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NOTES ON AQUATIC CONIDIAL FUNGI IN TWO WATER AREAS AT ASSIUT (UPPER EGYPT)

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The current study aimed to explore the biodiversity of water-borne spora of Ingoldian mycobiota from mixed submerged plant litter and surface water of two water areas at Assiut (Upper Egypt). Thirty-eight identified species in addition to three unidentified species and fifteen unknown fungal taxa related to twenty-five fungal genera were gathered from either submerged mixed plant litter or surface water samples collected from twenty water sites at Nile River and El-Ibrahimia canal at Assiut (10 sites for each). Of these fungi, twenty-one identified species, two isolates were identified on only genus level in addition to 14 unknown fungal taxa are new records for Egypt. The samples collected from the Nile River were the richest and highest diversity (38 identified species, 3 unidentified species which belong to 25 genera in addition to 14 unknown taxa) in comparison with those collected from the El-Ibrahimia canal (19 identified species and one unknown taxon which belong to 7 genera only). The fungal taxa were isolated from water samples using *Ficus* leaves as substrates (baits). The monitored Ingoldian fungi varied in their occurrence frequency, diversity and abundance depending upon the sampling source and the employed substrate. *Anguillospora, Dactylella, Triscelophorus, Flagellospora* and *Lemonniera* were the most prevalent fungal genera. *Anguillospora longissima, A. rosea, Dactyllela arnaudi* and *Triscelophorus monosporus* were the commonest species. The broadest species spectra were recorded for *Dactylella* (6 species), *Anguillospora* (4 species), *Lemonniera, Pyramidospora* and *Triscelophorus* (3 species for each). The samples collected from the Nile River exhibited a higher fungal diversity and abundance than those collected from the El-Ibrahimia canal. Twenty-five species related to 18 fungal genera in addition to 14 entirely unknown fungal taxa were exclusively recovered from the Nile River but completely missed in El-Ibrahimia Canal. All fungal genera and species gathered from the El-Ibrahimia canal, except one unknown taxon, were also represented in the samples collected from the Nile River. Most of the recovered fungi exhibited variable diversity, frequency of occurrence and abundance depending upon the sampling site, water body and substrate. This work provides a checklist, description and photos of some Ingoldian fungal taxa emerged from both experimented water bodies.

Keywords: Aquatic hyphomycetes, Nile River, EL-Ibrahimia Canal, *Anguillospora*, *Pyramidospora*, *Dactylella*

INTRODUCTION

Freshwater fungi are any fungal species relying on freshwater for all or some part of their life cycle, or any species colonizing substrata that are predominantly submerged in aquatic or semi-aquatic ecosystems in nature [1, 2]. Aquatic conidial fungi (also known as aquatic hyphomycetes or Ingoldian fungi) are a polyphyletic group of true fungi [3]. Aquatic hyphomycetes began with Ingold's [4] discovery of tetraradiate and sigmoid conidia which often colonize deciduous leaves that had fallen into the streams. The term "tetraradiate fungi" has been also frequently used to name this fungal group because many species produce conidia with a radiate or star-like shape, build by a central part, from which three or four arms are projected in divergent positions [5, 6]. Ingoldian fungi have adapted to running waters by their characteristic uncommon conidial shape, which facilitates dispersal as well as adherence to submerged plant substrata. The group of Ingoldian fungi comprises fungi that produce conidia exclusively in the aquatic ecosystem or the interstitial water among soil particles. The habitats of Ingoldian fungi are preferentially streams with clean, clear and well-aerated waters, with moderate turbulence, and also reservoirs and lakes with various kinds or pollution levels. The conidia may be trapped in foam, floating on the water surface, dispersed in the water or are associated with organic decomposing substrates as leaf litter and twigs [7]. From the taxonomical point of view, the Ingoldian fungi constitute an artificial phylogenetically heterogeneous group being anamorphs of Ascomycetes and Basidiomycetes [8, 9]. Their taxonomy and identification have traditionally been based mainly on the morphology and development and morphological features of asexually produced mitospores or conidia [9, 10]. The hydrodynamic shapes of the conidia confer to these fungi a higher ability to remain suspended in the water for extended periods and improve the chances of the propagules to become attached to organic substrates, available for colonization. However, among the aquatic conidial fungi, some species produce sigmoid, fusiform, coiled and spherical conidia too, which are also dependent on the aquatic environment to complete their life cycle [10, 11]. Ingoldian fungi play pivotal roles in the biological processes of many ecosystems and nutrient recycling [1, 2]. They are responsible for the degradation of leaf litter in woodland streams [12, 13]. They colonize allochthonous and autochthonous organic matter in streams and rivers and initiate their degradation to make it a more palatable and nutritious food source to aquatic invertebrate consumers [14-16].

In endeavor to unveil the global distribution patterns of Ingoldian fungi occurring in various water areas, several studies have been conducted worldwide such as that in Germany [17, 18], UK [19], Scotland [20], Ireland [21], France [22], Hungary [23, 24], Belgium [25], Sweden [26], Poland [27, 28], Portugal [29], Austria [30], Japan [31, 32], India [33-39], Hawaii [40], China [41-43], Philipin [44], Thailand [45], Canada [46], North America [47], Brazil [48-52], Puerto Rico [53], Venezuela [54-56], Australia [57-59], Turkey [60] and Iraq [61]. Nevertheless, Cudowski *et al.* [62] stated that existing knowledge on aquatic conidial fungi is fragmentary, and it is estimated that only approximately 7 % of the total number of Ingoldian fungal species have been identified and described to date [63]. This may be ascribed to the fact that taxonomical studies are usually conducted using only microscopic methods [55, 64], which are time-consuming and only allow the identification of fungi to the rank of the genus with high accuracy, while species designations are more problematic. Despite the widespread and abundance of the Ingoldian fungi all over the world being observed from the Acrtic Pole to Equator Line [65], the least studied regions are in Africa, with the exception of Nigeria [66], South Africa [67, 68] and Libya [69] that have been largely neglected [70]. Although as more species are being described, this is no longer likely, we can conclude that the freshwater fungi are still relatively poorly studied.

With respect to Egypt, as a subtropical region and African country, knowledge concerning the occurrence and diversity of Ingoldian fungi are scarce and, in its infancy, despite the primary importance of these fungi in stream ecosystem functioning. The distribution of Ingoldian fungi in Egyptian streams was practically untouched until the pioneering work of El-Hissy *et al.* [71] and Khallil *et al.* [72]. Thus, the current investigation aims to collate the preliminary knowledge of anamorphic aquatic conidial (Ingoldian fungi) and aims to shed the light as well as improve our understanding of their occurrence and biodiversity in two water areas at Assiut Governorate (Upper Egypt).

MATERIALS AND METHODS

Sampling sites and the collected materials:

Submerged mixed plant litter and leaf samples as well as surface water samples were concomitantly collected from two water bodies (Nile River and El-Ibrahimia canal; ten samples from ten water sites for each) at Assiut Governorate (Figs. 1 A, B). Both areas of sampling are characterized by a number of general vegetation types. Submerged plant litters were gathered from the different water sites in polyethylene bags, brought to the laboratory and kept at 4°C till fungal analysis.

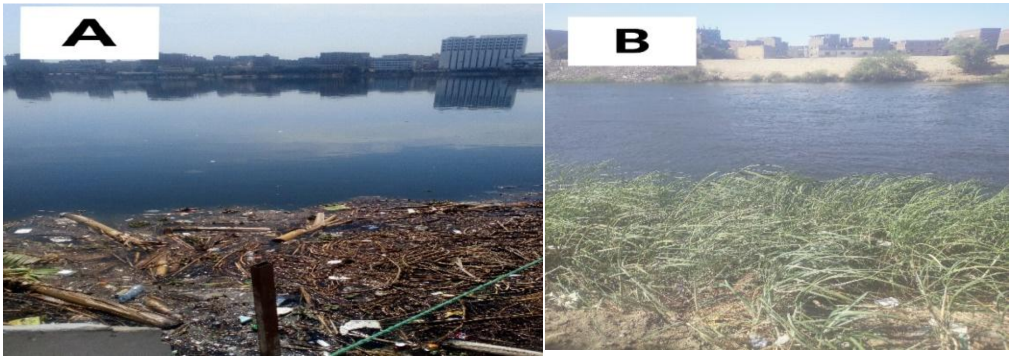


Fig. (1): Sampling sources: Nile River (A) and El-Ibrahimia Canal (B).

Water samples were also collected from the same sites using sterile bottles. The collected plant litter samples were processed using two methodological approaches (direct microscopic examination and submerged incubation). The plant litter was directly examined under a dissecting microscope for associated fungi usually on the leaves' edge or on exposed veins in areas where decaying is occurring [37], and conidial suspensions were used to prepare microscopic slides. The slides were then scanned with a compound microscope under phase contrast at magnification 10 x 40. When necessary, the objective x 100 with immersion oil was used. Submerged incubation following Bärlocher [3] was applied**,** some of the plant litters which did not show sporulating structures were vigorously washed with tap water to remove mud or other debris, then they were cut into segments of approximately 1 cm^2 and placed in Petri dishes (5 segments for each) containing sterile distilled water. The Petri dishes were incubated at 20±2 °C for 10 to 15 days during which the growing fungi were followed and identified.

Regarding the collected water samples, aliquots of water samples (about 30 ml each) were poured in 15 cm diameter Petri dishes (3 Petri dishes for each sample) containing small sterile discs of *Ficus retusa* leaves as baits [7, 52]. All treated Petri dishes were incubated at 20±2 °C for one month during which the plant segments were examined on alternate days using a light microscope to detect the conidia of hyphomycetes sporulating on the surface [5, 10]. After screening, the water in the Petri dishes was replaced by fresh sterile distilled water and the dishes were re-incubated. The hyphomycetes that developed in each sample were identified. To induce sporulation, which failed to sporulate, 10 leaf discs were placed under aeration in Erlenmeyer flasks containing 40 mL of sterile deionized water for 48 ± 4 h at 18 ºC.

To isolate a species of hyphomycetes in pure culture, single spores were identified from an inverted microscope, and these were isolated and withdrawn by micropipette, placed on 1% malt extract agar medium or Potato dextrose agar (PDA) and incubated at 20±2°C. After 24 h hyphal tips of fungal growth were transferred to further plates, and the required number of subcultures was made. Isolates were maintained on slopes of 2% malt extract agar medium and stored at 4°C and sub-cultured every 1–2 months. For the determination of the fungal population of aquatic hyphomycetes, the fungal species appearing on one water sample was counted as one colony forming unit (CFU).

Identification of Fungal Genera and Species

The recovered fungal taxa (genera and species) were identified according to the characteristic features of conidia using the following references: -

(Nilsson [73], Ingold [74], Descals and Webster [75], Marvanová and Descals [76], Descals *et al.* [77], Santos-Flores and Betancourt-López [78], González *et al.* [79], Marvanová and Bärlocher [80], Gulis *et al.* [81], Chen *et al.* [82], Bärlocher and Marvanová [83], Seifert *et al.* [84], Voglmayr [85], Fiuza and Gusmão [86], Sati *et al.* [87].

According to the characteristic features of conidia, it was able to identify directly stauroform (branched) and a few scolecoform conidia of aquatic hyphomycetes Unidentified spores may belong to other mitosporic fungi: aquatic or terrestrial, hypho- or coelomycetous. The identification of an interesting fungal taxon was confirmed using the modern molecular technique. Photographs were taken using an optical microscope coupled with a camera (Olympus SC30 U-TV1X-2, T2 Tokyo, Japan).

RESULTS AND DISCUSSION

General overview

The obtained data (Table 1) elucidate the diversity and occurrence frequency of aquatic hyphomycetes from mixed submerged substrates and surface water collected from two investigated water areas at Assiut (Upper Egypt). Thirty-eight identified species and three unidentified species related to twenty-five fungal genera in addition to fifteen unknown fungal taxa were isolated from either submerged mixed plant litters or surface water samples collected from twenty water sites at Nile River and El-Ibrahimia canal (Ten water sites for each). The diversity of Ingoldian fungi monitored during the current study was relatively higher in comparison with previous studies conducted by several authors in different geographical regions. In this respect, El-Hissy *et al.* [71] collected 35 species related to 26 genera of aquatic hyphomycetes from submerged decaying leaves collected from various Egyptian water areas. In Brazil, Schoenlein-Crusius *et al.* [48] reported 11 taxa of aquatic hyphomycetes isolated from leaves of *Quercus robus*, *Ficus microcarpa* and *Achornea triplonervi* submerged in a fast-running stream in the Atlantic rainforest of Paranapiacaba, State of São Paulo. Moreover, Khallil *et al.* [72] gathered 26 species assigning to 19 genera from water and submerged decaying leaves samples collected monthly in Egypt. Graca [88] collected only 12 aquatic fungal taxa from a river receiving strong sewage and mine pollution in Portugal. In Libya, Khallil [69] gathered 13 species of aquatic hyphomycetes from the rivulets of three hot springs. Abdel-Raheem and Ali [89] collected 26 species of aquatic hyphomycetes from unidentified plant segments in the North of Nile River (Delta region). In Iraq, Al-Saadoon and Al-Dossary [61] isolated 19 species of aquatic hyphomycetes from various plant debris collected from several locations of aquatic ecosystems. In Brazil, Fiuza *et al.* [50] isolated 15 taxa of Ingoldian fungi related to 12 genera from submerged leaves of *Calophyllum brasiliense.* In Poland, Pietryczuk *et al.* [28] gathered 23 Ingoldian fungal species from selected rivers of Central Europe, with various contaminations.

Table (1): Number of cases of isolation (NCI), and occurrence remark (OR) of aquatic hyphomyceteous fungi recovered from mixed submerged plant materials and surface water samples collected from Nile River and El-Ibrahimia Canal (Ten water sites for each).

	Nile River		**El-Ibrahimia Canal**		**Total**	
	NCI	**OR**	**NCI**	**OR**	**NCI %**	**OR**
Anguillospora *A. filiformis* Greathead *A. furtiva* Descals et Marvanova *A. longissima* Ingold *A. rosea* Descals et Marvanova	9 4 1 6 6	H M L H H	**8** 1 3 5 3	**H** L M H M	**85** **25** **20** **55** **40**	**H** **M** **L** **H** **M**
Articulospora tetracladia Ingold	**2**	**L**	**0**	**0**	**10**	**R**
Blodgettia indica * Subram, J. Ind. Bot	**1**	**L**	**0**	**0**	**5**	**R**
***Campylospora* sp**. * Fiuza & Gusmao	**2**	**L**	**0**	**0**	**10**	**R**
Clavariopsis aquatica* De Wildeman	**2**	**L**	**0**	**0**	**10**	**R**
Colispora cavincola * J. Gönczöl & Révay	**1**	**L**	**0**	**0**	**5**	**R**
Condylospora *C. gigantea** Nawawi et Kuthubuthen *C. spumigena* * Nawawi	**4** 2 2	**M** L L	**0** **0** **0**	**0** **0** **0**	**20** **10** **10**	**L** **R** **R**
Cruciger lignatilis* R. Kirschner & Oberw	**1**	**M**	**0**	**0**	**5**	**R**
Dactylella *D. arnaudi** Yadav *D. arrhenopa* * (Drechsler) K.Q. Zhang, Xing Z. Liu *D. rhombica* * Matsush *D. strobilodes** Drechsler *D. tenuifusarium** Xing Z. Liu, R.H. Gao, K.Q. Zhang & L. Cao *D. yunnanensis** K.Q. Zhang, Xing Z. Liu & L. Cao	**8** 4 3 3 3 1 1	**H** M M M M L L	**6** 5 2 1 2 0 0	**H** H L L **L** **0** **0**	**70** **45** **25** **20** **25** **5** **5**	**H** **M** **M** **L** **M** **R** **R**
Diplocladiella scalaroides * Marvanova et Barlocher	**1**	L	**0**	**0**	**5**	**R**
Fibulotaeniella canadensis * Marvanová & F.Bärlocher	**5**	H	**0**	**0**	**25**	**M**
Filosporella versimorpha * Alasoadura	**2**	M	**0**	**0**	**10**	**R**
Flabellospora verticillata * Alasoadura	**3**	M	**0**	**0**	**15**	**L**
Flagellospora *F. curvula* Ingold *F. fusirioides* Iqbal	**7** 4 3	H M M	**5** 3 4	**H** M M	**60** **35** **35**	**H** **M** **M**
Globoconidiopsis sp*	**1**	**L**	**0**	**0**	**5**	**R**
Isthmontricladia sp. Nawawi	**1**	**L**	**0**	**0**	**5**	**R**
Lemonniera *L. alabamensis* Sinclair et Morgan-Jones *L. aquatica* Dewild *L. pseudofloscula* * Dyko	**5** 2 3 2	**H** M M M	5 **2** **4** **0**	H **L** **M** **0**	**50** **20** **35** **10**	**H** **L** **M** **R**
Lunulospora curvula Ingold	**3**	**M**	**2**	**M**	**25**	**M**
Leptodiscella africana * Papendorf	**3**	**M**	**0**	**0**	**15**	**L**

Table (1): Cont.

	Nile River		El-Ibrahimia Canal		Total	
	NCI	OR	NCI	OR	NCI %	OR
Pyramidospora	**6**	**H**	**3**	**M**	**45**	**M**
P. casuarinae S.Nilsson	3	M	**3**	**M**	**30**	**M**
P. densa Alasooadura	3	M	**2**	**L**	**25**	**M**
P. quadricellularis * Oliveira, Malosso & R.F. Castañeda	1	L	**0**	**0**	**5**	**R**
Stellospora appendiculella * Alcorn & B. Sutton	**1**	**L**	**0**	**0**	**5**	**R**
Taeniospora descalsi * Marvanova et stalpers	**1**	**L**	**0**	**0**	**5**	**R**
Tetracladium marchalianum De Wild	**2**	**M**	**0**	**0**	**10**	**R**
Triscelophorus	**7**	**H**	**6**	**H**	**65**	**H**
T. monosporus Ingold	5	H	**4**	**M**	**45**	**M**
T. acuminatus * Nawawi	4	H	**2**	**M**	**30**	**M**
T. deficiens * Matsush	3	M	**1**	**M**	**20**	**L**
Volucrispora graminea Tubaki	**2**	**M**	**0**	**0**	**10**	**R**
Unkonown taxon 1	**1**	**L**	**0**	**0**	**5**	**R**
Unkonown taxon 2	**1**	**L**	**0**	**0**	**10**	**R**
Unknown taxon 3	**2**	**L**	**0**	**0**	**10**	**R**
Unknown taxon 4	**1**	**L**	**0**	**0**	**5**	**R**
Unknown taxon 5	**4**	**H**	**0**	**0**	**20**	**L**
Unknown taxon 6	**0**	**0**	**3**	**M**	**15**	**L**
Unknown taxon 7	**2**	**L**	**0**	**0**	**10**	**R**
Unknown taxon 8	**1**	**M**	**0**	**0**	**5**	**R**
Unknown taxon 9	**2**	**M**	**0**	**0**	**10**	**R**
Unknown taxon 10	**2**	**L**	**0**	**0**	**10**	**R**
Unknown taxon 11	**1**	**L**	**0**	**0**	**5**	**R**
Unknown taxon 12	**1**	**L**	**0**	**0**	**5**	**R**
Unknown taxon 13	**1**	**L**	**0**	**0**	**5**	**R**
Unknown taxon 14	**1**	**L**	**0**	**0**	**5**	**R**
Unknown taxon 15	**1**	**L**	**0**	**0**	**5**	**R**

*** New records for Egypt.**

. Occurrence Remark (OR)

H: High occurrence (More than 50 % of total samples).
M: Moderate occurrence (25 - ‹ 50 %).
L: Low occurrence (12 - ‹ 25 %).
R: Rare occurrence (Less than 12 % of total samples).

On the other side, several authors isolated a relatively higher number of species in various geographical regions worldwide. With this respect, Moro *et al.* [52] gathered 39 species from water and submerged mixed leaf litter samples from 22 waterfalls and rivers at Ilhabela State Park, municipality of Ilhabela, São Paulo State, Brazil. Conversely, a higher Ingoldian fungal diversity was recorded in Austria by Marvanová and Gulis [30] who listed 90 identified taxa and 19 unknowns. Approximately 300 species of Ingoldian fungi were thought to have been described, most from temperate regions [90]. In Hong Kong, 387 species of freshwater water fungi have been identified [91]. In Poland, Czeczuga *et al.* [92] **g**athered 65 fungal species from dead fragments of 22 species of submerged plants in different water bodies. In Portugal, a total of 113 fungal taxa were identified at least at the generic level, of which *ca*. 90% were classified as aquatic hyphomycetes [25]. In a recent revision [51] of the Brazilian Ingoldian fungi in the semiarid region, 69 taxa from tin three streams were collected.

According to available literatures, twenty-one identified (*Blodgettia indica*, *Clavariopsis aquatica*, *Colispora cavincola*, *Condylospora spumigena*, *Cruciger lignatilis*, *Dacylella arnaudi*, *D. arrhenopa*, *D. rhombica*, *D. strobilodes*, *D.tenuifusarium*, *D. yunnanensis*, *Diplocladiella scalaroides*, *Fibulotaeniella canadensis*, *Filosporella versimorpha*, *Lemonniera pseudofloscula*, *Leptodiscella africana*, *Pyramidospora quadricellularis*, *Stellospora appendiculella*, *Taeniospora descalsi*, *Triscelophorus acuminatus* and *T. deficiens*) and two unidentified species (*Campylospora sp.*, *Globoconidiopsis sp.*) in addition to 14 unknown fungal taxa are new records for Egypt (Table 1). This may be attributed to the scant information concerning Ingoldian fungi in Egypt. Thus, we propose that they have been overlooked inappropriately to date.

The monitored Ingoldian fungi varied in their occurrence frequency, diversity and abundance depending upon the sampling source and to a lesser extent on the employed substrates (Table 2 A & B). Similarly, Webster and Descals [65] stated that most aquatic hyphomycete species can colonize and grow on a wide range of substrates. Nevertheless, the relative frequencies of individual fungal species are influenced by the substrate. For instance, Bärlocher [93] elucidated that different aquatic fungal species dominate conifer needles than those that dominate deciduous leaves, and fungal communities of streams running through eucalypt stands are more similar to each other than to those running through mixed deciduous forest. Gulis [94] reported such differences when leaves are compared to wood or to grasses. Webster and Descals [65] reported that the distribution of many Ingoldian fungal species as well as their preferences regarding leaf substrate remain largely ignored. Laitung and Chauvet [95] showed that Ingoldian fungi have no specificity for leaf substrate. Thus, the response of aquatic fungal communities to changes in the diversity of riparian vegetation is, however, not fully understood.

Table (2 A): Ingoldian fungi recovered from Nile River samples according to the employed substrates.

Genera& species	**Water samples using *Ficus* leaves as baits**	**Collected grasses**	**Banana leaves**	**Mango leaves**	**Collected unidentified plant litters**
Anguillospora	+	-	-	-	+
A. filiformis	+	-	-	-	+
A. furtiva	+	-	-	-	+
A. longissima	+	-	-	-	+
A. rosea	+	-	-	-	+
Articulospora tetracladia	+	-	-	-	+
Blodgettia indica	+	-	-	-	-
***Campylospora* sp.**	+	-	+	-	+
Clavariopsis aquatica	+	-	-	-	+
Colispora cavincola	+	-	-	-	+
Condylospora	+	-	-	+	+
C. gigantea	+	-	-	+	+
C. spumigena	+	-	-	-	+
Cruciger lignatilis	+	-	-	-	+
Dactylella	+	-	-	-	-
D. arnaudi	+	-	-	-	+
D. arrhenopa	+	-	-	-	+
D. rhombica	+	-	-	-	+
D. strobilodes	+	-	-	-	+
D. tenuifusarium	+	-	-	-	+
D. yunnanens	+	-	-	-	+
Diplocladiella scalaroides	+	-	-	-	+
Fibulotaeniella canadensis	+	-	-	-	+
Filosporella versimorpha	+	-	-	-	+
Flabellospora verticillata	+	-	-	-	+
Flagellospora	+	-	-	-	+
F. curvula	+	-	-	-	+
F. fusirioides	+	-	-	-	+
***Globoconidiopsis* sp**	+	-	-	-	-
***Isthmontricladia* sp.**	+	-	-	-	+
Lemonniera	+	-	-	-	+
L. alabamensis	+	-	-	-	+
L. aquatica	+	-	-	-	+
L. pseudofloscula	+	-	-	-	+
Lunulospora curvula	+	-	+	-	-
Leptodiscella africana	+	-	-	-	+
Pyramidospora	+	-	-	-	-
P. casuarinae	+	-	-	+	+
P. densa	+	-	-	+	+
P. quadricellularis	+	-	-	+	+
Stellospora appendiculella	+	-	-	-	+
Taeniospora descalsi	+	-	-	-	+
Tetracladium marchalianum	+	-	-	-	+

Table 2 A Continued

Genera& species	Water samples using *Ficus* leaves as baits	Collected grasses	Banana leaves	Mango leaves	Collected unidentified plant litters
Triscelophorus	+	-	-	-	+
T. monosporus	+	-	-	-	+
T. acuminatus	+	-	-	-	+
T. deficiens	+	-	-	-	+
Volucrispora graminea	+	-	-	-	+
Unknown taxon 1	+	-	-	-	+
Unknown taxon 2	+	-	-	-	+
Unknown taxon 3	+	-	-	-	+
Unknown taxon 4	+	-	-	-	+
Unknown taxon 5	+	-	-	-	+
Unknown taxon 7	+	-	-	-	+
Unknown taxon 8	+	-	-	-	+
Unknown taxon 9	+	-	+	-	+
Unknown taxon 10	+	-	-	-	+
Unknown taxon 11	+	-	+	-	+
Unknown taxon 12	+	-	+	-	+
Unknown taxon 13	+	-	+	-	+
Unknown taxon 14	+	-	+	-	+
Unknown taxon 15	+	-	+	-	+

Table (2 B): Ingoldian fungi recovered from El-Ibrahimia Canal samples according to the employed substrates.

Genera and species	Water samples using *Ficus* leaves as baits	Collected grasses	Collected unidentified plant litters
Anguillospora	+	-	+
A. filiformis	+	-	+
A. furtiva	+	-	+
A. longissima	+	-	+
A. rosea	+	-	+
Dactylella	+	+	+
D. arnaudi	+	+	+
D. arrhenopa	+	+	+
D. rhombica	+	+	+
D. strobilodes	+	+	+
Flagellospora	+	-	+
F. curvula	+	-	+
F. fusirioides	+	-	+
Lemonniera	+	-	+
L. alabamensis	+	-	+
L. aquatica	+	-	+
Lunulospora curvula	+	-	+
Pyramidospora	+	+	+
P. casuarinae	+	-	+
P. densa	+	-	+
Triscelophorus	+	-	+
T. monosporus	+	-	+
T. acuminatus	+	-	+
T. deficiens	+	-	+
Unknown taxon 6	+	-	+

Occurrence and diversity of particular genera and species

Anguillospora (4 species), *Dactylella* (6 species), *Triscelophorus* (3 species), *Flagellospora* (2 species) and *Lemonniera* (3 species) were the most prevalent genera and were represented in 85%, 70.00%, 65.00%, 60.00% and 50.00% of total samples, respectively. Variable findings were recorded by some authors worldwide. In this respect, In Egypt, El-Hissy *et al.* [71] indicated that *Anguillospora* (2 species), *Triscelophorus* (2 species) and *Alatospora* (one species) were the most predominant genera of Ingoldian fungi in the Nile River at Sohag Governorate. In China, Yu and Liu [96] observed that out of 26 recovered Ingoldian fungal genera (51 species), *Tricladium* (7 spp.), *Anguillospora* (6 spp.) and *Dactylella* (6 spp.) were the most prevalent genera. Sudheep and Sridhar [35], indicated that species belonging to the genera *Anguillospora*, *Flagellospora*, *Lunulospora* and *Triscelophorus* were consistently well represented in streams. Hu *et al.* [43] recorded that *Tricladium* (7 spp.), *Anguillospora* (6 spp.), and *Dactylella* (6 spp.) were the commonest genera out of listed 26 Ingoldian fungi in China. A recent study by Khallil *et al* (2021, submitted for publication) revealed that *Anguillospora* (4, species 85% of total samples), *Dactylella* (6 species 70% of total samples), *Triscelophorus* (3 species 65% of the total sample), *Flagellospora* (2 species 60% of the total sample), *Lemonniera* (2 species 50% of total samples), *Pyramidospora* (3 species 45% of the total sample) were the most prevalent Ingoldain fungal genera in two interesting waterbodies receiving treated wastewater or industrial effluents.

Pyramidospora (3 species), *Fibulotaeniella* (one species) and *Lunulospora* (one species) appeared in moderate frequency of occurrence (45.00%, 25.00% and 25.00% of total samples, respectively). The remaining genera (Table 1) were of low or rare frequency of occurrence (5.00 – 20.00% of total samples).

Anguillospora longissima (55.00% of total samples), *A. rosea* (40.00%), *Dactyllela arnaudi* (45.00%) and *Triscelophorus monosporus* (45.00%), *Lemonniera aquatica*, *Flagellospora curvula*, *Flagellospora fusirioides* (35.00% of total samples each), *Pyramidospora casuarinae* and *Triscelophoru acuminatus* (30.00% of total samples each) were the most prevalent species (High or moderate frequency of occurrence). The remaining encountered fungal species (Table 1) were of low or rare frequency of occurrence (5.00 – 25.00% of total samples. Variable observations were recorded by many authors in different climatic regions worldwide. In this respect, Khallil *et al.* [72] recorded that *Alatospora acuminata* and *Trisclophorus monosporus* were the most prevalent species in Egypt. Similar results were obtained by Abdel-Raheem [97] who recorded that *Triscelophorus monosporus, Alatospora acuminata* and *Tetracladium marchalianum* were the major colonizers on all experimented leaf materials. Graca [88] indicated that *Tetracladium marchalianum*, *Lemonniera aquatica, Anguillospora longissima* and *Articulospora tetracladia* were the most abundant species out of 12 aquatic taxa recorded in a river receiving strong mine and sewage pollution. Sridhar *et al.* [98] recorded that *Tetracladium marchalianum* and *H. lugdunensis* were consistently among the top ranked species. In Poland, *Acrodictys elaeidicola, Anguillospora longissima, Angulospora aquatica, Lemonniera aquatica, Mirandina corticola, Tetracladium marchalianum, Tetracladium maxiliformis* and *Trinacrium subtile* were the most prevalent taxa out of collected 65 species associated with dead submerged plants [92]. Abdel-Raheem [89] indicated that out of collected 31 species, *Triscelophorus monosporus*, *Anguilospora longissima*, *Flagellospora curvula* and *Tetracladium marchalianum* were the predominant species. Abdel-Raheem and Ali [89] detected 26 species of Ingoldian fungi inhabiting unidentified plant segments collected from the North Nile River and found that *Alatospora acuminata, Anguillosporacrassa, Flagellaspora penicillioides, Lunulospra curvula, Tetracladium marchalianum* and *Triscelophorus monosporus* were the most common species. In Venezuela, out of 50 Ingoldian fungal species gathered from seven streams, *Campylospora chaetocladia, Clavatospora tentacula, Triscelophorus acuminatus* and *Triscelophorus monosporus* were the most common [56]. Sati and Pratibha [99] indicated that out of the 30 species collected from the fast-flowing stream, *Lunulospora cymbiformis, Tetracladium marchalianum* and *Triscelophorus monosporus* occur throughout the year, having maximum abundance. Schoenlein-Crusius *et al.* [100] showed that *Anguillospora crassa* and *Lunulospora curvula, Tetrachaetum elegans, Anguillospora longissimi* and *Camposporium pellucidum* were the most prevalent species. In Hungary, Vass *et al.* [24] indicated that *Anguillospora mediocris, Cylindrocarpon sp., Tetracladium marchalianum, Tricladium* sp., and an unidentified sigmoid were the commonest species during the whole study. Reports from India, Sudheep and

Sridar [101] revealed that out of 18 species, *Anguillospora longissima, Flagellospora curvula, Lunulospora curvula, Triscelophorus acuminatus, T. monosporus* and *T. konajensis* were the highest species recorded in Konaje stream. Pietryczuk *et al*. [28] found out of 23 collected taxa, *Helicoon gigantisporum, Heliscus lugdunensis*, and *Tetracladium maxilliforme* were the most prevalent in five rivers located in Central Europe (Poland). Moro *et al.* [52] in Brazil, indicated that out of 85 Ingoldian fungal species, *Anguillospora longissima* and *Flagellospora curvula* were most prevalent. Fiuza *et al.* [51] indicated that out of 69 taxa in three streams of the Rio de Contas basin in Brazil, *Triscelophorus acuminatus* was the most prevalent. Recently, Khallil *et al*. (2021, unpublished data) reported that *Lenulospora curvula* (25% of total samples), *Condylospora* (2 species 20 % of total samples), *Leptodiscella africana* (15 % of total samples), *Fibulotaeniella canadensis* (15 % of total samples), *Flabellospora vertcillatae* (15 % of total samples) which were of moderate frequency of occurrence. *Articulospora tetracladia* (10% of total samples), *Campospora* sp (10% of total samples), *Filosporela versimorpha* (10% of total samples), *Tetracladium marchalianum* (10% of total samples), *Volucrispora graminea* (10% of total samples) were of low frequency of occurrence. The fifteen unknown taxa (Table 1) were of rare or moderate frequency of occurrence (5.00- 20.00% of total samples)

In the present study the broadest species spectra were recorded for *Dactylella* (6 species), *Anguillospora* (4 species), *Lemonniera*, *Pyramidospora* and *Triscelophorus* (3 species for each). Hu and Cai [43] recorded that *Tricladium* (7 spp.), *Anguillospora* (6 spp.), and *Dactylella* (6 spp.) were the highest species spectra among the listed 26 Ingoldian fungal in China.

Variation of fungal diversity in the two different water bodies:

It can be hypothesized that fungal diversity and occurrence of species are different in the two water bodies. The submerged plant litters and surface water samples collected from Nile River were the richest and exhibited a higher fungal diversity and abundance (38 identified species, 3 identified to the genus level, related to 25 genera in addition to 14 unknown taxa) than those collected from El-Ibrahimia Canal (19 identified species belonging 7 genera in addition to only one unknown taxon). Twenty-five species related to 18 fungal genera in addition to 14 entirely unknown fungal taxa were exclusively recovered from the Nile River but completely missed in El-Ibrahimia Canal. All fungal genera and species gathered from the El-Ibrahimia canal, except one unknown taxon, were also represented in the samples collected from the Nile River. This may be attributed to the lotic nature and relatively clean water in the Nile River comparable to El-Ibrahimia Canal which receives some domestic effluents in the study area. Several investigations supported our findings and reported that Ingoldian fungi prefer clear and clean water. In this respect, Bärlocher [102] concluded that Ingoldian fungi are generally associated with clean and well-aerated freshwaters and are believed to be sensitive to pollution. Similarly, a decline in aquatic hyphomycetes diversity has been found in streams affected by organic pollution [103] or heavy metals [104, 105]. However, Sridhar and Raviraja [15] elucidated those aquatic conidial fungi have been reported from different polluted lotic habitats, which include animal waste, sewage, bird excreta, starch-factory effluent, coal-mine effluent and insecticide contamination. In contrast, unpolluted and sewage-polluted stretches of River Erms in Germany did not show any difference in aquatic hyphomycetes based on drift conidia, randomly sampled leaves and introduced leaves [106]. Recently, Ortiz-Vera *et al*. [107] stated that the contamination of natural water bodies with industrial, agricultural or urban wastewater can potentially modify composition, structure and microbial activity on a local and global scale, affecting aquatic life and soil fertility.

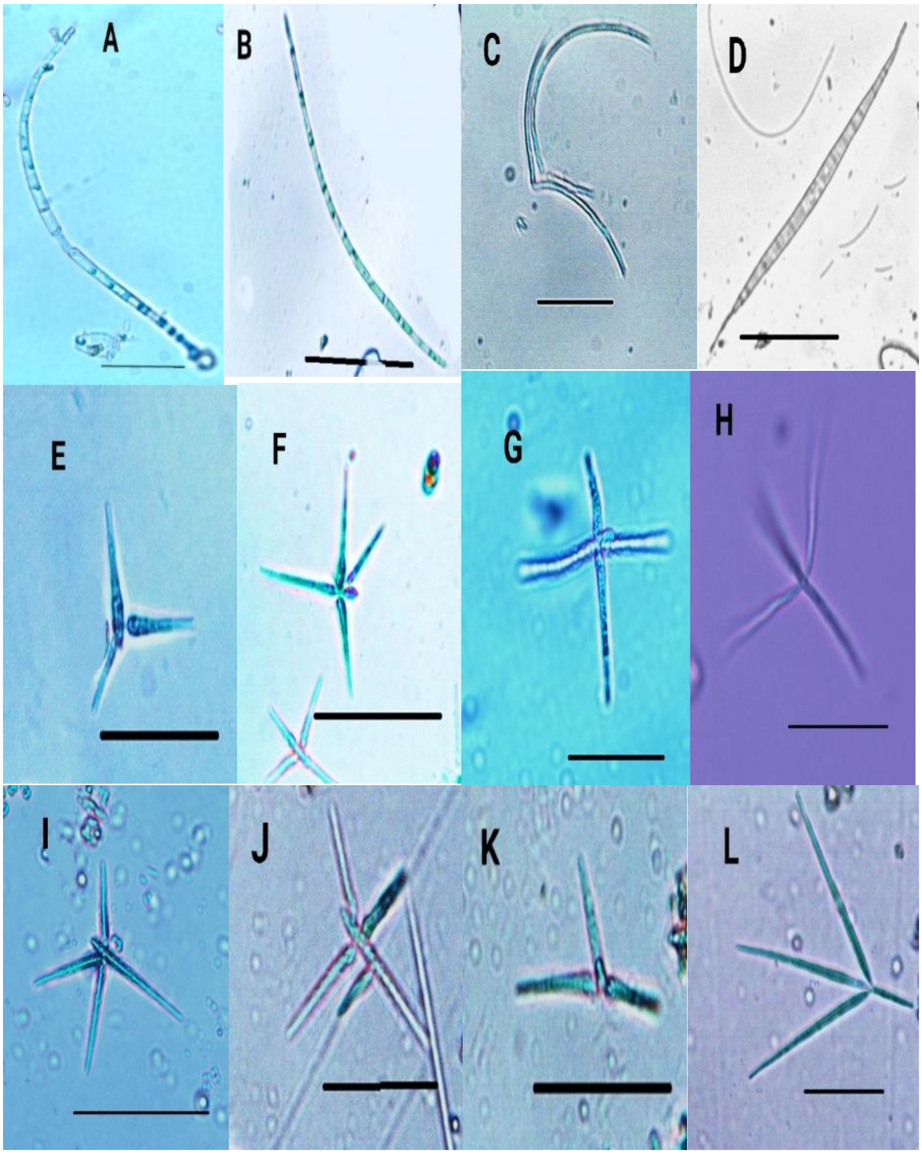
Six genera (*Anguillospora, Triscelophorus, Dactylella, Flagellospora, Lemonniera and Pyramidospora*) were the most widespread in both water bodies. *Anguillospora* was represented by 4 species in each of two water bodies but differ in occurrence (90% of total water samples in River Nile versus 80% in El-Ibrahimia Canal) *Triscelophorus* was also represented by 3 species in each of two water bodies (70% of total samples in Nile River compared to 60 % of total samples in El-Ibrahimia canal). *Dactylella* was represented by 6 species (80 % of total water samples) in the Nile River whereas it was represented by 4 species (60 % of total samples) in the El-Ibrahimia canal. *Flagellospora* was represented by 2 species in each of two water areas (70% of total samples in Nile River versus 50 % of total samples in El-Ibrahimia canal). *Lemonniera* was represented by 3 species (50% of total samples) in Nile River whereas it was represented by 2 species (50 % of total samples) in the El-Ibrahimia canal. *Pyramidospora* was represented by 3 species (60 % of total samples) in Nile River whereas compared to 2 species (30 % of total samples) in El-Ibrahimia canal.

Twenty-three identified taxa (*Articulospora tetracladia*, *Blodgettia indica*, *Campylospora* sp., *Clavariopsis aquatica*, *Colispora cavincola*, *Condylospora gigantea*, *Condylospora spumigena*, *Cruciger lignatilis*, *Dactylella tenuifusarium*, *Dactylella yunnanensis*. *Diplocladiella scalaroides*, *Fibulotaeniella canadensis*, *Filosporella versimorpha*, *Flabellospora verticillata*, *Globoconidiopsis* sp, *Isthmontricladia* sp., *Lemonniera pseudofloscula*, *Leptodiscella africana*, *Pyramidospora quadricelullaris*, *Stellospora appendiculella*, *Taeniospora descalsi*, *Tetracladium marchalianum*, *Volucrispora graminea*) in addition to 14 unknown taxa were recorded exclusively in Nile River (El-Fath) only but completely missed in El-Ibrahimia canal. On the other hand, only one unknown taxon appeared in the El-Ibrahimia canal only and was missed in samples collected from the Nile River. Photo of some representatives of recovered Ingoldian fungi are provided (Figs. 2& Fig. 3).

CONCLUSIONS

Despite the primary importance of Ingoldian fungi in stream ecosystem functioning, knowledge and investigations concerning their occurrence and diversity in various Egyptian water bodies are still scarce and, in its infancy. Results of the current preliminary investigation predict that the Ingoldian fungi have a wide distribution and diversity in the Egyptian water areas. So further intensive research is necessary in order to verify the presence of keystone species, Many Ingoldian fungal species await discovery in various Egyptian water bodies, and we hope forthcoming.

Fig (2) Conidia of some representatives of isolated aquatic hyphomycetes



. **A:** *Anguillospora longissima*. **B:** *Anguillospora filiformis*, **C:** *Lunulospora curvula* , **D**: *Dactylella tenuifusarium*, **E**: *Triscelophorus deficiens*, **F**: *Triscelophorus monosporus*, **G:** *Lemonniera aquatica*, **H**: *Lemonniera pseudofloscula*, **I**: *Triscelophorus acuminatus*, **J:** Unknown-4, **K**: *Volucrispora graminea*, **L**: *Articulospora tetracladia* .(bars=B, D=100 µ, A,C,E-L=50 µ).

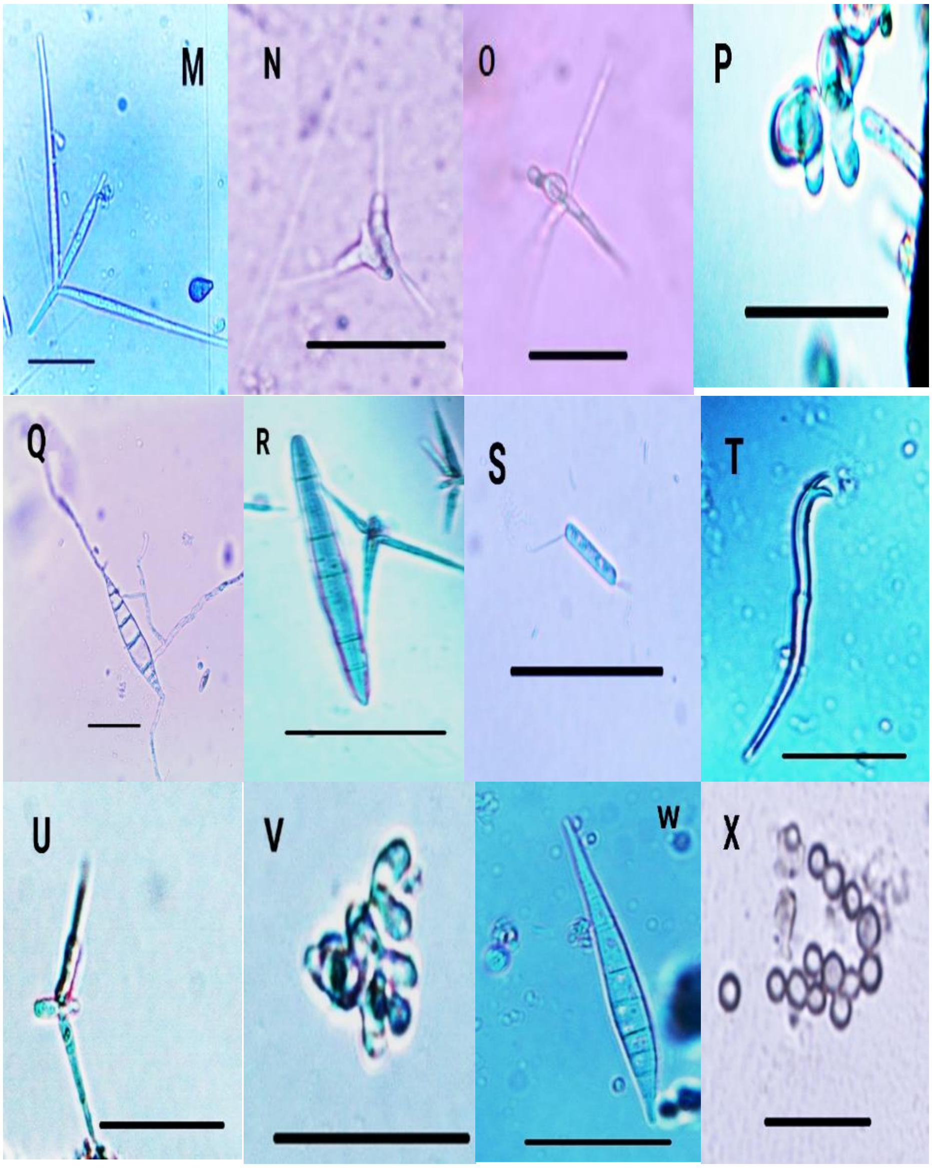


Fig. (3) Conidia of some representatives of isolated aquatic hyphomycetes **M**: *Isthmontricladia* sp, **N:** *Campylospora* sp, **O**: *Condylospoa gigantea*, **P:** *Pyramidospora casuarinae*, **Q**: *Dactylella arnaudi*, **R**: *Dactylella strobilodes*, **S**: *Leptodiscella africana*, **T**: Unknown6, **U**: Unknown7, **W**: *Dactylella yunnanensis*, **X**: *Globoconidiopsis* sp. (bars= 50 µ for M-W and 20 µ for X)

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الفطريات المائية الكونيدية فى جسمين مائيين بأسيوط

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هدفت هذه الدراسة الى رصد التنوع البيولوجى للهيفوميسيتات المائية (الفطريات المائية الكونيدية) فى خليط من العينات النباتية المغمورة وكذلك المياه السطحية والتى تم تجميعها من مواقع مائية مختلفة بنهر النيل والترعة الابراهيمية (١٠ مواقع لكل منهما) بمحافظة اسيوط - صعيد مصر .تم عزل ثمانية وثلاثين نوعًا تم تعريفها الى مستوى النوع وثلاثة فطريات تم تعريفها على مستوى الجنس فقط اضافة الى خمسة عشر عزلة فطرية غير معرفة على الاطلاق وتتبع جميعها خمسة وعشرين جنسًا فطريًا وذلك إما من خليط البقايا النباتية المغمورة أو من عينات المياه السطحية الخاضعة للدراسة.

كانت العينات التي تم تجميعها من نهر النيل هي الأغنى والأعلى فى تنوع الفطريات (38 عزلة فطرية معرفة على مستوى النوع ، 3 فطريات معرفة على مستوى الجنس فقط تنتمي إلى 25 جنسًا فطريا و 14عزلة غير معرفة) وذلك مقارنة مع العينات المماثلة والتي تم تجميعها من الترعة الإبراهيمية (19 نوعا فطريا وعزلة واحدة تم تعريفها على المستوى الجنس فقط تنتمى جميعها الى 7 اجناس فطرية، اضافة الى عزلة فطرية واحدة لم يتم التعرف عليها كليا). ومن الفطريات المعزولة فى هذه الدراسة، واحد وعشرون نوعا فطريا معرفا وعزلتين معرفة على مستوى الجنس فقط اضافة الى اربع عشرة عزلة فطرية غير معروفة تم رصدها لاول مرة فى المياه المصرية.

تم عزل الهيفومميسيتات المائية من عينات المياه باستخدام أوراق نبات الفيكس *Ficus* كبيئة Substrate للجراثيم الفطرية. اختلفت الفطريات الإنجولدية المرصودة في تكرار تواجدها وتنوعها ووفرتها اعتمادًا على مصدر أخذ العينات ونوع العينات النباتية المجموعة .

وكانت الاجناس الفطرية ***Anguillospora*** و ***Dactylella*** و ***Triscelophorus*** و ***Flagellospora*** و ***Lemonniera*** هى الأكثر شيوعًا.وانتشارا، كما كانت اكثر الأنواع انتشارًا هي ***Anguillospora longissima*** و ***A. rosea*** و ***Dactyllela arnaudi*** و ***Triscelophorus monosporus***. سجلت الاجناس الفطرية ***Dactylella*** (6 أنواع) و جنس ***Anguillospora*** (٤ أنواع) و أجناس ***Lemonniera*** ، ***Pyramidospora*** و ***Triscelophorus*** (٣انواع لكل منها) أعلى معدلات التنوع من بين الاجناس الفطرية المعزولة. .وقد أظهرت الدراسة ان العينات التي تم تجميعها من نهر النيل هى الأعلى تنوعا ووفرة فطرية من تلك التي تم تجميعها من قناة الإبراهيمية.

كان ظهور بعض الفطريات حصريا فى العينات التى جمعت من نهر النيل (خمسة وعشرين نوعًا فطريا تنتمى الى 18 جنسا فطريًا بالإضافة إلى 14 نوعًا فطريًا غير معروف) فى حين انها قد اختفت تماما فى العينات التى جمعت من الترعة الابراهيمية، فى حين ان جميع الفطريات التى تم رصدها فى الترعة الابراهيمية قد تم رصدها ايضا فى العينات التى جمعت من نهرالنيل باستثناء عزلة فطرية واحدة غير معروفة .أظهرت معظم الفطريات المعزولة تنوعًا وانتشارا ووفرة متباينا وذلك اعتمادًا على موقع أخذ العينات والجسم المائي والمواد النباتية التى تم جمعها .تم تقديم بعض الصور الفوتوغرافية لبعض الفطريات الانجولدية المعزولة مع وصف لها فى هذه الدراسة.