



## Freshwater fungi from the River Nile, Egypt

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### Abstract

This study represents the first published data of freshwater fungi from the River Nile in Egypt. Knowledge concerning the geographic distribution of freshwater ascomycetes and their asexual morphs in Egypt and in the Middle East is limited. Ninety-nine taxa representing 42 sexual ascomycetes, 55 asexual taxa and two basidiomycetes were identified from 959 fungal collections recorded from 400 submerged samples. Samples were randomly collected from the River Nile, in Sohag, Egypt in the winter and summer between December 2010 and August 2014. Fifty-eight taxa (22 sexual ascomycetes and 36 asexual taxa) were collected during winter, while 60 taxa (25 sexual ascomycetes, 33 asexual taxa and two basidiomycetes) were collected in summer season. Of the 99 taxa recorded, 50 are new records for Egypt, including five new genera and 30 new species. Three new genera and ten new species were described in previous articles. Fungi recorded from the two seasons were markedly different, with only 19 species common to both winter and summer collections. Asexual fungi dominated the fungal community during the two seasons. Taxonomical placements of 33 species were confirmed by molecular data based on LSU and SSU rDNA genes. *Lolia aquatica* (14.2%) was the dominant fungus in both winter and summer collections. Other dominant fungi were: *Ceratorhiza* sp. (19.5 %) and *Limnoperdon* sp. (13 %). These two basidiomycetes were the most common taxa in the summer, while they were absent in the winter. Common fungi were *Coleophoma emperii* (9.2 %), *Zopfiella latipes* (8 %), *Discosporium tremuloides* (5.5 %), *Trematophoma lignicola* (5.5 %) and *Ophioceras commune* (5 %). Specious genera recorded from the two seasons were *Dictyosporium* (6 species), *Monodictys*-like (3 species), *Aniptodera* (3 species), *Lolia* (3 species), *Podospora* (3 species), *Zopfiella* (3 species), and two species belong to each of the following genera: *Achaetomium*, *Annulatascus*, *Lentithecium*, *Linocarpon*, *Cirrenalia*, *Ciliochora*, *Coleophoma*, *Colletogloeum*, *Clohesyomyces*, *Periconia*, *Pseudorobillarda* and *Stagonospora*.

**Key words** – asexual fungi – coelomycetes – fungal diversity – fungal ecology – phylogeny

### Introduction

Woody debris and other plant remains enter freshwater through deforestation, irrigation, water runoff during rains and via dams. Filamentous freshwater fungi play a major role in decomposition of plant remains in streams, rivers and lakes and in nutrient recycling (Hyde & Goh 1998, 1999, Wong et al. 1998, Cai et al. 2003a, b, Jones & Choeyklin 2008, Raja et al. 2012, Hyde et al. 2016). Shearer (1993) defined freshwater ascomycetes as “all ascomycetes that occur on submerged or partially submerged substrata in aquatic habitats”. Freshwater ascomycetes were commonly recorded on woody tissues (Webster 1959, Eaton & Jones 1971, Hyde & Goh 1998,

1999, Wong et al. 1998, Raja et al. 2012), with asexual morphs common on senescent and decayed leaves (Ingold 1942, Goh 1997, Sridhar & Barlocher 2000), while basidiomycetes are rarely reported on submerged wood in freshwater habitats (Nawawi & Webster 1982, Marvanova & Suberkropp 1990, Hyde & Goh 1999, Sivichai & Jones 2004, Jones et al. 2014). Freshwater ascomycetes comprise an ecological group belonging to diverse taxonomic groups that increased in number from 288 (Shearer 1993) to 660 (Shearer & Raja 2016). The current number of asexual morphs of freshwater ascomycetes stands at 573, of which only 14 belong to coelomycetes (Shearer & Raja 2016). The lignicolous freshwater fungi belong mostly to the classes Dothideomycetes and Sordariomycetes (Hyde et al. 2013, Wijayawardene et al. 2014, Jones et al. 2014, Maharachchikumbura et al. 2015, 2016), a fewer taxa belong to the classes Eurotiomycetes and Orbiliomycetes (Swe et al. 2009, Su et al. 2015), while basidiomycetes and zygomycetes have rarely been encountered on decayed wood in freshwater habitats (Hyde & Goh, 1999, Jones et al. 2014). Sordariomycetes is the largest group of freshwater ascomycetes and account for 299 out of the 660 taxa (Shearer & Raja 2016).

Pioneer studies of freshwater ascomycetes have been carried out in lakes in England (Ingold 1954, 1955). In the following years work on freshwater ascomycetes were concentrated in temperate regions (e.g. Jones & Oliver 1964, Jones & Eaton 1969, Lamore & Goos 1978, Shearer & von Bodman 1983, Shearer & Crane 1986). In 1993, only 11 taxa were reported from the tropics (Shearer 1993). During the last three decades active research have been carried out on filamentous freshwater fungi in tropical regions of the world especially in Asia-Pacific: Papua New Guinea (Hyde 1994), Australia (Hyde 1996), Brunei (Ho et al. 2001, Hyde 2002), China (Hu et al. 2013), Hong Kong (Goh & Hyde 1999, Ho et al. 1999, Tsui et al. 2000), Thailand (Hu et al. 2010, Boonyuen et al. 2011, 2012), Peru (Raja et al. 2012). There are no detailed studies in the Middle East in general and only one study of freshwater ascomycetes from Africa (South Africa, Hyde et al. 1998).

Three-quarters of the samples collected during the present study were decayed submerged stems of *Phragmites australis* which is a tall perennial cosmopolitan grass found on all continents except Antarctica (Haslam 1972). It is a colonial plant forming large monospecific stands along the margins of streams, brackish water and in marshes and ditches (Weiss 1979). There have been several studies on the aquatic fungi on *P. australis* in freshwater (Ingold 1954, 1955, Dudka 1963, Taligoola et al. 1972, Apinis et al. 1972a,b, Luo et al. 2004) and estuarine habitats (Poon & Hyde 1998, Wong & Hyde 2001, Ryckegem & Verbeken 2005, Ryckegem et al. 2007, Abdel-Aziz 2008). In Egypt, a few studies have been carried out on filamentous freshwater fungi on submerged samples from the River Nile and irrigation canals (Abdel-Aziz 2001, 2004, Abdel-Aziz 2011, El-Sharouny 2011), however, those previous thesis are M.Sc. and PhD theses and their results are not yet published. This study has been carried out to document the diversity of filamentous freshwater fungi, study their seasonal distribution and taxonomy in the River Nile, Sohag, Egypt.

## Materials & Methods

### Sample examination

A total of 400 submerged decaying samples (50 decayed wood, 50 decayed date palm rachis and 300 *Phragmites australis* culm samples) were collected randomly in four collections (100 samples each collected during December 2010, August 2012, December 2012, August 2014) along four kilometer stretch (between 26°34'13.53"N, 31°42'27.72"E and 26°32'35.41"N, 31°42'56.96"E) of the River Nile bank in Sohag City, Egypt. Samples were returned to the laboratory and incubated in plastic boxes lined with sterilized moist tissue paper at room temperature. Samples were examined periodically for fungal fruiting structures over 3 month incubation. Methods used for the preparation of materials for light microscopy have been reported by Jones and Hyde (1988). Permanent slides and herbarium materials of the fungi recorded were deposited in the author's herbarium and can be examined on request. The following data were calculated for the study site:

Table 1 Frequency of occurrence of taxa recorded at the study :

Fungi	winter	summer	Total	Host
<b><u>Ascomycota</u></b>				
<i>Achaetomium</i> sp.1	2	-	1	Ph.
<i>Achaetomium</i> sp.2	-	4	2	D., Ph.
# ** <i>Angustospora nilensis</i> Abdel-Aziz gen. et sp. nov.	1	-	0.5	D.
<i>Aniptodera aquadulcis</i> (S.Y. Hsieh, H.S. Chang & E.B.G. Jones) J. Campb., J.L. Anderson & Shearer	2	-	1	D.
<i>Aniptodera chesapeakeensis</i> Shearer & M.A. Mill	2	-	1	D.
<i>Aniptodera fusiformis</i> Shearer	2.5	-	1.2	D.
*** <i>Annulatascus nilensis</i> Abdel-Wahab & Abdel-Aziz	2.5	-	1.2	Ph.
* <i>Annulatascus</i> sp.	-	1.5	0.7	Ph.
* <i>Aquaticola</i> sp.	-	1	0.5	Ph.
<i>Chaetomium</i> sp.	-	2	1	Ph.
*** <i>Helicascus aegyptiacus</i> Abdel-Wahab & Abdel-Aziz	-	6	3	D., Ph.
<i>Jahnula aquatica</i> (Kirschst.) Kirschst	3	-	1.5	D.
* <i>Lentithecium cangshanense</i> Z.L. Luo, X.J. Su & Hyde (Microthelia)	3	-	1.5	Ph.
# ** <i>Lentithecium unicellularis</i> Abdel-Aziz sp. nov.	-	2.5	1.2	D., Ph.
* <i>Leptosphaeria</i> sp.	1.5	4	2.7	D., Ph.
* <i>Lindra</i> sp.	1	-	0.5	Ph.
* <i>Linocarpon verminosum</i> (Mont.) K.D. Hyde	2.5	-	1.2	D., Ph.
* <i>Linocarpon</i> sp.	1.5	-	0.7	D., P.
# ** <i>Lolia aquatica</i> Abdel-Aziz & Abdel-Wahab gen. et sp. nov.	13.5	15	14.2	D., Ph.
*** <i>Lolia dictyospora</i> Abdel-Aziz sp. nov.	-	1	0.5	Ph.
*** <i>Lolia</i> sp. (Coelomycete 128)	-	6.5	3.2	Ph.
<i>Lulworthia</i> sp.	1	-	0.5	D., Ph.
* <i>Massarina</i> sp.	1	-	0.5	Ph.
# ** <i>Murispora</i> sp.	1	-	0.5	Ph.
<i>Nais aquatica</i> K.D. Hyde	-	2.5	1.2	Ph.
* <i>Nectria</i> sp.	-	3.5	1.7	Ph.
# <i>Ophioceras commune</i> Shearer, J.L. Crane & W. Chen	6	4	5	Ph.
* <i>Othia</i> sp.	2.5	-	1.2	D.
* <i>Orbillia</i> sp.	-	3	1.5	Ph.
<i>Pleospora vagans</i> var. <i>aconiti</i> Gawande & D.K. Agarwal	-	3	1.5	Ph.
# ** <i>Pleurotheciella</i> sp.	-	2.5	1.2	D.
* <i>Podospora carpinicola</i> Mouch	-	3.5	1.7	D., Ph.
*** <i>Podospora</i> sp. 1	-	2.5	1.2	D.
*** <i>Podospora</i> sp. 2	-	1.5	0.7	Ph.
*** <i>Pseudoastrophaeriella</i> sp.	2.5	-	1.2	Ph.
# * <i>Pseudohalonectria lignicola</i> Minoura & Muroi	1.5	4.5	3	Ph.
* <i>Thielavia antarctica</i> Stchigel & Guarro	1.5	-	0.7	Ph.
<i>Tirisporea unicaudata</i> E.B.G. Jones & Vrijmoed	-	2	1	Ph.
# ** <i>Westerdykella</i> sp.	-	4	2	Ph.
<i>Zopfiella leucotricha</i> (Speg.) Malloch & Cain	-	5	2.5	D., Ph.
<i>Zopfiella latipes</i> (N. Lundq.) Malloch & Cain	4	12	8	D., Ph.
* <i>Zopfiella</i> sp.	-	1.5	0.7	D.

Table 1 continued

<b><u>Asexual fungi</u></b>				
# ** <i>Acroclymma</i> sp.	-	1.5	0.7	D.
<i>Alveophoma caballeroi</i> Alcalde	2.5	4.5	3.5	P.
* <i>Aoria amphistroma</i> Cif	3	5.5	4.2	P.
* <i>Ceuthospora heteromelicola</i> Nag Raj	4	-	2	D.
* <i>Chaetasbolisia erysiphoides</i> Griffon & Maubl	3.5	2.5	3	D., P.
* <i>Chaetosphaeronema hispidulum</i> (Corda) Moesz	2.5	4.5	3.5	P.
# ** <i>Cheirosporium vesiculare</i> Abdel-Aziz sp. nov.	-	1.5	0.7	D.
* <i>Ciliochora longiseta</i> (Racib.) Höhn	2.5	-	1.2	P.
* <i>Ciliochora</i> sp.	1	-	0.5	Ph.
* <i>Cirrenalia</i> sp.1	2	-	1	D., Ph.
* <i>Cirrenalia</i> sp.2	3	-	1.5	Ph.
* <i>Clohesyomyces aquaticus</i> K.D. Hyde	-	3	1.5	Ph.
# ** <i>Clohesyomyces</i> sp.	-	2.5	1.2	Ph.
* <i>Coleophoma empetri</i> (Rostr.) Petr	5	13.5	9.2	P., Ph.
* <i>Coleophoma oleae</i> (DC.) Petr. & Syd	2	5	3.5	D., Ph.
* <i>Colletogloeum obtusum</i> B. Sutton	-	3	1.5	Ph.
* <i>Colletogloeum olacis</i> B. Sutton	-	2	1	Ph.
* <i>Crandallia juncicola</i> Ellis & Sacc.	3.5	-	1.7	D., Ph.
<i>Dialaceniopsis landolphiae</i> Bat.	1.5	2.5	2	D., Ph.
# ** <i>Dictyosporella aquatica</i> Abdel-Aziz gen. et sp. nov.	-	9	4.5	Ph.
# ** <i>Dictyosporium aquaticum</i> Abdel-Aziz sp. nov.	-	5.5	2.7	P.
* <i>Dictyosporium australiense</i> B. Sutton	6	-	3	D., P.
* <i>Dictyosporium bulbosum</i> Tzean & J.L. Chen	5	-	2.5	D., P.
<i>Dictyosporium cocophyllum</i> Bat.	8	-	4	D.
<i>Dictyosporium digitatum</i> J.L. Chen, C.H. Hwang & Tzean	7	-	3.5	P.
# ** <i>Dictyosporium palmae</i> Abdel-Aziz sp. nov.	-	4	2	P.
* <i>Diplodina microsperma</i> B. Sutton	6	2.5	4.2	P., Ph.
* <i>Diplozythiella bambusina</i> Died.	2	-	1	D., P.
* <i>Discosporium tremuloides</i> (Ellis & Everh.) B. Sutton	6.5	4.5	5.5	P., Ph.
<i>Hapalosphaeria deformans</i> (Syd. & P. Syd.) Syd.	2	-	1	P.
##** <i>Koorchalomella</i> sp.	3	-	1.5	Ph.
* <i>Megalodocheium elaeidis</i> (Beeli) Deighton	1.5	-	0.7	D.
# ** <i>Myrothecium</i> sp.	-	2.5	1.2	P.
# ** <i>Monodictys</i> sp. 1 (MD1308)	1.5	4	2.7	Ph.
# ** <i>Monodictys</i> sp. 2 (MD1309)	2	10	6	Ph.
# ** <i>Monodictys</i> sp. 3 (MD1314)	1	8	5	D., Ph.
* <i>Nigrospora</i> sp.	-	2	1	Ph.
* <i>Periconia laminella</i> E.W. Mason & M.B. Ellis	2	-	1	Ph.
<i>Periconia prolifica</i> Anastasiou	2.5	-	1.2	D., Ph.
* <i>Pesotum</i> sp.	2	-	1	Ph.
* <i>Phacidiella asperulina</i> (Bubák) B. Sutton	4	-	2	Ph.
* <i>Phyllosticta</i> sp.	1.5	-	0.7	Ph.
# ** <i>Pseudorobillarda</i> sp. 1	4.5	4	4.2	Ph.

Table 1 continued

*** <i>Pseudorobillarda</i> sp. 2	2	-	1	Ph.
** <i>Sporoschisma hemipsila</i> (Berk. & Broome) Zelski, A.N. Mill. & Shearer	-	2.5	1.2	Ph.
* <i>Stagonospora anglica</i> Cunnell	5.5	-	2.7	D.
* <i>Stagonospora caricis</i> (Oudem.) Sacc.	-	1.5	0.7	Ph.
* <i>Topospora uberiformis</i> (Kunze) Fr.	-	2.5	1.2	Ph.
<i>Torula herbarum</i> (Pers.) Link	4	-	2	D., Ph.
* <i>Trematophoma lignicola</i> Petr.	3	8	5.5	D., P.
*** <i>Tricocladium</i> sp. (algae)	-	2.5	1.2	Ph.
*Unknown coelomycete MD6041	-	4.5	2.2	P., Ph.
*Unknown coelomycete MD6042	-	2.5	1.2	P., Ph.
*Unknown coelomycete MD6043	-	4	2	P., Ph.
*** Unknown orange conidia MD6055	-	3	1.5	Ph.
<b><u>Basidiomycota</u></b>				
# ** <i>Ceratorhiza</i> sp.	-	39	19.5	D., Ph.
# ** <i>Limnoperdon</i> sp.	-	26	13	D., Ph.
Number of samples collected	200	200	400	
Total number of fungal taxa	58	60	99	
Number of Ascomycetes	22	25	42	
Number of Sordariomycetes	13	17	27	
Number of Dothideomycetes	9	8	15	
Number of Asexual fungi	36	33	55	
Number of Coeleomycetes	22	20	31	
Number of Hyphomycetes	14	13	24	
Number of Basidiomycetes	-	2	2	
Total number of fungal collections	355	604	959	
Number of fungi per wood sample	1.78	3.02	2.4	
* New record				
** New species				
# supported by molecular data				
D = Dicot wood				
P = Date Palm rachis				
Ph = <i>Phragmites australis</i>				

Percentage occurrence of each fungus =  $\frac{\text{Number of collections of the fungus}}{\text{Number of samples collected}} \times 100$

Number of fungi per sample =  $\frac{\text{Total number of fungal collections}}{\text{Number of samples collected}}$

Jaccard and Sorenson similarity indices for the mycota of the two seasons were calculated according to the formulae:

Jaccard similarity index (C j) =  $j / (a + b - j)$

Sorenson similarity index (C s) =  $2j / (a + b)$

Where j = is the number of species common to both seasons, and a = the number of species in site A, with b = the number of species in site B. For both indices, values of unity indicate cases of complete similarity, and a value of zero indicates 100% dissimilarity.

Menhinick's diversity indices were calculated for the summer and winter collections according to the formula:

DMn (Menhinick's diversity index) =  $S / \sqrt{N}$

Where **S** is the total number of species and **N** is the total number of fungal collections from the site. Photographs were taken using an Olympus BX51 differential interference contrast light microscope (Olympus, Tokyo, Japan) and Optika view version 7.3.1.7 (Italy) digital imaging system. Single spore cultures of the recorded fungi were obtained according the methods described by Abdel-Wahab et al. (2016).

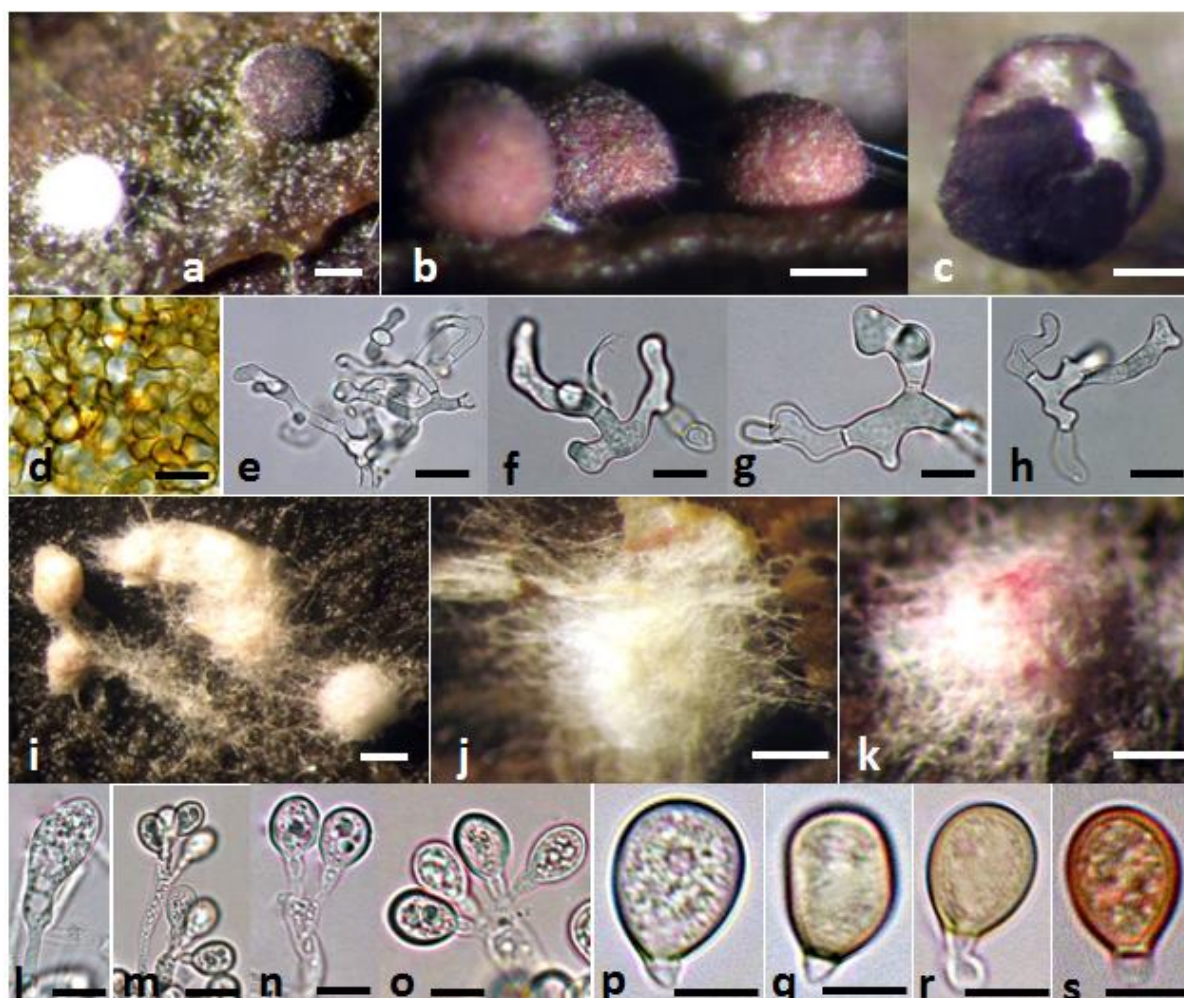
## Results

Ninety-nine taxa representing 42 sexual ascomycetes, 55 asexual taxa and two basidiomycetes were identified from 959 fungal collections recorded from 400 submerged samples. These were randomly collected from the River Nile, Sohag, Egypt in the winter and summer between December 2010 and August 2014. Of the 99 taxa recorded, 50 are new records for Egypt including five new genera and 30 new species, of which three new genera and ten new species were described in previous articles namely *Lolia aquatica* Abdel-Aziz & Abdel-Wahab (Abdel-Aziz & Abdel-Wahab 2010), *Annulatascus nilensis* Abdel-Wahab & Abdel-Aziz (Abdel-Wahab et al. 2011), *Helicascus aegyptiacus* Abdel-Wahab & Abdel-Aziz (Zhang et al. 2013), *Dictyosporium aquaticum* Abdel-Aziz (Liu et al. 2015), *Dictyosporella aquatica* Abdel-Aziz (Ariyawansa et al. 2015), *Angustospora nilensis* Abdel-Aziz (Li et al. 2016), *Lolia dictyospora* Abdel-Aziz (Abdel-Aziz 2016a), *Cheirosporium vesiculare* Abdel-Aziz and *Dictyosporium palmae* Abdel-Aziz (Abdel-Aziz 2016b) and *Lentithecium unicellularis* Abdel-Aziz (Hyde et al. 2016). Fifty-eight taxa (22 sexual ascomycetes and 36 asexual taxa) were collected during winter season, while 60 taxa (25 sexual ascomycetes, 33 asexual taxa and two basidiomycetes) were collected in summer. Fungal communities in the two seasons were markedly different, Jaccard and Sorenson similarity indices were 0.2 and 0.33 respectively which means that the similarity between the mycota at the two seasons was very low, with only 19 taxa (5 sexual ascomycetes and 14 asexual taxa) recorded consistently over the two seasons. This reflects different fungal community composition from one season to another. Menhinick's diversity indices were 3.08 and 2.44 for winter and summer collections, respectively, which indicates a higher fungal diversity during winter season. Asexual taxa dominated the fungal community in both seasons. Sexual ascomycetes (42 taxa) was the dominant fungal group followed asexual morphs. Taxonomical placements of 33 species were confirmed by molecular data based on LSU and SSU rDNA sequence data. *Lolia aquatica* (with 14.2 % total frequency of occurrence) was the dominant taxon from both winter and summer collections. Other dominant taxa were: *Ceratorhiza* sp. (19.5 %) and *Limnoperdon* sp. (13 %) (Fig. 1). These basidiomycetes were the most common fungi in summer season, while they were absent in winter. Common taxa included *Coleophoma emperti* (9.2 %), *Zopfiella latipes* (8 %), *Discosporium tremuloides* (5.5 %), *Trematophoma lignicola* (5.5 %) and *Ophioceras commune* (5 %). Specious genera recorded from the two seasons were *Dictyosporium* (6 species), *Monodictys*-like (3 species), *Aniptodera* (3 species), *Lolia* (3 species), *Podospora* (3 species), *Zopfiella* (3 species) and two taxa belonged to each of the following genera: *Achaetomium*, *Annulatascus*, *Lentithecium*, *Linocarpon*, *Cirrenalia*, *Ciliochora*, *Coleophoma*, *Colletogloeum*, *Clohesyomyces*, *Periconia*, *Pseudorobillarda* and *Stagonospora* (Table1). Of the 42 sexual ascomycetes reported in this study, 27 belong to Sordariomycetes and 15 to Dothideomycetes (Figs 2–4).

### *Fungi recorded in the winter season*

Fifty eight taxa (22 sexual ascomycetes and 36 asexual taxa) were identified from 355 fungal collection from 200 samples with an average of 1.77 species identified on each sample. The ratio of asexual taxa /ascomycetous taxa was 1.63. Frequency of occurrence of all taxa ranged from 1 to 13.5%. *Lolia aquatica* was the only frequent species (13.5%). *Dictyosporium cocophylum* (8%), *Dictyosporium digitatum* (7%), *Discosporium tremuloides* (6.5%), *Dictyosporium australiense* (6%), *Diplodina microsperma* (6%), *Ophioceras commune* (6%), *Stagonospora anglica* (5.5%), *Dictyosporium bulbosum* (5%) and *Coleophoma empetri* (5%) were occasional taxa, while 48 were recorded as rare taxa and are listed in table (1).





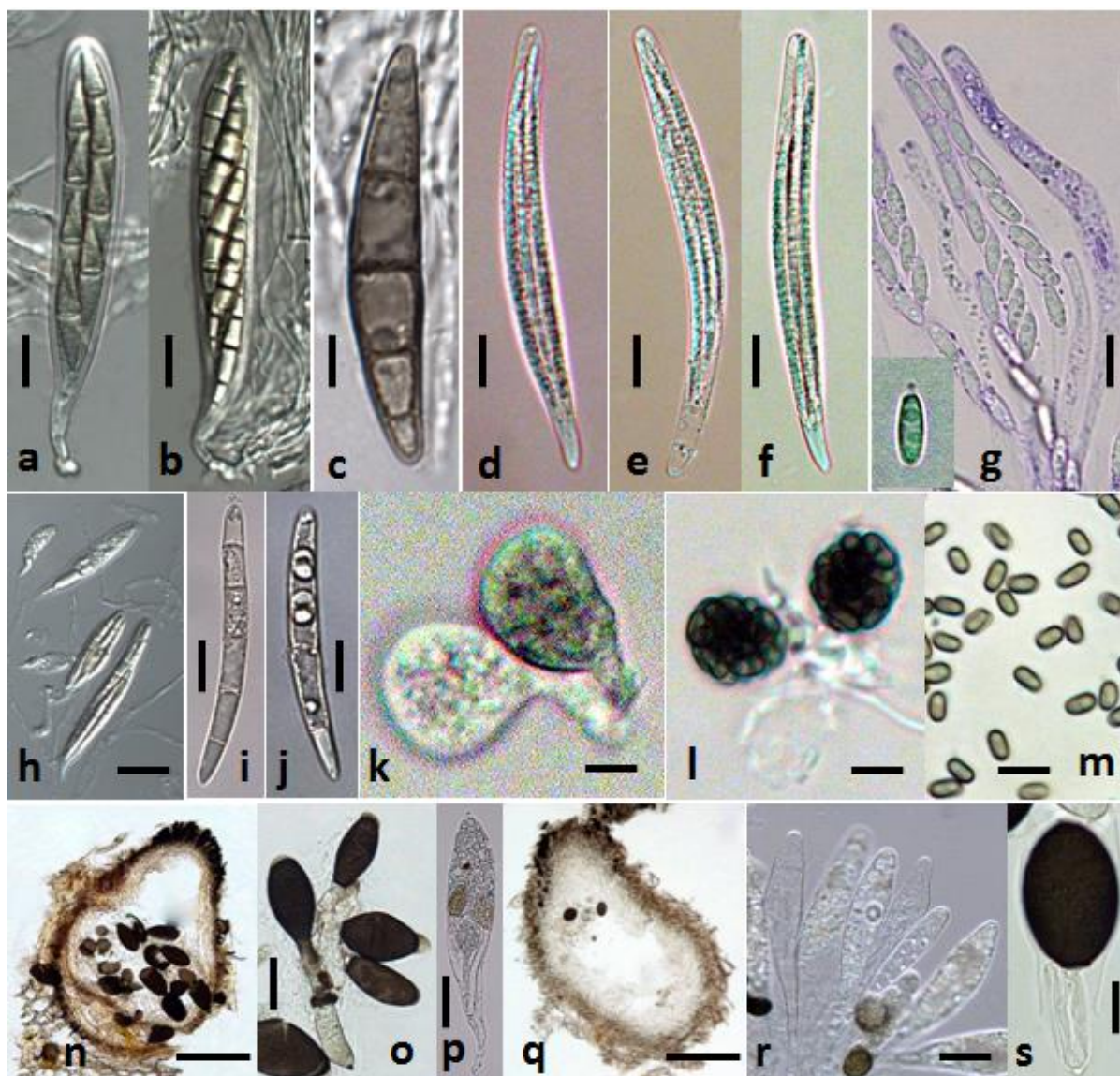
**Fig. 1 – a–h.** *Ceratorhiza* sp. a-c Sclerotia at different stages of maturation on wood. **d,c.** Surface view of the peridium. **e–h.** Branched and septate mycelia that found inside sclerotia. **i–s.** *Limnoperdon* sp. **i–k.** Basidiocarps on wood at different stages of development. **l.** Young basidium. **m–o.** Basidia and basidiospores. **p–s.** Variously shaped basidiospores. Scale bars: a–c, i–k = 200  $\mu$ m, d–h, l–s = 10  $\mu$ m.

### *Fungi recorded in the summer season*

Sixty taxa (25 sexual ascomycetes, 33 asexual taxa and two basidiomycetes) were identified from 604 fungal collections from 200 samples with an average of 3 species identified on each sample. The ratio of asexual taxa/sexual taxa was 1.22. Frequency of occurrence of all taxa ranged from 1 to 39%. *Ceratorhiza* sp. (39%) and *Limnoperdon* sp. (26%) were very frequent species and were recorded only in the summer season. *Lolia aquatica* (15%), *Coleophoma empetri* (13.5%) and *Zopfiella latipes* (12%) were frequent species and were recorded in the winter and summer. Eight species were occasional species, while 46 taxa were rare and are listed in Table 1.

### **Discussion**

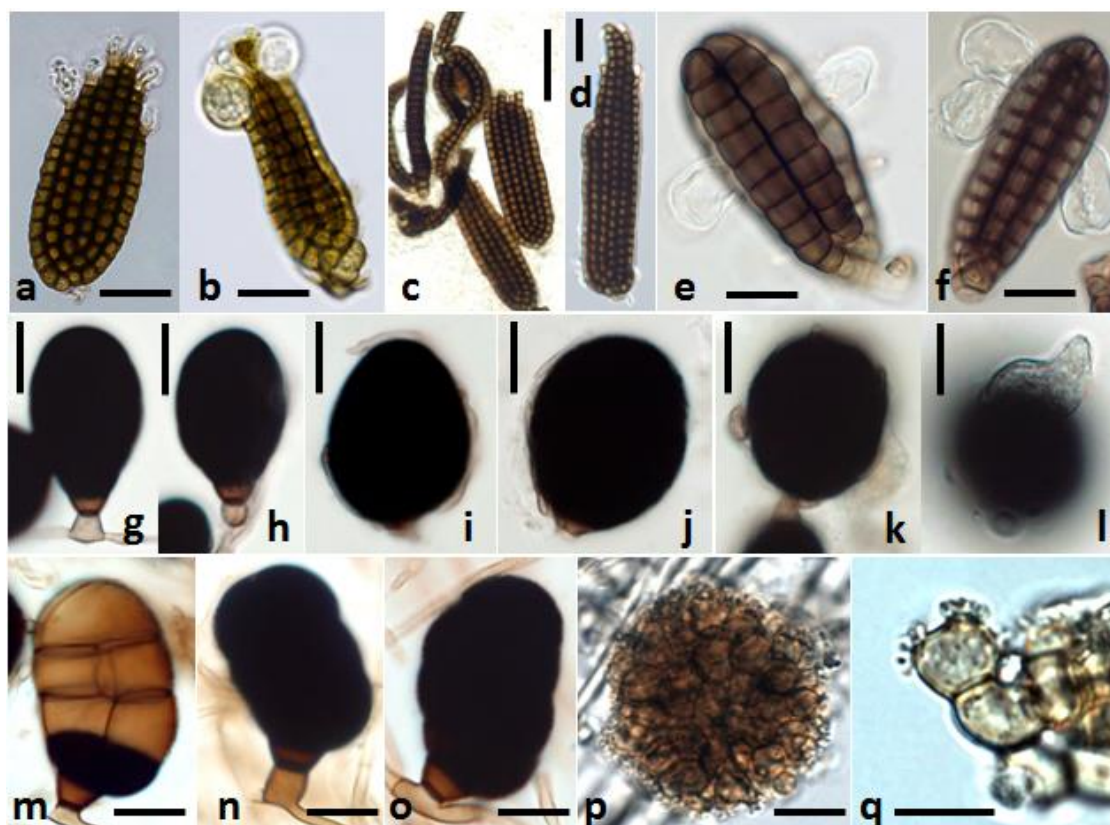
This study extends our knowledge on freshwater fungi in Egypt. A few studies have been carried out on freshwater fungi in Egypt and these include Abdel-Aziz (2001) who recorded 64 taxa from decayed wood samples collected from River Nile (Sohag, Qena and Aswan) and on wood blocks exposed at River Nile at Sohag governorate, of the 64 fungi recorded in this study only seven species were recorded in the present study. Abdel-Aziz (2004) recorded 116 (56 asexual ascomycetes and 60 asexual taxa) taxa from 668 samples collected from River Nile, irrigation canals and a high dam lake (unpublished data), of the 116 fungi recorded in this study, only 15 were recorded in this study.



**Fig. 2** – **a–c.** *Pseudoastrosphaeriella* sp. **a–b.** Asci. **c.** Ascospores. **d–f.** Asci of *Ophioceras commune*. **g.** Asci and ascospores (stained in blue) of *Aquaticola* sp. **h–j.** *Pseudohalonectria lignicola*. **h.** Asci. **i–j.** Ascospores. **k–m.** *Westerdykella* sp. **k–l.** Asci at different stages of maturity. **m** ascospores. **n–p.** *Podospora* sp.1 **n.** Vertical section through ascomata. **o.** Ascospores. **p.** Immature ascus. **q–s.** *Podospora* sp.2 **q.** Vertical section through ascomata. **r.** Immature asci. **s** Ascospore. Scale bars: a-b, h = 20  $\mu$ m, c-g, i-m = 10  $\mu$ m, n,q = 120  $\mu$ m, o,s = 10  $\mu$ m, p,r = 30  $\mu$ m.

In the present study, higher numbers of asexual taxa than sexual fungi was recorded from the two seasons (55 asexual fungi vs. 42 ascomycetes and 2 basidiomycetes). The ratios of asexual to sexual taxa were 1.63 in winter season and 1.22 in summer season. These results agree with those of Abdel-Aziz (2008) who recorded 34 asexual fungi and 26 ascomycetes from Lake Manzala (brackish water). Tsui et al. (2000) reported similar results from various freshwater habitats in Hong Kong namely: Tung Chung River (2.2 asexual: 1 sexual taxa), Hang Cho Shui and Tai Po Kau Forest Stream (2 : 1). Similar results were recorded from different parts of the world: Palmiet river, South Africa (1.1: 1) (Hyde et al. 1998), Lake Barrine, Queensland, Australia (1.5:1) (Hyde & Goh 1998) and Brunei (1.4: 1) (Ho et al. 2001). The reasons for the variation in dominance of asexual fungi over ascomycetes are unknown. Only one species of discomycete, *Orbillia* sp., was recorded in the present study, however, the occurrence of discomycetes on wood submerged in tropical and subtropical rivers is rare (Hyde et al. 2016).

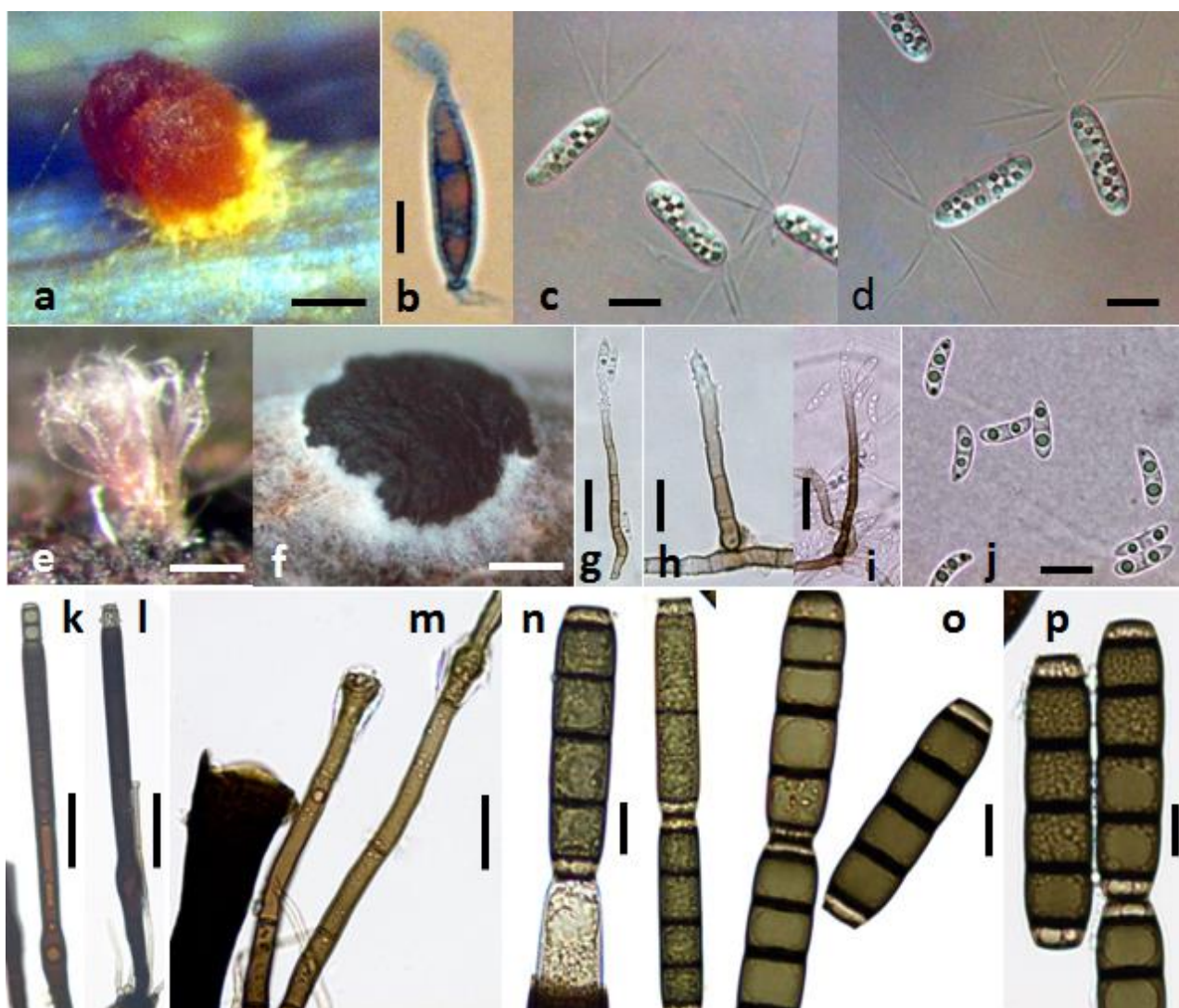




**Fig. 3** – a–b Conidia of *Dictyosporium aquaticum*. c–d. Conidia of *Dictyosporium palmae*. e–f. Conidia of *Cheirosorium vesiculare*. g–i. Conidia of *Monodictys* sp.1. j–l. Conidia of *Monodictys* sp.2. m–o Conidia of *Monodictys* sp.3. p–q. Unknown orange conidia. Scale bars: a–b, g–q = 10  $\mu$ m, c = 30  $\mu$ m.

Two new basidiomycetes species namely: *Ceratorhiza* and *Limnoperdon* were the most frequent fungi in summer. Jones et al. (2014) listed 115 Basidiomycetes from freshwater habitats, of which nine species were recorded from wood. Eleven *Ceratorhiza* species are currently described (Index Fungorum 2016). Species of *Ceratorhiza* are associated with roots and plant pathogens and the presence of species in freshwater habitats is unusual. The fungus produces white fluffy, superficial sclerotia that turn to brown to reddish dark-brown with age and contain white mass of branched and septate mycelia (Fig. 1). *Limnoperdon* species recorded in the present study represent the second species in the genus. *Limnoperdon incarnatum* G.A. Escobar was described from submerged hardwood twigs from a freshwater marsh on the shore of Union lake, Seattle, Washington, USA, and referred to the Gasteromycetes (Escobar et al. 1976). Subsequently it has been reported from wood blocks submerged in brackish water (Tubaki 1977) and paddy-field soil (Ito & Yokoyama 1979).

Thirty-one coelomycetes were recorded in the present and this is a high number of this fungal group compared to recorded results from different parts of the world. Only 14 species of coelomycetes were recorded worldwide (Shearer & Raja 2016). Thirty new fungi were recorded during the present study. This high percentage of new species might be explained by: (1) a few extensive studies have been carried out on filamentous freshwater fungi in Egypt. (2) Wood samples were exposed to direct sun light, high temperatures and low humidity level, thus samples and fungal material exposed to desiccation daily. Such condition creates a unique mycota different from those recorded from subtropical, tropical or temperate sites. Also fungal communities in temperate and tropical streams rarely overlap (Hyde & Goh 1999). Besides the water temperature, the biodiversity and communities of lignicolous freshwater fungi are affected by the structure and diversity of the riparian vegetation and the quality of stream water (Tsui et al. 2001, Vijaykrishna & Hyde 2006).



**Fig. 4** – **a–b.** *Koorchalomella* sp. **a.** Sporodochium on wood. **b.** Conidium with polar mucoid funnel-shaped appendages. **c–d.** Conidia of *Pseudorobillarda* sp.1. **e.** Sporodochium of *Murispora* sp. **f.** Sporodochium of *Myrothecium* sp. **g–j.** *Pleurotheciella* sp. **g–i.** Conidiophores. **j.** Conidia. **k–p.** *Sporoschisma hemipsila*. **k–n.** Conidiophores and conidiogenous cells. **o–p.** Conidia. Scale bars: a, e–f = 150 µm, b–d, g–j, n–p = 10 µm, k–l = 150 µm, m = 15 µm.

Of the 42 ascomycetes reported in this study, 27 belong to Sordariomycetes and 15 to Dothideomycetes. Higher percentages of the two classes were recorded from freshwater habitats around the globe (Hyde et al. 2016). Sordariomycetes represented around 60% of total ascomycetes in China (Hu et al. 2013) and 45% worldwide (Shearer & Raja 2016), while Dothideomycetes comprised around 34% worldwide (Shearer & Raja 2016). Dominance of Sordariomycetes and Dothideomycetes in freshwater might be explained by their abilities to produce superficial to immersed ascomata with gelatinous centrum, active ascospores dispersal and their ascospores equipped with elaborated appendages or gelatinous sheaths (Hyde and Goh 2003).

#### **Fungi on *Phragmites australis***

During the present study, sixty-nine taxa representing 32 ascomycetes, 35 asexual taxa and two basidiomycetes were identified from 300 submerged samples of *P. australis* during the two seasons. Shearer (1993) listed 34 freshwater ascomycetes from submerged portions of *P. australis* and that increased to 50 (47 ascomycetes and 3 asexual fungi) (Shearer & Raja 2016). Eighty-one taxa were recorded from *P. australis* in temperate regions (England) (Apinis et al. 1972a,b, Taligoola et al. 1972), of which only 23 species were listed by Shearer (1993) as freshwater fungi.



Luo et al. (2004) identified 21 fungi (8 ascomycetes and 13 asexual taxa) from 100 samples of *P. australis* collected from Lake Dianchi, a heavily polluted lake in Yunnan, China with only two species were common to this study namely: *Pseudohalonectria lignicola* and *Sporoschisma hemipsila*. Abdel-Aziz (2008) identified 60 taxa (26 ascomycetes and 34 asexual taxa) from 300 decayed samples of *P. australis* collected from Lake Manzala, a brackish lake in northern Egypt. Eight fungi were common to this study and Lake Manzala namely: *Aniptodera aquadulcis*, *A. fusiformis*, *Nais aquatica*, *Zopfiella leucotricha*, *Alveophoma caballerai*, *Dialaceniopsis landophiae*, *Hapalosphaeria deformans* and *Periconia prolifica* (Table 1).

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