Netherlands) (<cbs.knaw.nl>), MUCL (Belgium) (<cabri.org/htdig/index-ebrcn.html>) and the catalogue of the culture collection of the Assiut University Mycological Center (AUMC 2010) were also consulted. The systematic arrangement in the present article follows Kirk *et al.* (2008).

This study extended to more than eight years in documenting and updating the information on Egyptian fungi. All results of the present study can be checked against the last updated checklist (El-Abyad 1997).

RESULTS

General features of Egyptian fungi

The number of fungi recorded in Egypt is 2 281 species, out of which 105 taxa have been described from Egypt as new to science: one in *Chytridiomycota*, 47 in *Ascomycota*, 56 in anamorphic fungi, and one in *Basidiomycota*. Reichert introduced 24 of the new taxa, representing 24.7 % of the novel taxa, followed by Jean Mouchacca and his colleagues (Laboratoire de Cryptogamie, Muséum National d'Histoire Naturelle, Paris), who described 18 new species (17.1 % of the total), and Abdul-Wahid F. Moustafa (Fig. 2) and his colleagues and students at the Suez Canal University who contributed 11 new taxa.

Protozoan fungal analogues

The kingdom *Protozoa* contains 115 000 known species. They are extremely diverse in their cell structure, patterns of nutrition, metabolic needs, reproduction, and habitat. This kingdom contains a grab-bag of organisms that do not fit into the other kingdoms. *Protozoa* are extremely difficult to classify so for the purpose of this survey, they are grouped by their nutritional patterns. Protozoan fungal analogues are heterotrophic and most are decomposers that feed on dead plants and animals by endocytosis (Kendrick 2000). According to Kirk *et al.* (2008) there are about 1 165 fungal protozoan analogues described. Slime moulds are a small and relatively homogenous group of eukaryotic organisms, and these are referred to as *Myxomycota* (*Mycetozoa*). In Egypt the slime moulds have never been the target of any widescale study (Lado 1994, Stephenson & Stempen 1994), except for the pioneer study of Abdel-Raheem (2002) on those of Upper Egypt (Ndiritu *et al.* 2009).

Abdel-Raheem (2002) reported 20 species belonging to 17 genera in his first inventory of the protozoan fungal analogues (*Myxomycota*) of Upper Egypt from wood, bark of living and dead trees and leaf litter. Exhaustive examination of all available literature concerning protozoan fungal analogues in Egypt led to the discovery of reports of *Protostelium irregulare* (as "*irregularis*"; Olive & Stoianovitch 1969) and *Eidamella spinosa* (Kowalik & Sadurska 1973). The protozoan fungal analogues occurring on decaying wood, bark, leaf litter and papyrus papers presently amount to 57 species belonging to 25 genera. For more details refer to the PBI: Global Biodiversity of Eumycetozoans (<slimemold.uark.edu/fungi/default.aspx?selected=NameDetails&NameId=F2C1B99A-6D50-4963-8BE1-15FFC34F8D5D&StateId=&Sort=&TabNum=8>) and Farghaly (2008). In addition, three species representing three genera of *Cercozoa* (previously *Plasmodiophoromycota*) have been recorded: *Plasmodiophora*, *Spongospora,* and *Woronina*. No dictyostelid cellular slime moulds are so far known from Egypt (Cavender *et al.* 2010).

Chromistan fungal analogues

The kingdom *Chromista* (*Straminipila*) is a collection of eukaryotic, walled microorganisms that produce heterokont, wall-less cells in their life-cycles, including some fungal-like groups that are not considered to be ancestors of any members of the *Fungi* (Lutzoni *et al.* 2004). Kirk *et al.* (2008) estimated the Chromistan fungal analogues as 1 039 known species and included the phyla *Hyphochytriomycota*, *Labyrinthista*, and *Oomycota* along with some taxa of uncertain position (*incertae sedis*).

The late Farida T. El-Hissy (Botany Department, Faculty of Science, Assiut University; Fig. 2) was the founder of aquatic mycology research in Egypt. El-Hissy and her students published more than 60 papers on this topic. However, the plant pathogenic *Oomycota* have been the target of many research investigations since 1921, and in the present study, 186 taxa of chromistan fungal analogues were recorded, of which 172 belong to 40 genera of *Oomycota*. Four species and two genera of *Labyrinthista* were recorded, while *Hyphochytriomycota* are represented by six species within three genera. For more details refer to El-Helaly *et al*. (1963, 1966), Ali Hassanein *et al*. (1972), Khallil *et al*. (1995), and El-Hissy *et al*. (1990, 1992, 1997, 2004)

Fungi (Eumycota)

Blastocladiomycota

This phylum was once considered part of the chytrids. However, most of the true chytrids (*Chytridiomycota*) produce a limited mycelium while *Blastocladiomycota* usually make extensive mycelia. Thus, they superficially resemble the water moulds to which they were thought to have been affiliated. Like the chytrids, *Blastocladiomycota* and *Neocallimastigomycota* are the only members of the fungi in which motility has been retained. In overall growth habit, the blastocladiomycetes tend to be eucarpic, in which there is an extensive vegetative growth habit in which some part of the organism participates in reproduction (asexual and sexual). Members of this phylum do exhibit a complete alternation of generation between a haploid gametophyte and a diploid sporophyte (Barr 1990, James *et al.* 2006a). Kirk *et al.* (2008) give a world total for *Blastocladiomycota* of 179 species. In Egypt, 27 species and one variety belonging to seven genera of *Blastocladiomycota* were found in this study. For more details see Ragab (1956), Yusef (1964), Gad *et al.* (1967), Gad & Sadek (1968), El-Hissy (1974), El-Hissy *et al.* (1997), El-Abyad (1997), Shoulkamy *et al.* (2001), and Abdel-Moneim (2010).

Chytridiomycota

Chytridiomycota are a phylum of fungi that reproduce through the production of motile spores (zoospores), typically propelled by a single, posteriorly directed flagellum. These organisms, often referred to as chytrid fungi or chytrids, have a global total of approximately 1 000 described species (James *et al.* 2006a). Based on biochemical characteristics, including chitin in cell walls, the α-aminoadipic acid lysine synthetic pathway, and storage carbohydrates (i.e. glycogen), Bartnicki-Garcia (1970) classified *Chytridiomycota* as true fungi and this is supported by current molecular studies (Hibbett *et al.* 2007). In the past some authors considered the chytrids as a transitional group between protists and fungi because of their production of motile zoospores (Barr 1990). Kirk *et al.* (2008) give the number known *Chytridiomycota* as 706.

The study of Gaertner (1954) on *Chytridiomycota* of Africa is considered one of the pioneer mycological studies in Egypt. However, the real start of research on chytrids in Egypt must be credited to Samy Kamel Mohamed Hassan (Minia University) who obtained his PhD from the University of Warsaw for work on chytrids and aquatic fungi in 1982. Later, Hassan and Mohamed Abdel-Wahab El-Naghy (Minia University) made a series of studies on chytrids in Egypt.

Intensive revision of the nomenclature showed that 84 species belonging to 32 genera of *Chytridiomycota* were recorded in Egypt. For more details see El-Naghy *et al.* (1985, 1987), Hassan (1991a-d, 1993), Hassan & Fadl-Allah (1991), Hassan & Shoulkamy (1991), and Hassan & Shaban (1991).

Zygomycota

Zygomycota are a particularly ecologically diverse group of fungi, occurring as saprobes (*Mucorales*), harmless inhabitants of arthropod guts (*Harpellales*), plant mutualists forming ectomycorrhizas (*Endogonales*), and pathogens of animals, plants, amoebae, and especially other fungi (all *Dimargaritales* and some *Zoopagales* are mycoparasites) (James & O'Donnell 2007). Conversely, some *Mucorales* have a negative economic impact as they cause storage rots or plant diseases, while others can cause life-threatening opportunistic infections in diabetic, immuno-suppressed, and immuno-compromised patients. In addition, several species of *Microsporidia* cause serious human infections (de Hoog *et al.* 2000, James & O'Donnell 2007).

According to Kirk *et al.* (2008) the total world number of *Zygomycota* is 1 065 species. Data collected from previous studies show the *Zygomycota* in Egypt to be fragmentary because members belonging to this group either have long been overlooked or simply reported as rare taxa during routine isolations.

Abdel-Kader (1973) carried out a pioneering study in which he was able to isolate 11 species from a range of soils collected from various Egyptian localities. The second most relevant study is probably that of Al-Alfy (1995) who reported 21 species from various substrates, including soil, dung, stored seeds and grains, and the phyllosphere. In his recent contribution on *Zygomycetes* in Egypt, Moustafa (2006) reported 33 species, out of which nine were considered new Egyptian records.

Revision of all available data showed that *Zygomycota* in Egypt comprises 70 taxa including eight varieties and seven special forms within 35 genera. In addition, *Absidia aegyptiaca* (Sartory *et al.* 1939) is omitted from the list, as no living or other type of authentic material is apparently preserved; furthermore the name was not validly published as it lacked a

Latin diagnosis (Mouchacca 1995). For more information on Egyptian *Zygomycota* refer to Kharboush (1969a, b), Besada & Yusef (1968), Abdel-Rahman *et al.* (1990), Moubasher (1993), El-Abyad & Abu-Taleb (1993), Swelim *et al.* (1994), Mouchacca (1995), El-Abyad (1997), Abdel-Azeem (2003), Moustafa (2006), Ali & Ibrahim (2008), Afify *et al.* (2009), and Moubasher *et al.* (2010).

Glomeromycota

The *Glomeromycota* currently comprises 169 described species (Kirk *et al.* 2008). The phylum is not as diverse as other phyla of fungi with only three families and such a modest number of species. However, they make up for this uniformity by being among the most abundant and widespread of all fungi. As far as we know, all species of *Glomeromycota* are mutualistic with plants, forming endomycorrhizas. Although there are various types of mycorrhizas, involving different fungal and plant symbionts, the arbuscular mycorrhiza type is the most widespread occurring in around 80 % of plant species (Redecker & Raab 2006).

The pioneering work of Mostafa (1938) and Sabet (1939b, 1940, 1945; Fig. 2) is now accepted as the starting point of research on Egyptian *Glomeromycota* (Kelley 1950, Abdel-Moneim & Abdel-Azeem 2009). These studies were followed by many other investigations concerned mainly with the ecology and physiology of endomycorrhizas in Egypt, *viz.* Fares (1986), Ishac *et al.* (1986), Abdel-Fattah (1991), Aboulkhair & El-Sokkary (1994), Mankarios & Abdel-Fattah (1994), Abdel-Fattah & Mankarios (1995), Abdel-Fattah & Rabie (1995), Abdel-Fattah *et al.* (1996), Abdalla & Abdel-Fattah (2000), Abdel-Fattah (2001), and Abdel-Azeem *et al.* (2007).

However, surveys of Egyptian *Glomeromycota* are limited, and had never been the sole target of any study until Fares (1986) conducted a survey of vesicular arbuscular mycorrhizas, followed by Agwa (1990) on mycorrhizas and nodulation in some Egyptian plants. After 10 years, Agwa (2000) studied the arbuscular mycorrhizal fungi associated with medicinal plants as *Glomales* in Egypt (I)". Agwa & Abdel-Fattah (2002) followed up their work "*Glomales* in Egypt (II)" as an ecological view of some saline affected plants in the delta of the Mediterranean coast. A study of the distribution of *Glomales* in the Egyptian Protectorates was published by Agwa & Al-Sodany (2003) as "*Glomales* in Egypt (III)", which surveyed the distribution and ecology in some plants in the El-Omayed Biosphere Reserve. Later, other relevant studies were carried out by several investigators such as El-Zayat *et al.* (2007) and Abdel-Moneim & Abdel-Azeem (2009) on the Wadi Allaqi and Saint Katherine Protectorate, respectively. Recently, Mansour (2010) screened 71 soil and root samples for endomycorrhizas in North Sinai and adopted some of them as biocontrol agents against fusarium-wilt of tomato.

Eight genera and 19 species have been recorded in Egypt since 1938: *Acaulospora, Entrophospora, Gigaspora, Glomus, Paraglomus, Sclerocysti, Scutellospora* and *Rhizophagus*. Both *Paraglomus occultum* and *Rhizophagus* were recorded and never cited in any publication related to Egyptian *Glomeromycota*. For more details see Sabet (1939b) and Morton & Redecker (2001).

Lichen-forming fungi

Lichens are unique associations composed of two to three different organisms living together in a mutualistic relationship in which the fungal partner forms the external structure. The name used is that of the fungal parter, and the photosynthetic partner or partners have independent scientific names. Estimates for the number of lichen fungi worldwide vary, but a draft global checklist has 18 882 names of lichen-forming and allied fungi (Feuerer & Hawksworth 2007).

Egyptian lichens have received the attention of many researchers since the early 1800s (Delile 1813a, b, Nylander 1864, 1876, Müller 1880a–c, 1884, Stizenberger 1890, 1891, Sickenberger 1901, Steiner 1893, 1916, Werner 1966, Galun & Garty 1972, Temina *et al.* 2004, 2005, Seaward & Sipman 2006). Egyptian investigators have participated in a few studies of lichens, namely in North Sinai (Khalil 1995) and on trees (Koriem 2003), and there have also been some physiological studies on the bionts (Koriem 2006). Khalil (1995) recorded 43 species belonging to 18 genera, all of which are ascolichens without any basidiolichens at all, and only one of these had a perithecioid ascoma (*Gonohymenia sinaica*).

Seaward & Sipman (2006) reported 157 taxa of lichenized fungi (149 species and 8 infraspecific taxa) and six lichenicolous fungi (fungi obligately growing on lichens). Foliose lichens are very scarce, only being represented by the genera *Xanthoria* (7 species) and *Physcia* (1 species). The fruticose growth form is better represented, with members of the genera *Ramalina*, *Roccella*, *Seirophora* and *Tornabea*. At the family level, *Teloschistaceae* accommodated the most taxa (39), followed by *Roccellaceae* (16), and *Physciaceae* (12). For more information concerning Egyptian lichens please see: check-lists of Lichens and Lichenicolous Fungi (<biologie.uni-hamburg.de/checklists/portalpages/portalpage_checklists_switch.htm>), the Tel Aviv University Herbarium (TELA) (<tau.ac.il/~botany/Tela/lichen.html>), Galun & Garty (1972), Khalil (1995), Koriem (2003, 2006), Temina *et al.* (2004, 2005), and Seaward & Sipman 2006).

Ascomycota (non-lichenized)

Numerically *Ascomycota* constitute by far the largest group of fungi so far known, accommodating a relatively large assemblage of taxa estimated to be 65 % of all described fungi (Kirk *et al.* 2008) occurring in various habitats; aquatic or terrestrial, under moderate or stress conditions (Kodsueb *et al.* 2008a, b, Kruys & Ericson 2008, Thongkantha *et al.* 2008). A large number of *Ascomycota* species are economically important (e.g. *Fusarium* spp., Kvas *et al.* 2009; *Colletotrichum* spp., Damm *et al.* 2009, Hyde *et al.* 2009; *Mycosphaerella* spp., Crous 2009), while few are edible (morels and truffles), and some are used also in the production of food (including bread), drinks, organic acids, mycofungicides, fungal biofertilizers, cosmetics and hormones (Kaewchai *et al*. 2009, Hyde *et al.* 2010).

This phylum encompasses biologically diverse forms. Many are free-living saprobes including species which may be cellulose decomposers, chitinolytic, keratinolytic, or

coprophilous, others are parasitic forms including species which cause very serious plant diseases like powdery-mildew, wood-canker, ergot, rot, blight, scab, leaf curl, and leaf-spots (e.g. Alves *et al.* 2008, Aveskamp *et al.* 2008, Simonis *et al.* 2008, Wulandari *et al.* 2009). Others that are considered symbiotic forms contain species which live in association with insects or algae (lichens) or roots of plants (mycorrhizas).

Ascomycota characteristically, when reproducing sexually, produce non-motile spores (ascospores) in a distinctive "ascus". However, some members of the *Ascomycota* do not reproduce sexually and do not form asci or ascospores (anamorphic *Ascomycota*). These asexual members are assigned to *Ascomycota* based upon morphological and/or physiological similarities to ascus-bearing taxa, and in particular by phylogenetic comparisons of DNA sequences. In old classification systems these were often placed in a separate artificial phylum, the deuteromycota (or "fungi imperfecti"). Molecular analyses can now place these genera and species among ascus-bearing taxa, or more rarely in other phyla such as *Basidiomycota*.

The first reports of mutualistic non-lichenized ascus-forming fungi from Egypt were those of *Terfezia*, *Tirmania,* and *Morchella* by Reichert (1921), and then Melchers (1931) who recorded six species. Later, Sabet (1935) recorded some saprobic *Chaetomium* species. The saprobic *Ascomycota* did not receive attention, and therefore information remained limited until the early 1970s, when some research on the group was initiated by Moubasher and his co-workers during their studies on soil fungi. Since then, fragmentary information has been accumulating, but these fungi had never been the main objective of any Egyptian study focusing on their ecology, distribution, and substrate preferences, untill the study of Abdel-Azeem (2003).

Three hundred and three species of teleomorphic saprobic *Ascomycota* (including ascosporic yeasts) have been recorded from all terricolous substrates of Egypt (Moustafa & Abdel-Azeem 2010, and unpubl.). In their studies, 10 species of edible *Ascomycota* were recorded from Egypt within the genera *Morchella, Terfezia,* and *Tirmania*. In total, 328 taxa were recorded in this survey, of which only 32 species are ascosporic yeasts. Binyamini (1973) reported *Peziza vesiculosa* as a coprophilous fungus from occupied Palestine, and some samples were even collected from north Sinai during the occupation in 1967, but never cited as an Egyptian record in any checklist. In addition, *Byssonectria tetraspora* was recorded for the first time in Egypt by El-Saadawi & Shabbara (1999) as an association between a fungus and a moss.

For more details see Sabet (1936, 1939a), Binyamini (1973), El-Saadawi & Shabbara (1999), Abdel-Hafez *et al.* (1995), Ibrahim (1995), El-Abyad (1997), Zaki *et al.* (2005), Moustafa & Abdel-Azeem (2005a, b, 2006, 2008, 2010), and Abdel-Azeem (2009).

Records of phytopathogenic fungi in Egypt were scattered through the literature until 1921, when Israel Reichert (Fig. 2) carried out his pioneer study of Egyptian fungi. This was followed by a comprehensive checklist of plant diseases and fungi occurring in Egypt by Melchers (1931). Records concerning aspects of plant pathology in Egypt continued to be accumulated during many decades until El-Helaly *et al.* (1963, 1966) started to update the information, and another updated bibliography of agricultural studies conducted in Egypt between the period 1900 to 1970 appeared **(**Ali Hassanein *et al.* 1972). This revealed records of 82 species of teleomorphic plant pathogenic *Ascomycota*. For more details please check, Natrass (1933), Abou El-Seood (1968), Ghoniem (1985), El-Desouky & El-Wakil (2003), Phillips *et al.* (2006), and Hafez (2008).

Anamorphic genera are gradually disappearing into the overall ascomycete system, though it will take many years before anamorph genera have fully integrated.

A school of medical mycology in Egypt was formed at the beginning of 1967, when the late Youssef A. Youssef (Ain Shams University, Faculty of Science; Fig. 2) published two papers on fungus infection of the human ear. Youssef and his students and colleagues became interested in medical mycology, serology and fungi affecting human health. For more details see Youssef & Abdou (1967a, b), Hassan *et al.* (1980a–e, 1981), Youssef & Karam El-Din (1988a, b), Karam El-Din *et al.* (1994 a–c, 1995, 1996), and Youssef *et al.* (1989, 1992, 1993).

In 1979 Ismail Abdel-Razak M. El-Kady received credit as the Egyptian mycologist working on mycotoxin producing fungi in Egypt. El-Kady and his coworkers studied the majority of aspects related to toxinogenic fungi, e.g. factors affecting mycotoxin production, toxinogenic taxa in food and feed, and mutagenic effects of fungal toxins. For more details see El-Kady & Moubasher (1982 a, b), and El-Kady *et al.* (1989, 1994).

In 1987, Mamdouh S. Haridy (Minia University, Faculty of Science) became the pioneer Egyptian mycologist in yeast identification and taxonomy, having completed his PhD thesis on the taxonomy of yeasts ("Taxonomie milchwirtschaftlich wichtiger Hefen", Technical University, Munich). He conducted a series of extensive studies on the Egyptian saprobic yeasts from different ecological habitats and sources (Haridy 1992a, b, 1993a, b, 1994a, b, 2002).

Recently, other areas of Egyptian mycology have been established, such as on the identification of human and plant pathogens by molecular techniques. Youssuf A. Gherbawy (Botany Department, Faculty of Science, South Valley University) focused on the identification of plant pathogens and saprobic fungi of food by means of molecular techniques (Gherbawy 2004, Gherbawy & Abdelzaher 2002, Gherbawy & Farghaly 2002, Gherbawy & Voigt 2010), and Sherif M. Zaki (Microbiology Department, Faculty of Science, Ain Shams University) extended the research of Youssef A. Youssef using the molecular techniques in species identification of human pathogens (Zaki *et al.* 2005, 2009, Zaki 2008).

About 905 filamentous or yeast-like anamorphic fungi have been reported from Egypt. These taxa colonize, survive and multiply in air, litter, soil, plant surfaces, the human body and other substrates. Of these, only 28 are species

of anamorphic ascomycetous yeasts, which belong to three genera. Furthermore, five genera of basidiomycetous yeasts and 18 species are recorded from all habitats in Egypt.

For more information consult Al-Doory (1968), Abdel-Fattah (1985), Sherief (1985), Bagy & Abdel-Hafez (1985), Khater (1989), Shalouf (1989), Shindia (1990), Abdel-Mallek *et al.* (1995), Abdul Wahid *et al.* (1996), Hamdi & Hassanein (1996), El-Tanash (1997), Shalaby (1999), Mahmoud (1999), Ismail & Sabreen (2001), Teramoto *et al.* (2001), Abdel-Wahab (2002), Farghaly *et al.* (2004), Nofal & Haggag (2006), Haggag *et al.* (2007), Abdel-Hamed (2008), and Kottb (2008).

Aquatic and marine fungi

Marine fungi form an ecological, and not a taxonomic group (Raghukumar 2008, Jones *et al.* 2009, Hyde *et al.* 2000). Among these, the obligate marine fungi grow and sporulate exclusively in seawater, and their spores are capable of germinating in seawater (Hyde *et al.* 1998). On the other hand, facultative marine fungi are those obtained from freshwater or a terrestrial *milieu*, and have undergone physiological adaptations that allow them to grow and possibly also sporulate in the marine environment (Kohlmeyer & Kohlmeyer 1979). These fungi belong mostly to ascomycetes, their anamorphs, and a few basidiomycetes. Among the straminipilan fungi, those belonging to *Labyrinthulomycetes*, comprising the thraustochytrids, aplanochytrids, and labyrinthulids are obligate marine fungi (Raghukumar 2002), and those belonging to the oomycetes are also fairly widespread in the marine environment.

About 3000 fungi (exclusive of yeasts) have been reported from aquatic habitats of which *Ascomycota* (1 527 spp.) and anamorphic taxa (785 spp.) are the most diverse groups, followed by *Chytridiomycota* (576 spp.) with *Basidiomycota* (21 spp.) as the least diverse group (Vijaykrishna *et al.* 2006, Shearer *et al.* 2007).

Anwar Abdel Aleem (Faculty of Science, University of Alexandria), or Peripatetic Aleem as he was known among his colleagues, is one of the most brilliant Arab marine botanists and oceanographer extraordinaire. He is considered one of the pioneer marine Egyptian mycologists, with studies on marine fungi dating back to 1950 (Aleem 1950a–c, 1952a–c, 1953, 1962, 1974, 1975, 1978, 1980a, b, Aleem & Mailbari 1981).

In Egypt, obligate and facultative marine fungi are considered as forgotten fungi (Jones 2001) because they never featured in research topics until 1993, which is considered the starting point of marine mycology research in Egypt. This provided Mohamed Abdel-Wahab (Botany Department, Faculty of Science, South Valley University, Sohag, Egypt) the possibility to publish his pioneering study on the Egyptian obligate mangrove-inhabiting fungi of the Red Sea in 1996. Three contributions of El-Sharouny *et al.* (1998, 1999) and Abd-Elaah (1998) shed light on the ecology and taxonomy of mangrovicolous, algicolous and aquatic fungi of the Red Sea in Upper Egypt. Abdel-Wahab (2000) obtained his PhD on the biodiversity of fungi in subtropical mangroves; he recorded 25 fungi on intertidal wood of *Avicennia marina* collected from three mangrove stands of the Red Sea coast of Egypt. Abdel-Wahab *et al.* (2001a, b) published three new species, *Halosarpheia unicellularis*, *Swampomyces aegyptiacus* and *S. clavatispora,* from Red Sea mangroves. Pang *et al.* (2002) erected *Jahnulales* as a new lignicolous freshwater ascomycete order with the new species *Patescospora separans* from Egypt. Abdel-Raheem (2004) studied the effect of different techniques on diversity of freshwater hyphomycetes in the River Nile (Upper Egypt). Abdel-Wahab (2005) examined the diversity of marine fungi on intertidal decayed wood of *A. marina* and on decayed prop roots of *Rhizophora mucronata* in mangrove stands in the southern part of the Egyptian Red Sea coast; 39 species were identified on decayed wood of *A. marina,* of which 19 were new records for Egypt and the Red Sea. Freshwater fungi are those relying on freshwater for at least part of their life-cycle (Wong *et al.* 1998, Raja *et al.* 2009). Abdel-Aziz (2008) studied the diversity of aquatic fungi in Lake Manzala, which was the first report of aquatic fungi from the lake. Sixty taxa including 26 ascomycetes and 34 anamorphic fungi were recorded, of which 19 species were new records for Egypt. El-Sharouny *et al.* (2009) studied the fungal diversity in brackish and saline lakes in Egypt; 97 fungi (40 ascomycetes, 55 anamorphic fungi and 2 basidiomycetes) were identified from 764 collections, obtained from 545 samples, of which 70 were new records for Egypt.

The revision of all available data sources reveals that the total number of marine and aquatic fungi known in Egypt is 207 taxa (87 *Ascomycota*, 117 anamorphic taxa, and 3 *Basidiomycota*). There is no checklist of aquatic Egyptian fungi so far. For more details on these fungi see the website (<fungi.life.illinois.edu>), search mangrove fungi (<fungi.life.illinois.edu/search/mangrove_fungi>), and check relevant studies (Khallil 2001, Abdel-Aziz 2004, Abdel-Wahab *et al.* 2009, 2010).

Entomopathogenic fungi

The taxonomy of the entomopathogenic fungi has received much attention since the 1970s. More than 700 species of fungi are associated with insects, spiders, and mites (Samson *et al.* 1988, Hajek & St. Leger 1994, Sung *et al.* 2007, Aung *et al.* 2008).

The invertebrate pathogenic fungi can be classified in the *Mastigomycota*, *Zygomycota*, *Ascomycota*, and allied anamorphic fungi; no truly entomopathogenic basidiomycetes have been documented (Samson *et al.* 1988). Entomopathogenic fungi range from commensals or mutualists, through ectoparasites which do not seriously affect their hosts, to pathogens which are lethal and include representatives of all the groups of fungi (Hawksworth *et al.* 1995).

Few records appeared reporting the occurrence of entomogenous fungi in Egypt until Natrass (1932) published preliminary notes on some of these fungi in Egypt. He recorded five species: *Empusa grylli* (= *Entomophaga grylli*), *Beauveria bassiana*, *Aspergillus flavus*, *Mucor racemosum,* and *Metarhizium anisopliae*. In the beginning of the 1960s,

Egypt started to apply biocontrol methods to insects by entomopathogenic fungi, and Gad *et al.* (1967) studied the occurrence of *Coelomomyces indicus* in Egypt.

There are several studies on this ecological group of fungi in Egypt, such as Badran & Aly (1995), Shoulkamy *et al.* (1997), Shoulkamy & Lucarotti (1998), Hafez *et al.* (1997), Sewify (1997), Abdel-Baky (2000), Sewify <3.interscience.wiley.com/journal/119022140/abstract?CRETRY=1&SRETRY=0 - fn1#fn1&> Hashem (2001), Abdel-Sater & Eraky (2002), Ali (2003), <3.interscience.wiley.com/journal/119022140/abstract?CRETRY=1&SRETRY=0 - fn1#fn1> Abdel-Mallek *et al.* (2003 a, b), El-Hady (2004), Mourad *et al.* (2005), Abdel-Mallek & Abdel-Rahman (2006), El-Maraghy *et al.* (2006), and Moubasher *et al.* (2010). As a result of these only 18 species belonging to 13 genera were recorded as entomopathogenic fungi of Egypt. For more details please refer to this site (<arsef.fpsnl.cornell.edu>).

Nematophagous fungi

In Egypt, the study of nematophagous fungi dated back to 1963 when Hamdy Aboul-Eid **(**Department of Plant Pathology, Nematology Laboratory, National Research Centre, Dokki, Cairo) isolated and illustrated four species belonging to two genera. Various studies on the biocontrol of nematodes by fungi have been the target of many studies in Egypt; the most relevant are: Ali (1994, 1995), Ali & Barakat (1994), Aboul-Eid *et al.* (1997a, b, 2006), Ashour & Moustafa (1999), and Amin & Moustafa (2000). Out of these various data and information only 10 species belonging to seven genera were recorded as nematophagous fungi of Egypt.

Basidiomycota

The *Basidiomycota* contains about 31 503 described species, which represents 31.8 % of the known species of true *Fungi* (Kirk *et al.* 2008). This group includes mushrooms, puffballs, bracket fungi and some yeasts (Petersen *et al.* 2008, Wannathes *et al.* 2009). Many *Basidiomycota* decay dead organic matter, including wood and leaf litter symbiotic lifestyles (intimate mutually beneficial or harmful associations with other living organisms) are well developed in the *Basidiomycota*. They include major plant pathogens, such as "rusts" (*Uredinales*) and "smuts" (*Ustilaginales*), which attack wheat and other crops, and some human and animal pathogens. Not all symbiotic *Basidiomycota* cause harm to their partners. Indeed, some form ectomycorrhizas with the roots of plants, principally forest trees such as oaks, pines, dipterocarps, and eucalypts (Smith & Read 1997, Rinaldi *et al.* 2008). Other symbiotic *Basidiomycota* form associations with insects, including leaf-cutter ants, termites, scale insects, wood wasps, and bark beetles (Wheeler & Blackwell 1984, Mueller *et al.* 1998).

Macro-Basidiomycota

The first information on hyphenate macro-basidiomycota (phytopathogenic or saprobic) in Egypt dates back to Delile (1813a), Melchers (1931), and Morse (1933). In her study on the genus *Podaxis*, Morse referred to some samples collected from Egypt. After six decades more information about macro-basidiomycota came to light through a series of studies carried out by several investigators, such as Mouchacca (1977), Zakhary (1979), Salem & Michail (1980), Zakhary *et al.* (1983), MalenÇon (1984), Assawah (1991), Chen (1999), Abu El-Souod *et al.* (2000), El-Fallal (2003), El-Fallal & Khedr (n. dat.), El-Fallal & El-Diasty (2006), Kim *et al.* (2006), and Abdel-Azeem (2009).

An exhaustive revision of all the available literature and sources mentioned since 1931 shows that 108 taxa belonging to 65 genera, 104 species, and 4 varieties of Egyptian macro-basidiomycotese had been recorded up to the present time.

Plant pathogenic Basidiomycota

Though many basidiomycetes are saprobes or wood-rotters, the *Basidiomycota* contains two common and destructive groups of plant pathogens: rusts and smuts. Rust fungi are the largest group of fungal plant pathogens, containing 7 000 species that possess the most complex life-cycles in the kingdom fungi (Sert 2009). They are obligate biotrophs and cause disease on most crops, ornamentals, and many other plants (Hawksworth *et al.* 1995). In addition to basidia and basidiospores, rusts produce other types of spores such as teliospores spermatia, aeciospores, and uredospores. Rusts that produce all five types of spores are referred to as macrocyclic, while rusts that lack one or more spore type are referred to as microcyclic. Unlike rusts, smuts produce only basidiospores and teliospores which can survive in the soil away from a host plant. Smuts commonly infect the ovaries of grains and are easily recognized by the formation of galls which contain masses of black spores (Agrios 2005).

The initial research and documentation of rust and smut diseases in Egypt was by Reichert (1921), Briton-Jones (1922), Philp & Selim (1941), Abdel-Hak & Abdel-Rehim (1950), Ragab & Mahdi (1966), and Assawah (1969). Later, in-depth research was carried out by Egyptian and other investigators, with different targets such as taxonomy, pathogenicity, biocontrol and serology. The most relevant studies are: Sherif *et al.* (1991), El-Shamy (1996), Baka & Gjaerum (1996), Mennicken *et al.* (2005), Abd El Fattah *et al.* (2009), Abd EL-Ghany (2009) and Ismail *et al.* (2009). Baka & Gjaerum (1996) gave the first serious modern taxonomic treatment of local rusts, reporting 23 rust species on various monocotyledonous and dicotyledonous plants in the Nile Valley (see Mouchacca 2003b). As a result of these studies, 112 species of plant pathogenic *Basidiomycota* belonging to 21 genera were recorded from Egypt.

Total recorded species

After the omission of duplicate names, name correction, allowance for synonyms and taxonomic assignments of all reported taxa from Egypt, the number of the Egyptian fungi recorded is 2 281 taxa belonging to 755 genera (Table 1). At the generic level, some genera exhibit an extraordinary high species richness such as *Aspergillus* (100 spp.) and *Penicillium* (83). Other genera show moderate richness such as *Chaetomium* (53 spp.), *Fusarium* (49), *Puccinia* (41), *Pythium* (30) and *Alternaria* (27).

Table 1. Numbers of recorded Egyptian fungi.

Groups and Phyla		El-Abyad (1997)	Present survey
Protozoan fungal analogues	*Amoebozoa*	0	25
	Cercozoa	0	3
Chromistan fungal analogues	*Hyphochytriomycota*	1	3
	Labyrinthista	0	2
	Oomycota	25	40
	Incertae sedis	0	1
Blastocladiomycota		3	7
Chytridiomycota		21	32
Zygomycota		17	35
Glomeromycota		0	8
Ascomycota	Teleomorphic genera	80	251
	Anamorphic genera	181	261
Basidiomycota		32	87
Total no. of genera recorded in Egypt		360	755
Total no. of species recorded in Egypt		1246	2281

DISCUSSION

It is generally accepted that only about 7 % of all fungi have so far been discovered, and about 93 % still wait to be discovered. Fungi are neglected organisms and they are not well protected, but like animals and plants, they are endangered by human activities. Although the 1992 Convention on Biological Diversity extends protection to all groups of organisms, it is worded in terms of “animals, plants and microorganisms” and fungi do not fit well into these categories. In Egypt and up to now fungal biodiversity and conservation topics have been overlooked. As a result, countries which signed the Convention have almost universally overlooked fungi in preparing their biodiversity conservation plans: fungi are truly the orphans of Rio (Minter 2010).

Threats to fungi throughout the globe are of concern since they are not only beautiful but also play a significant role in human welfare. Three steps were suggested by Moore *et al.* (2001) for fungal conservation: (1) conservation of habitats; (2) *in situ* conservation of non-mycological reserves/ ecological niches; and (3) *ex situ* conservation especially for saprobic species growing in culture. To help collections of fungal cultures to maintain appropriate standards, the World Federation for Culture Collections (WFCC) has formulated guidelines which outline the necessary requirements (Hawksworth 1991, Smith *et al.* 2001, Smith 2003). There are 573 microbial culture collections in 68 countries registered in the World Directory of Collections of Microorganisms (DCM) (<wfcc.info/datacenter.html>). In Egypt only two centers are recorded: EMCC (WDCM583) Egypt Microbial Culture Collection, Cairo Microbiological Resources Centre (Cairo MIRCEN), Ain Shams University, and NODCAR WDCM822 Marwa Mokhtar Abd Rabo, National Organization of Drug Control and research. However, Moubasher and his colleagues founded the Assiut University Mycological Centre (AUMC) in 1999 where more than 6 000 fungal isolates belonging to more than 500 species are being preserved under low temperature (5 °C), deep-freezed (-80 °C), and lyophilized; this is the biggest reference culture collection in the Arab countries. The centre also has a collection of dried specimens (i.e. a fungarium) which is rare in Arab countries. In spite of this the AUMC is not yet registered with the WFCC.

The number of habitats that potentially support specialized fungi is enormous. The fungi described as new to science during 1981 to 1990 were associated with 1 982 host genera or substrata (Hawksworth & Rossman 1997). Some unexplored substrata and habitats from which these fungi were found include the rumens of herbivorous mammals, algae, lichens, mosses, marine plants, including mangroves and driftwood, rocks and insect scales.

The Egyptian fungi are presently represented by 2 281 taxa (1 035 species and 395 genera) out of the 101 202 world estimate. In comparing the fungal diversity recorded in Egypt with other countries, it is important to mention that some ecological groups of fungi are completely ignored or have never been studied in a comprehensive way in Egypt, such as *Trichomycetes* (a group of enigmatic fungi occurring in the hindguts of insects and other invertebrates; Lichtwardt 2002), in addition to hypersaline and black yeasts. Other groups needing more exploration such as algicolous fungi, invertebrate associated fungi, mycorrhizas, endophytic fungi, lichens, wood deteriorating, and coprophilous fungi. The potential fungal resources of Egypt are globally important and there are vast areas that are still unexplored. At present, Egypt needs more investigators and funds to explore and develop this research field and, therefore, the extensive collection of fungi in unexplored areas remains a priority.

This review will be followed by an updated checklist of all recorded Egyptian fungi up to the present, a bibliographic study of Egyptian mycological research, and a book on the fungi of Egypt, supplemented with provisional keys to all species listed.

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REFERENCES

Abdalla ME, Abdel-Fattah GM (2000) Influence of the endomycorrhizal fungus *Glomus mosseae* on the development of peanut pod rot disease in Egypt. *Mycorrhiza* **10**: 29–35.

Abd-Elaah GA (1998) The occurrence of fungi along the Red Sea coast and variability among isolates of *Fusarium* as revealed by isozyme analysis. *Journal of Basic Microbiology* **38**: 303–311.

Abdel-Azeem AM (2003) *Ecological and taxonomical studies on ascospore-producing fungi in Egypt*. PhD thesis, Faculty of Science, Suez Canal University, Egypt.

Abdel-Azeem AM (2009) Operation Wallacea in Egypt. I- A preliminary study on diversity of fungi in the world heritage site of Saint Katherine, Egypt. *Assiut University Journal of Botany* **38**: 29–54.

Abdel-Azeem AM, Abdel-Moneim TS, Ibrahim ME, Hassan MAA, Saleh MY (2007) Effect of long-term heavy metal contamination on diversity of terricolous fungi and nematodes in Egypt - a case study. *Water, Air, and Soil Pollution* **186**: 233–254.

Abdel-Aziz FA (2004) *Biodiversity of aquatic fungi, from the River Nile to the Sea*. PhD thesis, South Valley University, Egypt.

Abdel-Aziz FA (2008) Diversity of aquatic fungi on *Phragmites australis* at Lake Manzala, Egypt. *Sydowia* **60**: 1–14.

Abdel-Baky NF (2000) *Cladosporium* spp. an entomopathogenic fungus for controlling whiteflies and aphids in Egypt. *Pakistan Journal of Biological Sciences* **3**: 1662–1667.

Abd El Fattah AI, Alamri S, Abou-Shanab RAI, Hafez EE (2009) Fingerprinting of *Ustilago Scitaminea* (Sydow) in Egypt Using Differential Display Technique: Chitinase Gene the Main Marker. *Research Journal of Agriculture and Biological Sciences* **5**: 674–679.

Abdel-Fattah GM (1985) *Studies on thermophilic xylan-decomposing fungi in humus*. MSc thesis Faculty of Science, Mansoura University, Egypt.

Abdel-Fattah GM (1991) *Some physiological and ecological studies on vesicular-arbuscular (VA) mycorrhizal fungi*. PhD thesis, Mansoura University, Egypt.

Abdel-Fattah GM (2001) Measurement of the viability of AM fungi colonized in roots using three different stains and its relation to growth and metabolic activities of soybean plants. *Microbiological Research* **156**: 359–367.

Abdel-Fattah GM, Mankarios AT (1995) Functional activity of *Glomus mosseae* in the protection of soybean from infection by the pathogenic fungus *Chalara elegans*. *Egyptian Journal of Microbiology* **30**: 207–305.

Abdel-Fattah GM, Rabie GH (1995) Improved growth and tolerance of cowpea to irrigation with waste effluents from fertilizer's factories using mycorrhizal fungus (*Glomus fasiculatum*). *Zagazig Journal of Pharmaceutical Sciences, Zagazig University* **4**: 87–97.

Abdel-Fattah GM, Abo-Hamed SA, Mohamed ZA (1996) *The role of VA mycorrhizal fungus (Glomus mosseae) and kinetin in alleviation of salinity stress in Pisum sativum plants. 1- Plant growth, photosynthetic pigments, nodulation, proline and nutrient contents*. 1st International conference on fungi: Hopes and Challenges. Cairo, 2–5 September 1996, Al-Azhar University, Egypt: 67–81.

Abd EL-Ghany TM, El-Taher EM, El-Sheikh HH (2009) Efficacy of fungal rust disease on Willow plant in Egypt. *Australian Journal of Basic and Applied Sciences* **3**: 1527–1539.

Abdel-Hafez SII, El-Said AHM, Maghraby TA (1995) Studies on fungi isolated from skin diseases and associated fungi of students in Qena and Red Sea Governorates, Egypt. *Assiut Bulletin of Faculty of Science, Assiut University* **24** (2-D): 181–209.

Abdel-Hak T, Abdel Rehim MF (1950) Studies on long smut of sorghum in Egypt. *Laboratory Research Committee Monthly Report, Ministry of Agriculture, Egypt. November volume*: 226–229 (in Arabic).

AbdEl-Hamed NA (2008) *Ecological, physiological and taxonomical studies on the genus Fusarium in Egypt*. MSc thesis, Faculty of Science, Assiut University, Egypt.

Abdel-Kader MI (1973) *Mucorales in Egyptian soil*. MSc thesis. Faculty of Science, Assiut University, Egypt.

Abdel-Mallek AY, Abdel-Rahman MAA (2006) *Mycopathogens of the corn leaf aphid, Rhoplosiphum maidis (Fitch.) infesting wheat plants in Assiut, Egypt*. Ninth Arab Congress of Plant Protection, 19–23 November 2006, Damascus, Syria.

Abdel-Mallek AY, Omar SA, Bagy M K (1995) Influence of licid on fungi of human hair and keratin degradation. *Journal of Islamic Academy of Sciences* **8**: 119–126.

Abdel-Mallek AY, Abdel-Rahman MAA, Hamam GHA (2003a) *Survey of entomopathogenic fungi naturally infecting cereal aphids (Homoptera: Aphididae) in southern Egypt*. Proceedings of Abstracts of the 9th European Meeting of the IOBC/WPRS Working group "Insect Pathogens and Entomopathogenic Nematodes", University Kiel, Kiel, Germany: 2.

Abdel-Mallek AY, Abdel-Rahman MAA, Omar SA, Hamam GHA (2003b) Survey of entomopathogenic fungi naturally infecting cereal aphids infesting wheat plants in Assiut. *Bulletin of Faculty of Science, Assiut University* **32**(2-D): 29–43.

Abdel-Moneim TS (2010) *Occurrence of nematophagous fungi in Ismailia Governorate, Egypt*. The first international conference

on basic and applied mycology, 9–11 March 2010, Assiut, Egypt, Abstract book: 59.

Abdel-Moneim TS, Abdel-Azeem AM (2009) Operation Wallacea in Egypt. II- Diversity of arbuscular mycorrhizal fungi in different elevation wadis in Saint Katherine Protectorate, Egypt. *Assiut University Journal of Botany* **38**: 55–74.

Abdel-Raheem AM (2002) Myxomycetes from Upper Egypt. *Microbiological Research* **157**: 47–67.

Abdel-Raheem AM (2004) Study of the effect of different techniques on diversity of freshwater hyphomycetes in the River Nile (Upper Egypt). *Mycopathologia* **157**: 59–72.

Abdel-Rahman TMA, Salama AM, Ali MIA, Tharwat HA (1990) Fibrinolytic activity of some fungi isolated from self-heated composted fertilizer. *Journal of Plant Research* **103**: 313–324.

Abdel-Salam MM (1933) Damping-off and other allied diseases of lettuce. *Journal of Pomology and Horticultural Science* **11**: 259.

Abdel-Sater MA, Eraky SA (2002) Bulbs mycoflora and their relation with three stored product mites. *Mycopathologia* **153**: 33–39.

Abdel-Wahab GHF (2002) *Studies on the mycoflora of stored food*. MSc thesis, Faculty of Science, Mansoura University, Egypt.

Abdel-Wahab MA (1996) *Studies on mangrove-inhabiting fungi of the Red Sea*. MSc thesis, Faculty of Science, South Valley University, Sohag, Egypt.

Abdel-Wahab MA (2000) *Diversity of fungi in subtropical mangroves*. PhD thesis, Faculty of Science, South Valley University, Sohag, Egypt.

Abdel-Wahab MA (2005) Diversity of higher marine fungi from Egyptian Red Sea mangroves. *Botanica Marina* **48**: 348–355.

Abdel-Wahab MA, El-Sharouny HM, Jones EBG (2001a) Two new intertidal lignicolous *Swampomyces* species from Red Sea mangroves in Egypt. *Fungal Diversity* **8**: 35–40.

Abdel-Wahab MA, El-Sharouny HM, Jones EBG (2001b) *Halosarpheia unicellularis* sp. nov. (Halosphaeriales, Ascomycota) based on morphological and molecular evidence. *Mycoscience* **42**: 255–260.

Abdel-Wahab MA, Nagahama T, Abdel-Aziz FA (2009) Two new *Corollospora* species and one new anamorph based on morphological and molecular data. *Mycoscience* **50**: 147–155.

Abdel-Wahab MA, Pang KL, Nagahama T, Abdel-Aziz FA, Jones EBG (2010) Phylogenetic evaluation of anamorphic species of *Cirrenalia* and *Cumulospora* with the description of eight new genera and four new species. *Mycological Progress*: <DOI 10.1007/s11557-010-0661-x>.

Abdul Wahid OA, Moustafa AF, Moustafa AM (1996) Fungal population in the atmosphere of Ismailia City. *Aerobiologia* **12**: 249–255.

Abou El-Seood MS (1968) *Survey of some fungal diseases of weeds and their relation to some economic crops*. MSc thesis, Faculty of Agriculture, Assiut University, Egypt.

Aboul-Eid HZ (1963) *Studies on some aspects of nematode biological control*. MSc thesis, Faculty of Agriculture, Cairo University, Egypt.

Aboul-Eid HZ, Abdel-Bari AM, Korayem HA, Noweer EA (1997a) Concomitant occurrence of nematode-antagonistic fungi and bacteria associated with prevalent nematodes in Mansouria region soils. *Egyptian Journal of Agronematology* **1**: 37–58.

Aboul-Eid HZ, Abdel-Bari AM, Ameen HA, Noweer EA (1997b) The morphological identify of tweleve nematode-antagonistic fungi and the bacterium *Pasteuria penterans* isolated from El-Mansouria region soils (Giza, Egypt). *Egyptian Journal of Agronematology* **1**: 59–76.

Aboul-Eid HZ, Hasabo SA, Noweer EMA (2006) Effect of a nematode-trapping fungus *Dactylaria brochopaga* on *Meloidogyne incognita* infesting olives and coconut palms in Egypt. *International Journal of Nematology* **16**: 65–69.

Aboulkhair KS, El-Sokkary IH (1994) Effect of salinity, boron and sodium on the growth and root infection by VAM, *Rhizobium* and *Frankia* of seedlings of three tree species. *Journal of Agricultural Sciences*, Egypt **19**: 2969–2980.

Abu El-Souod SM, Assawah S, Bedaiwy M (2000) *Survey of mushrooms and polypores fungi in Delta region of Egypt*. Proceeding of 1st International Conference of Biological Sciences (ICBS) Faculty of Science, Tanta University 7–8 May, 2000.

Adl SM, Leander BS, Simpson AGB, Archibald JM, *et al.* (2007) Diversity, nomenclature, and taxonomy of Protists. *Systematic Biology* **56**: 684–689.

Afify AS, Mahmoud MA, Emara HA, Abdelkreem KI (2009) Phenolic Compounds and COD Removal from Olive Mill Wastewater by Chemical and Biological Procedures. *Australian Journal of Basic and Applied Sciences* **3**: 1087–1095.

Agrios GN (2005) *Plant Pathology*. 5th edn. Elsevier Academic Press, London, UK.

Agwa HE (1990) *Vesicular arbuscular mycorrhizae and nodulation in some Egyptian plants*. PhD thesis, Tanta University, Egypt.

Agwa HE (2000) Arbuscular mycorrhizal fungi (*Glomales*) in Egypt. I. A field survey of Arbuscular mycorrhizal fungi associated with medicinal plants and effect of inoculation on growth of some plants. *African Journal of Mycology and Biotechnology* **8**: 1–12.

Agwa HE, Abdel-Fattah GM (2002) Arbuscular mycorrhizal fungi (Glomales) in Egypt II. An ecological view of some saline affected plants in the Deltatic Mediterranean coastal land. *Acta Botanica Hungarica* **44**: 1–17.

Agwa HE, Al-Sodany YM (2003) Arbuscular-mycorrhizal fungi (*Glomales*) in Egypt. III: Distribution and ecology in some plants in El-Omayed Biosphere Reserve. *Egyptian Journal of Biology* **5**: 19–26.

Al-Alfy SM (1995) *Ecological studies on Mucorales fungi in Ismailia Governorate*. MSc thesis. Faculty of Science, Suez Canal University, Egypt.

Al-Doory Y (1968) Theisolation of keratinophilic fungi from African soils. *Mycopathologia* **36**: 113–116.

Aleem AA (1950a) A fungus in *Ectocarpus granulosus* C. Agardh near Plymouth. *Nature* **165**: 119–120.

Aleem AA (1950b) *Phycomycetes marins* de diatomees et d'algues dans la region de Banyuls-sur-Mer (Pyrenees-Orientales). *Vie et Milieu* **1**: 421–440.

Aleem AA (1950c) *Phycomycetes marins* parasites de diatomees et d'algues. *Comptes Rendus Hebdomadaires des Seances de l'Academie des Sciences* **231**: 713–721.

Aleem AA (1952a) Marine fungi from the west coast of Sweden. *Arkiv för botanik* **2** (3): 1–31.

Aleem AA (1952b) *Olpidiopsis feldmanni* sp. nov. champignon marin parasite d'algues de la famille des Bonnemaisoniacees. C*omptes Rendus Hebdomadaires des Seances de l'Academie des Sciences* **235**: 1250–1252.

Aleem AA (1952c) Sur la présence de *Melanopsamma tregoubovii* Ollivier (Pyrénomycète) dans la Manche Occidentales. Parasite de *Dilophus fasciola* (Roth) Howe. *Bulletin du Laboratoire Maritime de Dinard* **36**: 21–24.

Aleem AA (1953) Marine fungi from the west-coast of Sweden. *Arkiv för Botanik* **2, 3**: 1–33, 2 pls.

Aleem AA (1962) Marine fungi from the White Sea. *Botanicheskii Zhurnal SSSR* **47**: 1582–1595. Akademia Nauk, Moscow and Leningrad, USSR.

Aleem AA (1974) Marine fungi from Romania. *Cercetari Marine, Institutul Roman de Cercetari Marine, Constanta* **7**: 27–55.

Aleem AA (1975) Marine fungi from Rumania. *Rapport Commission International pour l'exploration scientifique de la Mer Mediterranee* **23**: 73–74.

Aleem AA (1978) New records of marine fungi from the Red Sea. *Bulletin Faculty of Science, King Abdel-Aziz University, Jeddah* **2**: 131–132.

Aleem AA (1980a) *Pythium marinum* Sparrow (Phycomycetes) infesting *Porphyra leucosticta* Thuret in the Mediterranean Sea. *Botanica Marina* **23**: 405–407.

Aleem AA (1980b) Distribution and ecology of marine fungi in Sierra Leone (tropical West Africa). *Botanica Marina* **23**: 679–688.

Aleem AA , Malibari AA (1981) Studies in tropical marine fungi I. Mangrove fungi from Sierra Leone (West Africa). 1. Deuteromycetes. *Bulletin Faculty of Science, King Abdul Aziz University, Jeddah* **5**: 51–58.

Ali Hassanein MDE, Morsi AAE, El-Sherif MAE (1972) *Annotated bibliography of agricultural studies conducted in Egypt*. Part one (1900–1970).

Ali AHH (1994) Studies on some fungal nematode antagonists in relation to nematode egg hatching and reproduction. *Egyptian Journal of Biological Pest Control* **4**: 57–65.

Ali AHH (1995) *Chaetomium spirale* a potential fungus as a biocontrol agent for the reniform nematode on cotton. *Egyptian Journal of Biological Pest Control* **5**: 55–60.

Ali AHH, Barakat MLE (1994) Utilization of *Trichoderma harzianum* as a biological agent against root-knot nematode *Meloidogyne incognita*. *Egyptian Journal of Biological Pest Control* **4**: 67–77.

Ali FU, Ibrahim ZM (2008) Production and some properties of fibrinolytic enzyme from *Rhizomucor miehei* (Cooney & Emerson) Schipper. *Journal of Applied Sciences Research* **4**: 892–899.

Ali MAM (2003) *Biological and ecological studies of certain pets of honey bee*. PhD thesis. Faculty of Agriculture, Ain Shams University, Cairo, Egypt.

Alves A, Crous PW, Correia, A, Phillips AJL (2008) Morphological and molecular data reveal cryptic speciation in *Lasiodiplodia theobromae*. *Fungal Diversity* **28**: 1–13.

Amin WA, Mostafa FAM (2000) Management of *Meloidogyne incognita* infecting sunflower by integration of *Glomus mosseae* with *Trichoderma viride, T. harzianum* and *Arthrobotrys oligospora*. *Egyptian Journal of Agronematology* **4**: 21–30.

Arthur J (2000) *Mushrooms and mankind: the impact of mushrooms on human consciousness and religion*. Book tree, Escondido, California, USA.

Ashour EH, Mostafa FAM (1999) Effect of certain heavy metals on *Meloidogyne* spp. on the growth effect of the nematophagous fungus, *Arthrobotrys oligospora*, trap formation, root-knot nematode infection and enzymes production. *Pakistan Journal of Biological Sciences* **2**: 515–522.

Assawah MW (1969) *Pileolaria terebinthis* on pistachio in UAR (Egypt). *Phytopathologia Mediterranea* **8**: 157–161.

Assawah MW, El-Arosi H (l960) Fungi associated with wheat, barley and maize grains. *Egyptian Journal of Botany* **3**: 64–79.

Assawah WS (1991) *Biochemical studies on some mushrooms in Egypt*. PhD thesis. Faculty of Science, Tanta University, Tanta, Egypt.

Aue R, Müller E (1967) Vergleichende Untersuchungen an einigen Chaetomium Arten. *Berichte der Schweizerischen Botanischen Gesellschaft* **77**: 187–207.

AUMC (2010) *Catalogue of Culture Collection*. 2nd edn. Assiut University Mycological Center, Assiut.

Aung OM, Soytong K, Hyde KD (2008) Diversity of entomopathogenic fungi in rainforests of Chiang Mai Province, Thailand. *Fungal Diversity* **30**: 15–22.

Aveskamp MM, Gruyter J de, Crous PW (2008) Biology and recent developments in the systematics of *Phoma*, a complex genus of major quarantine significance. *Fungal Diversity* **31**: 1–18.

Badran RAM, Aly MZY (1995) Studies on the mycotic inhabitants of *Culex pipiens* collected from fresh water ponds in Egypt. *Mycopathologia* **132**: 105–110.

Bagy MMK, Abdel-Hafez AAI (1985) Mycoflora of camel and goat hairs from Al-Arish, Egypt**.** *Mycopathologia* **92**: 125–128**.**

Baka ZA, Gjaerum HG (1996) Egyptian *Uredinales*. I. Rusts on wild plants from the Nile Valley. *Mycotaxon* **60**: 291–303.

Barr DJS (1990) Phylum *Chytridiomycota*. *In: Margulis L, Corliss JO, Melkonian M, Chapman DJ (eds), Handbook of Protoctista*: 454–466. Jones & Bartlett, Boston, USA.

Bartnicki-Garcia S (1970) Cell wall composition and other biochemical markers in fungal phylogeny. *In: Harborne JB (ed.) Phytochemical Phylogeny*, 81-103, Academic Press, London, UK.

Besada WH, Yusef HM (1968) On the mycoflora of UAR soil. *Proceedings of the Egyptian Academy of Science* **21**: 103–109.

Besada WH, Yusef HM (1969) *Chaetomium mareoticum* sp. nov. *Transactions of the British Mycological Society* **52**: 502–504.

Binyamini N (1973) Coprophilous Fungi of Israel. III. *Israel Journal of Botany* **22**: 159–165.

Bishara I (1928) Cotton insects. *Ministry of Agriculture, Egypt, Monthly Report* **1**: 4.

Briton-Jones HR (1922) The smuts of millet. *Ministry of Agriculture, Egypt. Technical Series Bulletin* **18**: 1–9.

Briton-Jones HR (1923) A wound parasite of cotton bolls. *Ministry of Agriculture, Egypt.Technical Series Bulletin* **19**: 1–8.

Briton-Jones HR (1925) Mycological work in Egypt during the period 1920–1922. *Ministry of Agriculture, Egypt. Technical Series Bulletin* **49**: 1–129.

Brusca RC, Brusca GJ (2003) *Invertebrates*. 2nd edn. Sinauer Associates, Sunderland, Massachusetts, USA.

Budge, EAW (1967) *The Egyptian Book of the Dead (the papyrus of Ani)*. Dover Publications, Mineola, New York, USA.

Cavalier-Smith T (1998) A revised six-kingdom system of life. *Biological Review* **73**: 203–266.

Cavender JC, Landolt JC, Ndiritu GG, Stephenson SL (2010) Dictyostelid cellular slime moulds from Africa. *Mycosphere* **1**: 147–152.

Chen C (1999) *Genetical and molecular systematic study on the genus Montagnea Fr., a desert adapted Gasteromycete.* MSc thesis Virginia Polytechnic Institute and State University, USA.

Crous PW (2009) Taxonomy and phylogeny of the genus *Mycosphaerella* and its anamorphs. *Fungal Diversity* **38**: 1–24.

Crous PW, Rong IH, Wood A, Lee S, Glen H, Botha W, Slippers B, Beer WZ de, Wingfield MJ, Hawksworth DL (2006) How many species of fungi are there at the tip of Africa? *Studies in Mycology* **55**: 13–33.

Damm U, Woudenberg JHC, Cannon PF, Crous PW (2009) *Colletotrichum* species with curved conidia from herbaceous hosts. *Fungal Diversity* **39**: 45–87.

Delile AR (1813a) *Flore d'Egypte*. Paris.

Delile AR (1813b) *Florae aegyptiacae illustratio*. Paris.

El-Abyad MS (1997) *Biodiversity of Fungal Biota in Egypt. Up-dated check-list*. [Publication of National Biodiversity Unit No. 7.] Egyptian Environmental Affairs Agency.

El-Abyad MS, Abu-Taleb A (1993) II-Soil Fungi. Ecology of fungal flora. In: *Publication of National Biodiversity Unit.* No. 1. *Habitat Diversity*: 237–262. Egyptian Environmental Affairs Agency, Egypt.

El-Desouky SM, El-Wakil AA (2003) Occurrence of *Monosporascus* root rot and vine decline of cantaloupe and watermelon in Egypt. *Egyptian Journal of Phytopathology* **31**: 141–150.

El-Fallal AA (2003) Agaricales from the countryside and grasslands of East Delta region, Egypt. *Journal of Environmental Sciences* **26**: 339–352.

El-Fallal AA, Khedr AA [undated] *Podaxis pistillaris* (Lin. ex. Press) Fr., an edible gasteromycete, from Zaranik protected area, North Sinai, Egypt. <www.mans.eun.eg/FacSciD/arabic/PCVS/79069.htm>.

El-Fallal AA, El-Diasty GG (2006) Evaluation of Egyptian white-rot fungi for their ability to produce ligninolytic enzymes and decolorization of Poly R. *Bulletin of Faculty of Science, El-Minia University* **17**: 1–44.

El-Hady MM (2004) Susceptibility of the citrus brown mite, *Eutetranychus orientalis* (Klein) to the entomopathogenic fungi, *Verticillium lecanii* and *Metarhizium anisopliae*. *Egyptian Journal for Biological Pest Control* **14**: 409–410.

El-Helaly A, Ibrahim I, Assawah M, El-Arosi H, Abou El-Dahab M, Michael S, Abdel-Rahim M (1963) General Survey of plant diseases and pathogenic organisms in the UAR (Egypt) until 1962. *Alexandria Journal of Agricultural Research* **8**: 1–107.

El-Helaly A, Ibrahim I, Assawah M, El-Arosi H, Abou El-Dahab M, Michael S, Abdel-Rahim M, Wasfy EH, El-Goorani MA (1966) General Survey of plant diseases and pathogenic organisms in the UAR (Egypt) until 1965. *Alexandria Journal of Agricultural Research* **15**: 1–153.

El-Hissy FT (1974) On freshwater fungi in Egypt. *Egyptian Journal of Botany* **17**: 187–189.

El-Hissy FT, Khallil AM, El-Nagdy MA (1990) Fungi associated with some aquatic plants collected from freshwater areas at Assiut (Upper Egypt). *Journal of Islamic Academy of Sciences* **3**: 298–304.

El-Hissy FT, Khallil AM, Abdel-Raheem AA (1992) Occurrence and distribution of zoosporic fungi and aquatic hyphomycetes in Upper Egypt. *Bulletin of Faculty of Science, Assiut University* **21**(2-D): 45–64.

El-Hissy FT, El-Zayat S, Khallil AM, Massoud MS (1997) Aquatic fungi from the submerged mud of Aswan High Dam Lake. *Microbiological Research* **152**: 27–32.

El-Hissy FT, Ali EH, Abdel-Raheem AM (2004) Diversity of zoosporic fungi recovered from the surface water of four Egyptian lakes. *Ecohydrology and Hydrobiology* **4**: 77–87.

El-Kady IA, Moubasher MH (1982a). Toxigenicity and toxins of *Stachybotrys* isolates from wheat straw samples in Egypt. *Experimental Mycology*, **6**: 25–30.

El-Kady IA, Moubasher MH (1982b). Some cultural conditions that control biosynthesis of roridin E and satratoxin H by *Stachybotrys chartarum*. *Cryptogamie Mycologie* **3**: 151–162.

El-Kady IA, Moubasher AH, El-Maraghy SSM (1989). Zearalenone production by several genera of fungi other than *Fusarium*. *Egyptian Journal of Botany* **31**: 99–108.

El-Kady IA, El-Maraghy SSM, Zohri AA (1994). Mycotoxin producing potential of some isolates of *Asperigllus flavus* and *Eurotium* group from meat products. *Microbiolgical Research* **149**: 297–307.

El-Maraghy SS, Abdel-Rahman MAA, Abdel-Malek AY, Hussein KA (2006) *Natural incidence of entomopathogenic fungi isolated from soil in Assiut, Egypt*. Ninth Arab Congress of Plant Protection, 19–23 November 2006, Damascus, Syria.

El-Naghy MA, Hassan SKM, El-Komy HM (1985) Some chytrids from water streams in Minia Governorate. *Bulletin of Faculty of Science, Assiut University* **14**: 17–32.

El-Naghy MA, Hassan SKM, El-Komy HM (1987) Saprophytic rhizophlyctoid and cladochytrioid fungi from water canals in Upper Egypt. *Bulletin of Faculty of Science, El-Minia University* **1**: 77–102.

El-Saadawi WE, Shabbara HM (1999) The first report on a moss-fungus association in Egypt. *Arab Gulf Journal of Scientific Research* **17**: 221–229.

El-Shamy MMG (1996) *Studies on what rust diseases in Egypt*. PhD thesis, Faculty of Agriculture, Kafr El-Sheikh, Tanta University, Egypt.

El-Sharouny HM, Raheem AM, Abdel-Wahab MA (1998) Manglicolous fungi of the Red Sea in Upper Egypt. *Microbiological Research* **153**: 81–96.

El-Sharouny HM, Abd-Elaah GA, Abdel-Wahab MA (1999) *Fungal species isolated from algae and decayed leaves and the combined effect on salinity and temperature on three marine fungi*. Proceedings of the second International Conference on Fungi: Hopes and Challenges. Cairo, 29th Sept. – 1st Oct. 1999. Vol. I: 39–52.

El-Sharouny HM, Gherbawy YAMH, Abdel-Aziz FA (2009) Fungal diversity in brackish and saline lakes in Egypt. *Nova Hedwigia* **89**: 437–450.

El-Tanash AB (1997) *Studies on some fungi degrading tannins*. MSc thesis, Faculty of Science, Mansoura University, Egypt.

El-Zayat SA, Abdel-Azeem AM, Abdel-Moneim TS, Deyab AS (2007) Association of arbuscular mycorrhizal fungi in Southern Eastern

Desert (Wadi El-Alaqi, biosphere reserve) Aswan, Egypt. *El-Minia Science Bulletin* **18**: 158–182.

Everhart SE, Keller HW (2008) Life history strategies of corticolous myxomycetes: the life cycle, fruiting bodies, plasmodial types, and taxonomic orders. *Fungal Diversity* **29**: 1–16.

Fahmy T (1923) The production by *Fusarium solani* of a toxic excretory substance capable of causing wilting in plants. *Phytopathology* **13**: 543.

Fares CA (1986) *Studies on vesicular arbuscular mycorrhizal in Egypt*. MSc thesis, Faculty of Agriculture, Ain Shams University, Egypt.

Farghaly MSEB (2008) *Biodiversity and some physiological studies of Myxomycetes in Upper Egypt*. MSc thesis, Faculty of Science, Sohag University, Egypt.

Farghaly RM, Gherbawy YAMH, Yousef MS (2004) Contamination of meat stored in home refrigerators in Qena (Egypt). *Czech Mycology* **56**: 53–62.

Feuerer T, Hawksworth DL (2007) Biodiversity of lichens, including a world-wide analysis of checklist data based on Takhatajan's floristic regions. *Biodiversity and Conservation* **16**: 85–98.

Fletcher F (1902) Notes on two diseases of cotton. *Journal of Khedive Agricultural Society and School of Agriculture Giza, Egypt* **4**: 2.

Gad MA, Sadek S (1968) Experimental infection of *Anopheles pharoensis* larvae with *Coelomomyces indicus*. *Journal of the Egyptian Public Health Association* **43**: 387–391.

Gad MA, Sadek S, Fateen AY (1967) The occurrence of *Coelomomyces indicus* in Egypt. *United Arab Republic Mosquito News* **27**: 201–202.

Gaertner A (1954) Über das Vorkommen neiderer Erdphycomyceten in Afrika, Schweden und an einigen mitteleuropäischen Standorten. *Archiv für Mikrobiologie* **21**: 4–56.

Galun M, Garty J (1972) Lichens of north and central Sinai. *Israel Journal of Botany* **21**: 243–254.

Gherbawy YAMH (2004) Genetic variation among isolates of *Alternaria* spp. from some Egyptian crops. *Archives of Phytopathology and Plant Protection* **28**: 77–89.

Gherbawy YAMH, Abdelzaher HMA (2002) Using of RAPD-PCR for Separation of *Pythium spinosum* Sawada into two varieties: var. *spinosum* and var. *sporangiferum*. *Cytologia* **67**: 83–94.

Gherbawy YAMH, Farghaly RM (2002) Mycological studies on chicken-viscera with the aid of RAPD-PCR techniques as a tool for confirmation. *Mycobiology* **30**: 5–12.

Gherbawy YAMH, Voigt K (eds) (2010) *Molecular Identification of Fungi*. Springer, Heidelberg, Germany.

Ghoniem KEA (1985) *Studies on Powdery Mildew diseases in Egypt*. MSc thesis, Faculty of Agriculture, Kafr El-Sheikh, Tanta University, Egypt.

Groombridge B, Jenkins MD (2002) *World Atlas of Biodiversity: Earth's Living Resources in the 21st Century*. University of California Press, Los Angeles, USA.

Hafez M, Zaki FN, Moursy A, Sabbour M (1997) Biological effects of the entomopathogenic fungus *Beauveria bassiana* on the potato tuber moth *Phthorimaea operculella* (Seller). *Anzeiger für Schädlingskunde* **70**: 158–159.

Hafez YM (2008) Effectiveness of the antifungal black seed oil against powdery mildews of cucumber (*Podosphaera xanthii*) and barley (*Blumeria graminis* f.sp. *hordei*). *Acta Biologica Szegediensis* **52**: 17–25.

Haggag MW, Saker MM, Ibrahim AM (2007) Biocontrol activity and molecular characterization of three *Tilletiopsis* spp. against grape powdery mildew. *Plant Protection Bulletin* **49**: 39–56.

Hajek AE, St. Leger RJ (1994) Interactions between fungal pathogens and insect hosts. *Annual Review of Entomology* **39**: 293–322.

Hamdi A, Hassanein AM (1996) Survey of Fungal Diseases in North Egypt. *LENS Newsletter* **23(1/2)**: 52–56.

Haridy MSA (1992a) A survey of yeasts found in the air of El-Minia city, Egypt. *The Korian Journal of Mycology* **20**: 269–272.

Haridy MSA (1992b) Yeast flora of raw milk in El-Minia city, Egypt. *Cryptogamie Mycologie* **13**: 321–326.

Haridy MSA (1993a) Yeast spoilage of some soft fruits in El-Minia city, Egypt. Bulletin of the Faculty of Science, Assiut University **22**: 13–29.

Haridy MSA (1993b) Yeast microflora of some aquatic habitats in El-Minia governorate, Egypt. *Korian Journal of Mycology* **21**:127–132.

Haridy MSA (1994a) A survey of yeasts found in some plant flowers. *El-Minia Science Bulletin* **7**: 77–88.

Haridy MSA (1994b) Yeasts flora of bakeries in El-Minia city, Egypt. *El-Minia Science Bulletin* **7**: 89–98.

Haridy MSA (2002) Occurrence of yeast in cultivated soils in El-Minia city, Egypt. *Mycobiology* **30**: 27–30.

Hassan HY, Waraki SE, Madkour M, Hussein HA, Awad M, Safwat T, Youssef YA, Taha M, Hassan MN, Hammad HA (1980a) The study of mycoflora of sputum in patients with various bronchopulmonary diseases in Egypt. *Egyptian Journal of Chest Diseases and Tuberculosis* **23**: 5–18.

Hassan HY, Refai M, Youssef YA, Taha M, Hassan MN, Hammad HA, Waraki SE, Madkour M, Hussein HA, Awad M, Safwat T (1980b) Incidence of yeasts in the sputum of patients with bronchopulmonary diseases in Egypt. *Egyptian Journal of Chest Diseases and Tuberculosis* **23**: 27–32.

Hassan HY, Youssef YA, Abogamra M, Hammad HA, Refai M (1980c) Mycological and serological studies on grain worker in mill factories in Cairo Egypt. *Egyptian Journal of Chest Diseases and Tuberculosis* **23**: 33–48.

Hassan HY, El-Sarangawy A, Youssef YA, Hassan MN, Taha M, Hammad HA, Refai M (1980d) Preliminary study of mycoflora in sputum of poultry workers and screening of their sera for antifungal precipitins. *Egyptian Journal of Chest Diseases and Tuberculosis* **23**: 61–70.

Hassan HY, Youssef YA, Refai M, Taha M, Barakat E (1980e) Fungi in the air of different departments of Ain Shams Hospitals. *Ain Shams Medical Journal* **31**: 345–355.

Hassan HY, Awad M, Taha M, Youssef YA, Refai M, Hammad H, Salem A (1981) The search of fungi in pleural effusion. *Egyptian Journal of Chest Diseases and Tuberculosis* **24**: 9–18.

Hassan SKM (1991a) Chytrids in Egypt: I- Saprophytic species of the cladchytriaceae from water streams. *Cryptogamie Mycologie* **12**: 211–225.

Hassan SKM (1991b) Chytrids in Egypt: II– New records of species of *Entophlyctidaceae*. *Cryptogamie Mycologie* **12**: 227–240.

Hassan SKM (1991c) Chytrids in Egypt: III– Cellulolytic rhizophlyctoid fungi from water canals. *Bulletin of Faculty of Science, Assiut University* **19 (2–D)**: 283–298.

Hassan SKM (1991d) Chytrids in Egypt: V- Additional species and parasitic behaviour of some members. *Bulletin of Faculty of Science, El-Minia University* **4**: 89–104.

Hassan SKM **(**1993) Occurrence and distribution of Chytridiales related to some physical and chemical factors. *Acta Mycologica* **28**: 31–38.

Hassan SKM, Fadl-Allah EM (1991) Studies of some zoosporic fungi in soils of Upper Egypt. *Acta Mycologia* **27**: 157–170.

Hassan SKM, Shaban JM (1991) Common chytrids in moist soil in El–Minia during different seasons. *Bulletin of Faculty of Science, El-Minia University* **4**: 131–144.

Hassan SKM, Shoulkamy MA (1991) Chytridiaceous fungi from water streams in Upper Egypt. *Zentralblatt Mikrobiologie* **146**: 509–523.

Hawksworth DL (1991) The fungal dimension of biodiversity: magnitude, significance, and conservation. *Mycological Research* **95**: 641–655.

Hawksworth DL (2001) The magnitude of fungal diversity: the 1.5 million species estimate revisited. *Mycological Research* **105**: 1422–1432.

Hawksworth DL, Kalin-Arroyo MT (1995) Magnitude and Distribution of Biodiversity. *In: Heywood V. (ed.), Global biodiversity assessment,* 107–191. Cambridge, UK: Cambridge University Press.

Hawksworth DL, Rossman AY (1997) Where are all the undescribed fungi? *Phytopathology* **87**: 888–891.

Hawksworth DL, Kirk PM, Sutton BC, Pegler DN (1995) *Ainsworth and Bisby's Dictionary of the Fungi (8th Ed.)*. CAB International, Wallingford, UK.

Hibbett DS, Binder M, Bischoff JF, *et al.* (2007). A higher-level phylogenetic classification of the Fungi. *Mycological Research* **111**: 509-547.

Hoog GS de, Guarro J, Gene J, Figueras MJ (2000) *Atlas of Clinical Fungi.* 2nd edn. Centraalbureau voor Schimmelcultures, Baarn, The Netherlands.

Hyde KD (1996) Measuring biodiversity: diversity of microfungi in north Queensland. In: *Measuring and Monitoring Biodiversity in Tropical and Temperate Forests* (Boyle TJB, Boontawee B, eds). CIFOR, Bogor: 271–286.

Hyde KD, Sarma VV, Jones EBG (2000) Morphology and taxonomy of higher marine fungi. In: *Marine Mycology- A Practical Approach* (eds KD Hyde, SB Pointing): 172–204. [Fungal Diversity Research Series No. 1.] Fungal Diversity Press, Hong Kong.

Hyde KD, Fröhlich J, Taylor JE (1997) Diversity of ascomycetes on palms in the tropics. In: *Biodiversity of Tropical Microfungi* (ed. KD Hyde): 141–156. Hong Kong University Press, Hong Kong

Hyde KD, Gareth-Jones EB, Leaño E, Ponting AD, Vrijmoed LLP (1998) Role of fungi in marine ecosystems. *Biodiversity and Conservation* **7**: 1147–1161.

Hyde KD, Cai L, Cannon PF, *et al.* (2009) *Colletotrichum* – names in current use. *Fungal Diversity* **39**: 147–182.

Hyde KD, Bahkali AH, Moslem MA (2010) Fungi – an unusual source of cosmetics. *Fungal Diversity* **43**: 1–9.

Ibrahim RA (1995) *Studies on desert truffles*. MSc thesis, Faculty of Science, Cairo University, Cairo, Egypt.

Ishac YZ, El-Haddad ME, Daft MJ, Ramadan EM, El-Demerdash ME (1986) Effect of seed inoculation, mycorrhizal infection and organic amendment on wheat growth. *Plant and Soil* **90**: 373–382.

Ismail AE, Ghoneem KM, Elwakil MA (2009) *Puccinia pimpinellae*, a new pathogen on anise seed in Egypt. *Plant Pathology Journal* **8**: 165–169.

Ismail MA, Sabreen MS (2001) Associated mycobiota of some types of cheese and cooking butter. *Assiut Veterinary Medical Journal* **44**: 176–190.

James TY, O'Donnell K (2007) *Zygomycota. Microscopic 'Pin' or 'Sugar' Molds. Version 13 July 2007 (under construction)*. http://tolweb.org/Zygomycota/20518/2007.07.13 in The Tree of Life Web Project, <tolweb.org/>

James TY, Letcher PM, Longcore JE, Mozley-Standridge SE, Porter D, Powell MJ, Griffith GW, Vilgalys R (2006a) A molecular phylogeny of the flagellated fungi (*Chytridiomycota*) and description of a new phylum (*Blastocladiomycota*). *Mycologia* **98**: 860–871.

James TY, Kauff F, Schoch CL, *et al.* (2006 b) Reconstructing the early evolution of the fungi using a six gene phylogeny. *Nature* **443**: 818–822.

Jones EBG (2001) The forgotten fungi: facultative marine fungi. In: *8th International Marine and Freshwater Mycology Symposium*, *Hurghada, Egypt*: 13.

Jones EBG, Sakayaroj J, Suetrong S, Somrithipol S, Pang KL (2009) Classification of marine *Ascomycota*, anamorphic taxa and *Basidiomycota*. *Fungal Diversity* **35**: 1–187.

Kaewchai S, Soytong K, Hyde KD (2009) Mycofungicides and fungal biofertilizers. *Fungal Diversity* **38**: 25–50.

Karam El-Din AA, Youssef AY, Soliman AK, Elias M (1994a) Comparative serological study on Cryptococcosis. *African Journal of Mycology and Biotechnology* **2**: 125–138.

Karam El-Din AA, Youssef AY, El-Kholy EM (1994b) Prevalence of fungi in clinical specimens from patients with fever of unknown origin, leukemia and cancer. *African Journal of Mycology and Biotechnology* **2**: 139–154.

Karam El-Din AA, Youssef AY, Hassan Y (1994c) Prevalence of pathogenic yeast fungi in clinical specimens from patients with candidiasis. *African Journal of Mycology and Biotechnology* **3**: 37–47.

Karam El-Din AA, Youssef AY, Taher EM (1995) Mycotic keratitis: Seasonal, Etiological and Biochemical study. *African Journal of Mycology and Biotechnology* **3**: 133–152.

Karam El-Din AA, Youssef AY, Zaki Sh (1996) Distribution of pathogenic and potentially pathogenic fungi among soil fungal flora in Egypt. *African Journal of Mycology and Biotechnology* **4**: 23–39.

Kassas M (2002) Biodiversity: gaps in knowledge. *The Environmentalist* **22**: 43–49.

Kelley A (1950) *Mycotrophy in plants*. Chronica Botanica, Waltham, Massachsetts, USA.

Kendrick B (2000) *The Fifth Kingdom.* 3rd edn. Focus Publishing, Newbury. Massachsetts, USA.

Khalil HME (1995) *The effect of microenvironmental variation on the distribution of the macrolichens in Gebel Dalfa, North Sinai, Egypt*. MSc thesis, Faculty of Science, Suez Canal University, Egypt.

Khallil AM (2001) Ingoldian and other filamentous fungi of hot springs. *Bulletin of the Faculty of Science, Assiut University* **30** (1-D): 21–31.

Khallil AM, El-Hissy FT, Ali E (1995) Seasonal fluctuations of aquatic fungi recovered from Egyptian soil (Delta Region). *Journal of Basic Microbiology* **35**: 93–102.

Kharboush MAM (1969a) On the ecology of soil fungi. I-Distribution of the soil fungal flora in the different types of soil in the UAR. *Bulletin of Faculty of Science Alexandria University* **9**: 683–698.

Kharboush MAM (1969b) On the ecology of soil fungi. II-Some ecological aspects of the soil fungal flora in the UAR. *Bulletin of Faculty of Science Alexandria University* **9**: 699–716.

Khater HM (1989) *Survey of soil from different sites at Cairo for yeast fungi*. MSc thesis. Faculty of Science, Ain Shams University.

Kim HM, Paik S, Ra KS, Koo KB, Yun JW, Choi JW (2006) Enhanced production of exopolysaccharides by fed-batch culture of *Ganoderma resinaceum* DG-6556. *The Journal of Microbiology* **44**: 233–242.

Kirk P, Cannon PF, Minter DW, Stalpers JA (2008) *Ainsworth & Bisby's Dictionary of the Fungi.* 10th edn. CAB International, Wallingford, UK.

Kodsueb R, McKenzie EHC, Lumyong S, Hyde KD (2008a) Diversity of saprobic fungi on Magnoliaceae. *Fungal Diversity* **30**: 37–53.

Kodsueb R, McKenzie EHC, Lumyong S, Hyde KD (2008b) Fungal succession on woody litter of *Magnolia liliifera* (*Magnoliaceae*). *Fungal Diversity* **30**: 55–72.

Kohlmeyer J, Kohlmeyer E (1979*) Marine Mycology. The Higher Fungi*. Academic Press, New York, U.S.A.

Koriem AM (2003) *Light and electron microscopic study of the lichen Xanthoria Parietina infecting fruit trees in Egypt*. 8th Arab Congress of Plant Protection, 12–16 October 2003, El-Beida, Libya.

Koriem AM (2006) *First isolation and cultivation of the fungus and the alga of the lichen Xanthoria parietina infecting mango trees in Egypt*. 9th Arab Congress of Plant Protection, 19–23 November 2006, Damascus, Syria.

Kottb MR (2008) *Survey and characterization of Trichoderma and Gliocladium species and specification of their biocontrol ability*. MSc thesis, Faculty of Science, Suez Canal University, Egypt.

Kowalik R, Sadurska I (1973) Microflora of papyrus from samples of Cairo Museum. *Studies in Conservation* **18**: 1–24.

Krug JC, Khan RS, Jeng RS (1994) A new species of *Gelasinospora* with multiple germ pores. *Mycologia* **86**: 250–253.

Kruys Å, Ericson L (2008) Species richness of coprophilous ascomycetes in relation to variable food intake by herbivores. *Fungal Diversity* **30**: 73–81.

Kvas M, Marasas WFO, Wingfield BD, Wingfield MJ, Steenkamp ET (2009) Diversity and evolution of *Fusarium* species in the *Gibberella fujikuroi* complex. *Fungal Diversity* **34**: 1–21.

Lado C (1994) A checklist of myxomycetes of Mediterranean countries. *Mycotaxon* **LII**: 117–185.

Lichtwardt R (2002) *Biogeographical implications of trichomycete distributions*. (Abstract). IMC7 Book of Abstracts, p. 48.

Lundqvist N (1969) *Zygopleurage* and *Zygospermella* (*Sordariaceae* s. lat., *Pyrenomycetes*). *Botanska Notiser* **122**: 353–374.

Lundqvist N (1970) New *Podospora* (*Sordariaceae s. lat.*, *Pyrenomycetes*). *Svensk Botanisk Tidskrift* **64**: 409–420.

Lutzoni FF, Kauff CJ, Cox D, *et al.* (2004) Assembling the fungal tree of life: progress, classification, and evolution of subcellular traits. *American Journal of Botany* **91**(10): 1446–1480.

Mahmoud YAG (1999) First environmental isolation of *Cryptococcus neoformans* var. *neoformans* and var. *gatti* from the Gharbia Governorate, Egypt. *Mycopathologia* **148**: 83–86.

Malençon G (1984) *Phallus roseus* A. Delile 1813, alias *Itajahya rosea* (Delile) Ed. Fischer 1929. *Bulletin de la Société Mycologique de France* **100**: 15–33.

Mankarios AT, Abdel-Fattah GM (1994) Ecology of VA-mycorrhiza in Some Egyptian soils. *Egyptian Journal of Botany* **34**: 135–152.

Mansour MAI (2010) *Endomycorrhizal fungi as a biocontrol mean of tomato-fusarial –wilt in North Sinai*. MSc thesis, Faculty of Education, University of Suez Canal, Al-Arish, Egypt.

McNeely JA, Miller KR, Mittermeier R, Werner TB (1990) *Conserving the World's Biological Diversity*. International Union for Conservation of Nature and Natural Resources, Gland, Switzerland.

Melchers LE (1931) A check list of plant diseases and fungi occurring in Egypt. *Transactions of the Kansas Academy of Science* **34**: 41–106.

Mennicken M, Maier W, Oberwinkler F (2005) A contribution to the rust flora (*Uredinales*) on *Zygophylloideae* (*Zygophyllaceae*) in Africa. *Mycotaxon* **91**: 39–48.

Minter DW (2010) Conservation of fungi: the orphans of the Rio De Janeiro Convention. In: *The First International Conference on Basic and applied Mycology, 9–11 March 2010, Assiut, Egypt*: 22–23.

Montasir AH, Mostafa MA, Elwan SH (1956) Development of soil microflora under *Zygophylum album* L. and *Zygophylum coccinum* L. *Ain Shams Science Bulletin*, No. 1.

Moore D, Nauta MN, Evans SE, Rotheroe M (eds) (2001) *Fungal Conservation, Issues and Solutions*. Cambridge University Press, Cambridge, UK.

Morse EE (1933) A study of the genus *Podaxis*. *Mycologia* **25**: 1–33.

Morton JB, Redecker D (2001) Two new families of *Glomales*, *Archaeosporaceae* and *Paraglomaceae*, with two new genera *Archaeospora* and *Paraglomus*, based on concordant molecular and morphological characters. *Mycologia* **93**: 181–195.

Mostafa MA (1938) Mycorrhiza in *Tropaeolum majus* L. and *Phlox drummondii* Hook. *Annals of Botany* **2**: 481–490.

Mostafa MA, Gayed SK (1953) Interaction between *Trichoderma viride* and *Fusarium vasinfectum* and its possible bearing on the biological control of the cotton-wilt disease in Egypt. *Extrait du Bulletin de l'Institut d'Égypte* **35**: 191–211.

Moubasher AH (1993*) Soil fungi of Qatar and other Arab Countries*. The Scientific and Applied Research Centre, University of Qatar.

Moubasher AH , Abdel-Rahman MA, Abdel-Mallek AY, Hammam GHA (2010) Biodiversity of entomopathogenic fungi infecting cereal and cabbage aphids in Assiut. In: *The First International Conference on Basic and applied Mycology, 9–11 March 2010, Assiut, Egypt*: 34.

Mouchacca J (1977) Les champignons de la momie de Ramsès. *Comptes Rendus de l'Academie des Sciences de Paris 285*: 515–517**.**

Mouchacca J (1995) Check-list of novel fungi from the Middle East described mainly from soil since 1930. *Sydowia* **47**: 240–257.

Mouchacca J (1999) A list of novel fungi described from the Middle East, mostly from non-soil substrata. *Nova Hedwigia* **68**: 149–174.

Mouchacca J (2001a) Biodiversité des récentes découvertes fongiques, dans les états arides de l'est méditerranéen (Moyen-Orient). *Bocconea* **13**: 131–143.

Mouchacca J (2001b) New fungi described from north east Africa and other Arab countries since 1940. What conclusions could be drawn from this scientific activity? *Cairo University African Studies Review* **23**: 49–84.

Mouchacca J (2003a) Annotated basic references of novel fungal taxa introduced from the Middle East (1940–2000). *Mycotaxon* **88**: 19–40.

Mouchacca J (2003b) A selection of bibliography on the biodiversity and phytopathology of African fungi (–1994). *Cryptogamie Mycologie* **24**: 213–263.

Mouchacca J (2004) Novel fungal taxa from the arid Middle East (1940–2000): omissions from previous notes. *Cryptogamie Mycologie* **25**: 149–171.

Mouchacca J (2005) Mycobiota of the arid Middle East: check-list of novel fungal taxa introduced from 1940 to 2000 and major recent biodiversity. *Journal of Arid Environments* **60**: 359–387.

Mouchacca J (2008) Novel fungal taxa from the arid Middle East introduced prior to the year 1940. I - Non lichenized Ascomycetes. *Cryptogamie Mycologie* **29**: 365–388.

Mouchacca J (2009a) Novel fungal taxa from the arid Middle East introduced prior to the year 1940. II – Anamorphic fungi: Hyphomycetes. *Cryptogamie Mycologie* **30**: 199–222.

Mouchacca J (2009b) Novel fungal taxa from the arid Middle East introduced prior to the year 1940. III – Anamorphic fungi: Coelomycetes. *Cryptogamie Mycologie* **30**: 377–403.

Moustafa AF (2006) *Fungi of Egypt. Zygomycetes*. AUMC Descriptions, No. 1. Assiut.

Moustafa AF, Abdel-Azeem AM (2005a) *Zygopleurage zygospora* (Sepg.) Boedijn, a new record to the Egyptian Ascomycetes. *Assiut University Journal of Botany* **34**: 165–169.

Moustafa AF, Abdel-Azeem AM (2005b) The genus *Chaetomium* in Egypt. *El-Minia Science Bulletin* **16**: 235–256.

Moustafa AF, Abdel-Azeem AM (2006) Some new records to the Egyptian Ascomycetes with a provisional key to their identification. *Assiut University Journal of Botany* **35**: 87–103.

Moustafa AF, Abdel-Azeem AM (2008) *Thielavia gigaspora*, a new thermotolerant ascomycete from Egypt. *Microbiological Research* **163**: 441–444.

Moustafa AF, Abdel-Azeem AM (2010) *An annotated check-list of Egyptian Ascomycota reported from soil and other terricolous substrates.* [Unpublished data.]

Mourad AK, Zaghloul OA, Kady EL, Nemat FM, Morsy ME (2005) A novel approach for the management of the chalkbrood disease infesting honeybee *Apis mellifera* L. (Hymenoptera: Apidae) colonies in Egypt. *Communications in Agricultural and Applied Biological Sciences* **70**: 601**–**611.

Mueller UG, Rehner SA, Schultz TR (1998) The evolution of agriculture in ants. *Science* **281**: 2034–2038.

Müller J (1880a) Les lichens d'Egypte. *Revue Mycologique* **2**: 38–40.

Müller J (1880b) Enumeratio lichenum aegyptiacorum hucusque cognitorum [1]. *Revue Mycologique* **2**: 40–44.

Müller J (1880b) Enumeratio lichenum aegyptiacorum hucusque cognitorum [2]. *Revue Mycologique* **2**: 73–83.

Müller J (1884) Enumerationis lichenum aegyptiacorum. Supplement I. *Revue Mycologique, Toulouse* **6**: 15–20.

Naim MS, Mahmoud SAZ, Hussein AM (1957) Qualitative and quantitative studies on the rhizosphere microflora of some Egyptian cotton varieties. *Ain Shams Science Bulletin* **2**: 65–83.

Natrass RM (1932) Preliminary notes on some entomogenous fungi in Egypt. *Ministry of Agriculture, Egypt. Technical Series Bulletin* **120**: 1–9.

Natrass RM (1933) A new species of *Hendersonula* (*H. toruloidea*) on deciduous trees in Egypt. *Transactions of the British Mycological Society* **18**: 189–198.

Ndiritu GG, Winsett KE, Spiegel FW, Stephenson SL (2009) A checklist of African myxomycetes. *Mycotaxon* **107**: 353–356.

Nofal MA, Haggag WM (2006) Integrated management of powdery mildew of mango in Egypt. *Crop Protection* **25**: 480–486.

Nylander W (1864) Lichenes in Aegypto a cel. Ehrenberg collecti. *Actes de la Société Linnéenne de Bordeaux* **25**: 63–70.

Nylander W (1876) Lichenes in Aegypto a cel. Larbalestier collecti. *Flora* **59**: 281–285.

Olive LS, Stoianovitch C (1969) Monograph of the genus *Protostelium*. *American Journal of Botany* **56**: 979–988.

Pang KL, Abdel-Wahab MA, Sivichai S, El-Sharouny HM, Jones EBG (2002) *Jahnulales* (*Dothideomycetes*, *Ascomycota*): a new order of lignicolous freshwater ascomycetes. *Mycological Research* **106**: 1031–1042.

Petersen RH, Desjardin DE, Krüger D (2008) Three type specimens designated in *Oudemansiella*. *Fungal Diversity* **32**: 81–96.

Phillips AJL, Oudemans PV, Correia A, Alves A (2006) Characterisation and epitypification of *Botryosphaeria corticis*, the cause of blueberry cane canker. *Fungal Diversity* **21**: 141–155.

Philp J, Selim AG (1941) Rust-resistant wheats for Egypt. *Nature* **147**: 209–209.

Ragab MA (1956) A contribution to the fungi of Egypt. *Mycologia* **48**: 167–168.

Ragab MA, Mahdi MT (1966) Studies on *Tolyposporium ehrenbergii* the cause of long smut of Sorghum in Egypt (UAR). *Mycologia* **58**: 184–191.

Raghukumar C (2002) Bioremediation of coloured pollutants by terrestrial versus facultative marine fungi. In: *Fungi in the Marine Environment* (ed. KD Hyde): 317–344. [Fungal Diversity Research Series no.7.] Fungal Diversity Press, Hong Kong.

Raghukumar C (2008) Marine fungal biotechnology: an ecological perspective. *Fungal Diversity* **31**: 19–35.

Raja HA, Ferrer A, Shearer CA (2009) Freshwater ascomycetes: a new genus, *Ocala scalariformis* gen. et sp. nov, and two new species, *Ayria nubispora* sp. nov. and *Rivulicola cygnea* sp. nov. *Fungal Diversity* **34**: 79–86.

Redecker D, Raab P (2006) Phylogeny of the *Glomeromycota* (arbuscular mycorrhizal fungi): recent developments and new gene markers. *Mycologia* **98**: 885–895.

Reichert I (1921) DiePilzflora Äegypten. *Engler's Botanischen Jahrbüchen* **56**: 595–727.

Rinaldi AC, Comandini O, Kuyper TW (2008) Ectomycorrhizal fungal diversity: separating the wheat from the chaff. *Fungal Diversity* **33**: 1–45.

Rojas C, Stephenson SL (2008) Myxomycete ecology along an elevation gradient on Cocos Island, Costa Rica. *Fungal Diversity* **29**: 117–127.

Rossman AY (2003) A strategy for an All Taxa Inventory of Fungal Biodiversity. In: *Biodiversity and Terrestrial Ecosystems*(eds CI Peng, CH): 169–194. Taipei.

Saad SI (1958) Studies in atmospheric pollen grains and fungus spores at Alexandria. *Annals of Allergy* **21**: 471.

Sabet YS (1935) A preliminary study of Egyptian soil fungi. *Bulletin of the Faculty of Science, Egyptian University, Cairo* **5**: 1–29.

Sabet YS (1936) Preliminary study of *Penicillium egyptiacum* v. Beyma. *Zentralblatt für Bakteriologie* **94**: 97–102.

Sabet YS (1938) Contributions to the study of *Penicillium egyptiacum* v. Beyma. *Transactions of the British Mycological Society* **21**: 198–210.

Sabet YS (1939a) On some fungi isolated from soil in Egypt. *Bulletin of the Faculty of Science, Fouad I University, Egyptian University, Cairo* **19**: 1–112.

Sabet YS (1939b) Cotton mycorrhiza. *Nature* **144**: 37.

Sabet YS (1940) Mycorrhizal habit in the date palm (*Phoenix dactyliferea* L.). *Nature* **145**: 782.

Sabet YS (1945) Reactions of citrus mycorrhiza to manurial treatment. *Proceeding of Egyptian Acadamy of Science* **1**: 21–28.

Salem MA, Michail SH (1980) *Inonotus psuedohisbidus* on *Populous nigra* in Egypt. *Transactions of the British Mycological Society* **74**: 107–110.

Samson RA, Evans HC, Latg JP (1988) *Atlas of Entomopathogenic fungi*. Springer, Berlin Heidelberg New York.

Sartory A, Meyer J, Tawfik Z (1939) Contribution à l'étude d'une Mucoracée, Absidia aegyptiacum n. sp., ferment alcoolique de la Bouza d'Egypte. *Comptes rendus hebdomadaires des Séances de l'Académie des Sciences, Paris* **208**: 1842–1843.

Seaward MRD, Sipman HJM (2006) An updated checklist of lichenized and lichenicolous fungi for Egypt. *Willdenowia* **36**: 537–555.

Sert HB (2009) Additions to rust and smut fungi of Turkey. *Phytoparasitica* **37**: 189-192.

Sewify G (1997) Occurrence and pathogenicity of entomopathogenic fungi in Egypt. In: *7th National conference of pest and diseases of vegetables and fruits in Egypt. Ismailia, Suez Canal University, Egypt 25–26 November 1997*: 380–395.

Sewify G, Hashem YM (2001) Effect of the entomopathogenic fungus *Metarhizium* anisopliae (Metsch.) Sorokin on cellular defence response and oxygen uptake of the wax moth *Galleria mellonella* L. (Lep., *Pyralidae*). *Journal of Applied Entomology* **125**: 533–536.

Shalaby KEEM (1999) *Physiological studies on some chitin-degrading fungi*. MSc thesis, Faculty of Science, Zagazig University, Egypt.

Shalouf HMS (1989) *Studies on fungal leaf spots of some plants in Egypt*. MSc thesis Faculty of Science, Mansoura University, Egypt.

Shearer CA, Descals E, Volkmann-Kohlmeyer B, Kohlmeyer J, Marvanová L, Padgett D, Porter D, Thorton HA, Voglmayr H, Raja HA, Schmit JP (2007) Fungal biodiversity in aquatic habitats. *Biodiversity and Conservation* **19**: 49–67.

Shearer A (1924) *Cotton wilt 3rd Annual Report, Cotton Research Board, Ministry of Agriculture. Egypt*: 37.

Sherief AA (1985) *Studies on xylan-decomposing fungi Egypt*. PhD thesis, Faculty of Science, Mansoura University, Egypt.

Sherif S, Ghanem EH, Shafik I, Mustafa EE, Abdel-Aleem MM (1991) Integrated control of wheat loose smut in Egypt. *Assiut Journal of Agricultural Science* **22**: 153–163.

Shindia AAE (1990) *Studies on fungal degradation of composts in Egypt*. PhD thesis, Faculty of Science, Zagazig University, Egypt.

Shoulkamy MA, Lucarotti CJ (1998) Pathology of *Coelomomyces stegomyiae* in larval *Aedes aegypti*. *Mycologia* **90**: 559–564.

Shoulkamy MA, Lucarotti CJ, El-Ktatny MST, Hassan SKM (1997) Factors affecting *Coelomomyces stegomyiae* infections in adult *Aedes aegypti*. *Mycologia* **89**: 830–836.

Shoulkamy MA, Abdelzaher HMA, Shahin AAB (2001) Ultrastructural changes in the muscles, midgut, hemopoietic organ, imaginal discs and Malpighian tubules of the mosquito Aedes aegypti larvae infected by the fungus *Coelomomyces stegomyiae*. *Mycopathologia* **149**: 99–106.

Sickenberger E (1901) Lichenes. *Memoires de l'Institut d'Egypte* **4**: 319–331.

Sirag El-Din A (1931) The citrus twig gum disease in Egypt. *Ministry of Agriculture, Egypt. Technical Series Bulletin* **109**: 1–16.

Simonis JL, Raja HA, Shearer CA (2008) Extracellular enzymes and soft rot decay: Are ascomycetes important degraders in fresh water? *Fungal Diversity* **31**: 135–146.

Smith D (2003) Culture collections over the world. *International Microbiology* **6**: 95–100.

Smith D, Ryan MJ, Day JG (eds) (2001) *The UK National Culture Collection Biological Resource: properties, maintenance and management*. UK National Culture Collection, Egham.

Smith SE, Read DJ (1997) *Mycorrhizal Symbiosi.* 2nd ed. Academic Press, London.

Steiner J (1893) Beiträge zur Lichenenflora Griechenlands und Egyptens. *Sitzungsberichte der Kaiserlichen Akademie der Wissenschaften* **102**: 152–176.

Steiner J (1916) Aufzählung der von J. Bornmüller im Oriente gesammelten Flechten. *Annals Naturhistorische Museum Wien* **30**: 24–39.

Stephenson SL, Stempen H (1994) *Myxomycetes: a hand book of slime molds*. Timber Press. Portland, Oregon, USA.

Stizenberger E (1890) Lichenaea Africana. *Berichte über die Tätigkeit der St. Gallischen Naturwissenschaftlichen Gesellschaft* **1888–89**: 105–249.

Stizenberger E (1891) Lichenaea Africana. *Berichte über die Tätigkeit der St. Gallischen Naturwissenschaftlichen Gesellschaft* **1889–90**: 133–268.

Sung GH, Hywel-Jones NL, Sung JM, Luangsa-Ard JJ, Shrestha B, Spatafora JW (2007) Phylogenetic classification of *Cordyceps* and the clavicipitaceous fungi. *Studies in Mycology* **57**: 5–59.

Swelim MA, Baka ZAM, El-Dohlob SM, Hazzaa MM, El-Sayed TI (1994) Mycoflora of stored poultry fodder in Egypt and their ability to produce aflatoxins. *Microbiological Research* **149**: 435–442.

Tangley L (1997) How many species are there? *US News and World Report Aug. 18, 1997.* <www.usnews.com/usnews/culture/articles/970818/archive_007681.htm>

Temina M, Wasser SP, Nevo E (2004) New records of lichenized fungi from the Near East, *Mycologia Balcanica* **1**: 139–151.

Temina M, Nevo E, Wasser SP (2005) The lichen genus *Acarospora* in Israel and its vicinity. *Nova Hedwigia* **80**: 433–451.

Teramoto Y, Yoshida S, Ueda S (2001) Characteristics of Egyptian boza and a fermentable yeast strain isolated from the wheat bread. *World Journal of Microbiology and Biotechnology* **17**: 241–243.

Thongkantha S, Lumyong S, McKenzie EHC, Hyde KD (2008) Fungal saprobes and pathogens occurrence on tissues of *Dracaena loureiri* and *Pandanus* spp. *Fungal Diversity* **30**: 149–179.

Udagawa S, Ueda S (1983) *Thermoascus aegyptiacus*. *Transactions of the Mycological Society of Japan* **24**: 135.

Vijaykrishna D, Jeewon R, Hyde KD (2006) Molecular taxonomy, origins and evolution of freshwater ascomycetes. *Fungal Diversity* **23**: 351–390.

Wannathes N, Desjardin DE, Hyde KD, Perry BA, Lumyong S (2009) A monograph of *Marasmius* (Basidiomycota) from Northern Thailand based on morphological and molecular (ITS sequences). *Fungal Diversity* **37**: 209–306.

Werner RG (1966) Notes de lichenologie libano-syrienne, VIII et egyptienne. *Bulletin de la Societe Botanique de France* **113**: 74–83.

Wheeler Q, Blackwell M (1984) *Fungus-insect Relationships*. Columbia University Press, New York.

Whittaker RH (1969) New concepts of kingdoms of organisms. *Science* **163**: 150–160.

Wilson EO (1992) *The Diversity of Life*. Harvard University Press, Cambridge, Massachusetts, USA.

Wong KMK, Goh TK, Hodgkiss IJ, Hyde KD, Ranghoo VM, Tsui CKM, Ho WH, Wong SW, Yeun TK (1998) Role of fungi in freshwater ecosystems. *Biodiversity and Conservation* **7**: 1187–1206

Wulandari NF, To-anun C, Hyde KD, Duong LM, Gruyter J de, Meffert JP, Groenewald JZ, Crous PW (2009) *Phyllosticta citriasiana* sp. nov., the cause of Citrus tan spot of *Citrus maxima* in Asia. *Fungal Diversity* **34**: 23–39.

Yousef HM (1946) The mycorrhizae of *Iris germanica* Lange and *Asparagus sperengeri* Regel. *Proceedings of Egyptian Academy of Science* **20**: 45–61.

Youssef YA, Abdou MH (1967a) Studies on fungus infection of the external ear. I. Mycological and clinical observations. *Journal of Laryngology and Otology* **81**: 401–412.

Youssef YA, Abdou MH (1967b) Studies on fungus infection of the external ear. II. On the chemotherapy of Otomycosis. *Journal of Laryngology and Otology* **81**: 1005–1012.

Youssef YA, Karam El-Din A (1988a) Airborne spore of opportunistic fungi in the atmosphere of Cairo, Egypt. I. Mould Fungi. *Grana* **27**: 89–92.

Youssef YA, Karam El-Din A (1988b) Airborne spores of opportunistic fungi in the atmosphere of Cairo Egypt. II. Yeast Fungi. *Grana* **27**: 247–250.

Youssef YA, Karam El-Din A, Mohamed A (1989) Survey of soil for human pathogenic fungi from Ismailia Governorate. Egypt. *Bulletin of Faculty of Science, Mansoura University* **16**: 153–163.

Youssef YA, Karam El-Din A, Hassanein SM (1992) Occurrence of keratinolytic fungi and related dermatophytes in soils in Cairo, Egypt. *Zentralblatt für Mikrobiologie* **147**: 80–85.

Youssef YA, Karam El-Din A, Ismail ThFM (1993) Occurrence of *Cryptococcus meningitis* in Cairo, Egypt. *African Journal of Mycology and Biotechnology* **1**: 107–115.

Yusef HM (1964) Observations on phytopathogenic fungi new to UAR (Egypt). *Journal of Botany of the United Arabic Republic* **7**: 87–94.

Zakhary JW (1979) *Studies on edible mushrooms in Egypt*. MSc Thesis, Faculty of Agriculture, Alexandria University, Egypt.

Zakhary JW, Abo-Bakr TM, El-Mahdy AR, El-Tabery SAM (1983) Chemical composition of wild mushrooms collected from Alexandria, Egypt. *Food Chemistry* **11**: 31–41.

Zaki MK (1960) *Studies on dissemination of pollen grains and spores in Cairo area*. MSc thesis, Cairo University, Egypt.

Zaki SM (2008) Molecular Identification of Phaeohyphomycosis Agents Inhabiting Natural environments in Egypt. *International Journal of Biotechnology and Biochemistry* **4**: 293–301.

Zaki SM, Mikami Y, Karam El-Din AA, Youssef YA (2005) Keratinophilic fungi recovered from muddy soil in Cairo vicinities, Egypt. *Mycopathologia* **160**: 245–251.

Zaki SM, Ibrahim N, Aoyama K, Shetaia YM, Abdel-Ghany K, Mikami Y (2009) Dermatophyte Infections in Cairo, Egypt. *Mycopathologia* **67**: 133–137.