Research Article

SOHAG JOURNAL OF SCIENCES

https://doi.org/10.21608/sjsci.2025.346237.1243

Fungal community and chemical analyses of agricultural soil in Sohag governorate, Upper Egypt

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Received: 21st January 2025, **Revised:** 16th March 2025, **Accepted:** 22nd March 2025
Published online: 15th June 2025

Abstract: The investigation was conducted to find out the fungal diversity, and chemical characteristics of agricultural soils in Sohag governorate, Upper Egypt. Examined soils have mean values of 1.66% organic matter, 0.03% total dissolved salts, 7.02% pH value and 12.8 % moisture content. All agricultural soil samples proved to be contaminated by filamentous fungi. A total of 87 fungal species + 8 varieties of 27 genera were isolated and identified from fifty soil samples on Czapek's-glucose and potato-dextrose agar media using dilution plate method. The gross fungal count on Czapek's-glucose was higher 1409649 CFU/g of dry soil, 25 genera & 86 species + 8 species-varieties, than 1212310 CFU/g of dry soil, 19 genera & 66 + 6 on potato-dextrose agar media. Aspergillus was the most dominant genus on both media (100 % & 94 % of the samples tested), respectively followed by Mucor, Trichoderma, Fusarium and Talaromyces. On the other hand, Chaetomium herbarum, Cunninghamella spp., Humicola spp., Rhizopus stolonifer and Stachybotrys cartarum appeared on Czapek's-glucose and completely disappeared on PDA, while Cephalosporium trigonosporum and Rhodtorula mucillignosa appeared in rare on PDA and completely missed on Czapek's-glucose. Finally, microorganisms especially fungi played an important role in fertility of agricultural soils in Upper Egypt.
Keywords: Agricultural soil - Chemical analyses - Filamentous fungi - Czapek's-glucose agar medium - Potato Dextrose agar medium - Sohag, Upper Egypt.

1. Introduction

Soil is vital for the provision of ecosystem services that are essential for human wellbeing. Soil for earth is considered the living skin [1]. Agricultural area in Egypt is mainly distributed around Nile Valley and Delta area, which are subjected to Mediterranean moderate climate [2]. Agricultural practices can directly affect soil environmental conditions and consequently soil ecosystems and fertility [3]. The physical, chemical and biological properties of soils are influenced by the decomposition of plant and animal residues for their conversion into soil organic matter by the soil microbes [4].

In addition, soil organic matter plays a vital role in stabilizing soil structure. Various components of organic matter act as binding agents which essentially "glue" the mineral particles together [5]. It is essential in providing energy, substrates, and the biological diversity necessary to sustain numerous functions [6,7], as well as it interacts with soil physical, chemical, and biological parameters which determine the ecosystem stability [8].

Soil is a main component of the Earth's ecosystem which comprises organic matter, minerals, gases and a large number of macro and microorganisms. Microorganisms are of assistance in increasing the soil fertility and plant growth. Soil is a complex heterogeneous habitat for a wide variety of organisms including bacteria, fungi, protozoa, nematodes and earthworms in which organisms interact with each other and with their physical environment contributing to plant nutrition, soil structure, soil fertility, decomposition of organic matter, cycling of nutrients, suppression of soil borne pathogens and removal of toxins [9-11]. Microorganisms found in natural environments are responsible for most of the biological transformations that lead to formation of soil nutrients,

Microorganisms also play a very important role in the soil structure and aggregates formation, as well as functions related to plant health and pathogens suppression [12]. Soil microorganisms play several beneficial roles such as decomposing organic materials, releasing nutrients to plants, and bioremediation of pesticide-polluted soils. Therefore, soil microorganisms are considered key players in maintaining soil fertility. A large and active microorganism community is needed for efficient nutrient cycling and steady supply of nutrients to the plants [13-15].

Fungi are one of the principal groups present in the soil and play essential role in the composition of the soil [16]. The role these organisms play is driving various biogeochemical cycles of elements, fixing carbon and nitrogen, mineralizing dead organic matter and protection of plants from biotic and abiotic stresses. They play a very important role in the health and ecological balance of these environments. Soil fungi play an important role in nutrient cycling, plant health and development [17]. Also, soil fungi play an important role as major decomposers in soil ecosystem. They also provide mankind with very useful pharmaceutical products, such as antibiotics and other valuable substances, including organic acids, enzymes, pigments and fermentation. In addition, many soil fungi are biological control agents for plant pathogens and insect pests. On other hand, some of them are very harmful causing food spoilage and diseases to plants, animals, and

humans with significant economic losses and produce mycotoxins in certain products [18].

The quantity of different microorganisms present in the soil depends upon the soil moisture, aeration, pH, temperature and nutrients available etc. The pH of a soil is a measure of the H+ ion concentration in the soil solution. Acid soils have a pH below 6, while alkaline soils being greater than 7.5. Plant growth is not affected by the pH itself, but by the changes in soil chemistry that can occur when the pH changes. Soil acidification is a natural process resulting from weathering of rocks and loss of nutrients by leaching. Plants and microorganisms are an important part of the natural process. Sometimes, under agricultural systems, the rate of decline of pH is increased with the resulting induced "soil acidity."(5) Soil acts as a key element for food production on which life sustains on this earth. Soil ecosystem provides various functional services; such as maintenance of soil fertility, promoting ecosystem stability, and regulating climate change [19,20].

The agricultural soil is a highly variable and complex active medium for the plant's life [21]. Soil is considered a non-renewable natural resource and it is of great environmental concern to keep it in a healthy and productive state [22]. Soil is a highly complex and variable active medium made of mineral particles, organic matter, water, air and living organisms. It represents the natural habitat for the gene pool and the growth medium for plants' life, and it results in being the food, biomass, and raw materials provider for human activities. Soil also stores, filters, and transforms many substances, including water, nutrients, and carbon [23].

The present investigation was designed to study the influence of organic matter contents, pH values and total dissolving elements on filamentous fungi isolated from fifty soil samples in Sohag governorate, Upper Egypt.

2. Materials and methods

I- Samples collection: -

A total of 50 samples (~ 500g) of agricultural soils were collected from different places (Sohag, Akhmim, Maragha, Tahta, Tema, Al Monshah, Gerga, Al Balyana, Dar- Alsalam and Saqulta) in Sohag governorate, Upper Egypt as shown in Table S (1).

II- Chemical analyses of soil samples: -

II-1. Moisture content: -

The moisture content of soil samples was determined by oven dry method [24]. Twenty gm of each soil sample (W_1) in a ceramic crucible were dried in an oven at 105^{O}C for 24 h. Then the sample was put in a desiccator until cool and re-weighted to constant weight (W_2). The moisture content (MC) was then calculated on oven dry basis as a percentage according to the following equation: -

$$(\%MC) = \frac{\text{Mw (mass of water = W1- W2)}}{\text{W1 (weight of initial sample)}} \times 100$$

Where: -W1 = initial weight (20 gm) of soil , W2 dry weight of soil.

II- 2. Organic carbon: -

Organic carbon was determined by wet digestion method [25], through oxidation of soil carbon using acid dichromate reagent.

II- 3. Determination of pH Value:

The pH-meter (EUTECH instruments pH 510 pH/mV/°C meter) was used to determine soil pH. The pH was measured potentiometrically in a suspension of 10 gm soil/ 100 ml sterile distilled water [26].

II- 4. Total dissolving salts: -

Total dissolved salts were estimated by a known weight of soil (10 gm) was shaken in a known volume of distilled water (100 ml of bi-dist. Water) for about 2 hours and the mixture was left overnight to settle. The soil extract was then filtered and a known volume was evaporated in an oven at 105°C. The dry residue was then weighed and the amount of total soluble salts per percentage-dry soil was calculated [27].

III- Isolation and identification of soil fungi:

III-1. Soil Dilution Plate Method: -

The Filamentous fungal species were isolated by serial soil dilution plate technique as described by Pitt and Hocking 2009 [28]. Ten grams of soil sample were suspended in 90ml of double distilled sterile water to make dilutions of soil suspensions (10^{-1} -10^{-3}). Triplicate of each dilution were used to isolate fungal species. 1ml of each dilution was put into 10 sterilized Petri dishes, 5 plates containing sterile Czapek's-glucose agar (CZ) and another 5 plates containing potato-dextrose agar (PDA) media at pH 6.5. Combination of 1% of each of streptomycin solution and chloramphenicol as antibacterial agents were added to the medium. The plates were incubated at 28± 2^{o}C for 4 -7 days. Fungal growth was daily examined. Growing Fungal species on the agar plates were isolated and identified based on their morphological colony and microscopic characteristics [29-34]. Purified identified fungal species were maintained onto fresh Czapek's-glucose agar slants at 4°C [35].

III-2. Isolation Fungal Media: -

III-2.1. Czapek's-glucose agar medium: -

The composition of this medium as gm/l was: $NaNO_3$, 3.; K_2HPO_4, 1; $MgSO_4$. $7H_2O$, 0.5; KCl, 0.5; glucose, 10; agar-agar, 18- 20 at 28°±1°C, and pH 6.5 as employed by [30].

III-2.2. Potato dextrose agar medium: -

Potato infusion can be made by boiling 200 gm of sliced (washed but unpeeled) potatoes in ~ 1 liter distilled water for 30 minutes and then decanting or straining the broth through cheese cloth. Distilled water is added such that the total volume of the suspension is 1 liter. Twenty gm of dextrose and 20 gm agar powder were then added and the medium is sterilized by autoclaving at 15 pounds per square inch (100 KPa) for 20 minutes [35].

III-3. Morphological identification of isolated fungi: -

Morphological identification of isolated fungal species on basis of macro- and microscopic characteristics of hyphae and spores was performed using the following references; Raper and Thom (1949) [29], Raper and Fennell (1965) [30], Rifai (1969) [36], Ellis (1971 & 1976) [33,34], Christensen and Raper (1978) [37], Pitt (1977 & 1985) [38,39], Hawksworth *et al*. (1983) [40], Brayford (1996) [41], Leslie and Summerell (2006) [42], Domsch *et al*. (2007) [43].

3. Results and Discussion:

I-Soil analyses of agricultural soil samples: -

The agricultural soil samples were subjected to some chemical analyses as follows:

I-1. Moisture content: The moisture content (MC%) of agricultural soil samples tested ranged 2.52 – 31.58 %.Whereas, 10% of tested samples (5 samples) had the lowest moisture contents ranging between 2.52 – 5.00% and these were No 46, 16, 47,12 and 9, respectively as recorded in Table S (1). While, moisture contents of 7 samples as the richest moisture values ranged between 20.19 – 31.58% and these were No.14 (20.19%), No. 1 (23.22%), No. 32 (24.46%), No. 34 (25.39%), No. 45 (27.16%), No. 48 (27.37%) and No.15 (31.58%). On the other hand, the most samples (38 samples out of 50 tested accounting 76%), their moisture contents ranged between (5.72- 19.05%) as shown in Table S (1).

I-2. Organic matter content of soil samples: -

The organic matter (OM %) of agriculture soil samples tested was fluctuated between 1.39 - 1.73% (mean = 1.66 %). The lowest organic content was recorded in 2 samples; No 39 from Dar Alsalam (1.39%) and No 43 from Saqulta (149%). While the highest contents (1.73%) were recorded in 9 samples out of 50 tested (18% of samples) and these were Nos 4, 7, 11, 20, 22, 28, 29, 32 and 48 as listed in Table S (2). The organic content of most samples (78% of samples) was fluctuated between 1.55- 1.72% as shown in Table S (2).

I-3. pH value: -

The pH value fluctuated between 6.50 - 7.70 (mean = 7.02). The lowest pH was recorded in sample No 33 from Al-Balyana, whereas the highest value was recorded in sample No 26 from Gerga. The pH values of 26 samples (52% of samples) were relatively acidic and ranged between 6.50 – 6.95 while, one sample only No 5 from Sohag (2% of samples), was neutral pH 7, whereas 23 samples (46%) were relatively alkaline and their pH values ranged between 7.02 – 7.70 as shown in Table S (2).

I-4. Total dissolving salts: -

Data in Table S (2) revealed that the total dissolving salts (TDS) ranged between 0.001-0.08 mg/g soil (mean = 0.03). The lowest value was recorded in sample No 5 from Sohag, whilst the highest values were recorded in samples No 1 from Sohag, and No 16 from Maragha.

II- Mycobiota of agriculture soils:

A total of 87 fungal species + 8 varieties of 27 genera were isolated and identified from fifty collected agriculture soil samples tested on Czapek's-glucose and potato-dextrose agar media. In comparison, Czapek's-glucose agar medium was the most favorable that the gross fungal count was higher (1409980 colonies/g dry soil, 25 genera & 86 species + 8 species-varieties) than potato-dextrose agar medium (1212312 colonies/g dry soil, 19 genera & 66 + 6) as recorded in Table S (3). *Aspergillus* was the most dominant genus on the two media used based on frequency of occurrence (100 % & 94 % of the samples tested) accounting (74.22 % & 65.13 % of gross count) on Czapek's-glucose and potato dextrose agar media, respectively. The genus was represented by 30 species + 4 varieties.

A. niger, A. ficuum, A. fumigatus and *A. terreus* were the most dominant species on the two tested media with high frequencies of occurrence and variable degree of counts. *A. phoenicis* was identified in high occurrence only on potato-dextrose agar medium in 33 out of 50 samples tested, while, it appeared in moderate occurrence (24 out of 50 tested samples) on Czapek's-glucose agar medium as recorded in Table S (3).

A. aeneus, A. oryzae, A. flavus, A. carbonarius and *A. parasiticus* had moderate frequencies of occurrence only on Czapek's-glucose agar medium. Whereas *A. flavus* and *A. parasiticus* retarded to low frequencies of occurrence on potato-dextrose agar medium. Whereas other *Aspergillus* species were identified in low (6 - 11 samples) or rare frequencies of occurrence (1 – 5 samples out of 50 tested). *Mucor* occupied the second order among isolated fungi on potato-dextrose agar medium with high occurrence (41samples out of 50 tested), accounting 176998 colonies as14.60% of gross count fungi and represented by 3 species namely; *M. circinelloides* (40 samples, high occurrence & 157664 colonies as 13% of fungal count), *M. hiemalis* (6 samples, low occurrence & 19333.7 colonies as1.59%) and *M. racemosus* (2, rare & 2999.3 as 0.24%). Whilst, on Czapek's-glucose agar medium *Mucor* retarded to fifth place after *Trichoderma* with low occurrence in 11 samples out of 50 tested with 16333 colonies accounting 1.15% of fungal gross count, and represented by 2 species only: *M. circinelloides* (11 samples, low occurrence &15666 colonies as 1.11% of fungal cross count) and *M. hiemalis* (only one sample, rare occurrence & 667 colonies as 0.04%).

Fusarium was represented by 11 species and one variety, ranked the second order on Czapek's-glucose and the third order on potato-dextrose agar medium according to frequencies of occurrence (39 & 40 samples out of 50 tested) and gross total count (43996.7 and 3.12 % & 50331.4 colonies/gm dry weight soil and 4.15% of total count) on Czapek's-glucose and potato-dextrose agar media respectively. *F. solani* was the superior species isolated in moderate frequencies of occurrence (13 & 12 samples) accounting (23002 and 1.89% & 18999 and 1.34% of total count) on potato-dextrose and Czapek's-glucose agar media, respectively. *F. moniliforme* and *F. moniliforme* var. *subglutinans* appeared in low occurrence (6 – 11samples) only on Czapek's-glucose and in rare occurrence on the other medium. Whilst the other 9 *Fusarium* species were isolated in rare occurrence (1 - 5 samples) on the two media used as shown in Table S (3).

Talaromyces (6 & 5 species) occupied the third place on Czapek's-glucose agar and the fourth order among isolated fungal genera, appeared in moderate frequencies of occurrence from cultivated soil samples tested represented (74998.5 colonies, 5.32% of gross count & 20 samples and 34998, 2.88% & 19) on the two media used, respectively. Of which, 2 species (*T. purpurgenus* and *T. luteus*) had appeared in low frequencies of occurrence (11 & 8 samples of each on both media) and with variable degrees of count (15333 colonies & 1.08% of total count and 9998 colonies & 0.88% for *T. purpurgenus*) and (38000 colonies and 2.69% of gross count and 18667 colonies & 1.53% for *T. luteus*), respectively on both media used. The other *Talaromyces* species were isolated in rare frequencies of occurrence. As well as *T. stipitatus* was completely missed on potato-dextrose agar medium as listed in Table S (3).

Trichoderma was represented by three species namely; *T. koningii, T. ressei* and *T. viride,* ranked the fourth order on Czapek's glucose agar and the fifth place on potato-dextrose agar among isolated fungi. It was isolated in moderate occurrence in 17 samples out of 50 tested with 78666 colonies accounting 5.58% of gross total fungi on Czapek's-glucose agar, while, it recovered with low occurrence in10 samples accounting for 103000 colonies as 8.49% on potato-dextrose agar medium.

Eurotium was represented by four species and one variety namely; *E. chevalieri, E. amstelodami, E. repens, E. rubrum* and *E. chevalieri* var. *intermedius,* ranked the fifth order on Czapek's glucose agar and the sixth place on potato-dextrose agar among isolated fungi. It was appeared in moderate occurrence in 14 samples out of 50 tested with 29001 colonies accounting 2.05% of gross total fungi on Czapek's-glucose agar, while it recovered with low occurrence in11 samples accounting 12665 colonies representing 1.04% of fungal total count on potato-dextrose agar medium. *E. chevalieri* only appeared in low occurrence in 9 samples accounting 23668 comprising 1.67% of gross fungal count on Czapek's-glucose agar medium, while other isolated *Eurotium* species were appeared in rare occurrence on both media used.

Penicillium ranked the sixth order on Czapek's glucose agar and retarded to the eighth place on potato-dextrose agar among isolated fungi. It was appeared in low frequencies of occurrence (8 & 6 cases out of 50 tested) on both media, respectively. It was represented by four species and one variety namely; *P. citrinum, P. cyclopium, P. nigricans, P. tardum* and *P. cyclopium* var. *echinulatum.*

Emerciella ranked the seventh order on both media. It was appeared in low frequencies of occurrence (6 & 8 cases out of 50 tested) among isolated fungi on both media, respectively. It was represented by one species (*E. nidulans*) and one variety (*E. nidulans* var. *dentatus*) as listed in Table S (3).

Paecilomyces ranked the eighth order among isolated fungi in low frequencies occurrence (6 cases out of 50 tested) on Czapek's glucose agar, while appeared in rare (one case only) on potato-dextrose agar medium. It was represented by two species; *P. fusisporus* and *P. variotii* on the first medium and by *P. variotii* only on the second medium as stated in Table S (3).

The remaining fungi (17 genera & 21 species) were isolated in rare frequencies of occurrence (1 – 5 cases out of 50 tested), collectively of fungal total count on Czapek's-glucose agar medium (90328 colonies, 6.4%) and on potato-dextrose agar medium (24996 colonies, 2.1%) as shown in Table S (3).

Twenty-two fungal species only isolated on Czapek's-glucose agar medium and completely missed on potato-dextrose agar medium, on contrast, 10 fungal species appeared only on potato-dextrose agar medium and completely disappeared on the first medium. All the previous fungal species were recorded in rare frequencies of occurrence as shown in Table S (3).

Discussion

I- Chemical analyses of soil samples: -

Data revealed that the moisture content (MC%) of agricultural soil samples tested ranged between 2.52–31.58 % (mean = 12.8 % MC). Also, organic matter (OM %) of samples tested was fluctuated between 1.39 - 1.73% (mean = 1.66 %), the pH value was fluctuated between 6.50 - 7.70 (mean = 7.02) and the total dissolving salts (TDS) ranged between 0.001-0.08mg/g soil (mean = 0.03). These results are in full agreement that cultivated soil in Upper Egypt has moderate moisture content (mean= 15.75%), organic matter (mean =1.41%), pH (7.17) and 0.04 % as mean of total dissolving salts [44]. As well as, stratification of soil organic matter, dissolved salts and activities of soil biota can react to change in land cover and have been suggested as indicators of soil ecological functioning [45]. Depending on the type of interaction between fungi and plant, fungi have been proven to have a beneficial effect to plant. *A. aculeatus* was found to be beneficial in increasing the bioavailability of phosphorus content in the soil by its potential in the solubilizing insoluble form of phosphorus to a form that plant can uptake [46].

Fungi are very successful inhabitants of agricultural soils, due to their high plasticity and their capacity to adopt various forms in response to adverse or unfavorable conditions [47]. They are able to produce a wide variety of extracellular enzymes, break down all kinds of organic matter, decompose soil components and thereby regulating the balance of carbon and different nutrients [48]. Fungi convert dead organic matter into biomass, organic plus amino acids and carbon dioxide [49]. The diversity and activity of fungi are regulated by various biotic (plant and other organisms) and abiotic (soil pH, moisture, salinity, structure and temperature) factors [50,51]. Fungi can be found in almost every environment and can live in a wide range of abiotic factors [52]. Therefore, the present study was designed to throw light on soil analyses, and mycological composition of agricultural soils in Sohag government, Upper Egypt.

II- Fungal community of agricultural soils: -

Based on the dilution plate method of fifty agricultural soil samples, using glucose-Czapek's agar and potato-dextrose agar media at 28 ± 2°C for isolation of mesophilic fungi. A total of 87 fungal species + 8 varieties of 27 genera were isolated and identified on Czapek's-glucose as the most favorable medium that the gross fungal count was higher (**1409649** colonies/g dry soil, 25 genera & 86 species + 8 species-varieties) than potato-dextrose agar medium (**1212310** colonies/g dry soil, 19 genera & 66 + 6). These results are in harmony with that obtained by other researchers in Egypt on Czapek's-glucose agar medium using dilution-plate technique from 40 cultivated soil samples collected from different places of Upper Egypt, they isolated and identified 148 species + 7 varieties of 40 genera as glucophilic fungi [53]. In this respect, soil fungi can be classified into three functional groups including (1) biological controllers, (2) ecosystem regulators, and (3) species participating in organic matter decomposition and compound transformations [54,55]. Ecosystem regulators are responsible for soil structure formation and modification of habitats for other organisms by regulating the dynamics of physiological processes in the soil environment. Biological controllers can control diseases, pests, and the growth of other microorganisms [56]. Also, fungi improve plant growth by increasing nutrient uptake and protecting them against pathogens [44,56]. The cultivated soils in Upper Egypt in general are fertile but not completely healthy. Therefore, microorganisms are biofertilizer and biocontrol agents against pathogens, so it must be taken in

the consideration for increasing the fertility of the soils and facing the pathogenic fungi [44].

Agricultural soil samples tested for fungal diversity proved to be rich in saprophytic fungi especially on Czapek's-glucose agar (28199.6 colonies/g dry soil in every 50 samples) than potato-dextrose agar (24246.2colonies/g dry soil in every 50 samples). This result is full agreement with that obtained previously from 40 soil cultivated samples examined for fungal diversity, the samples proved to be rich in saprophytic fungi (652.4 colonies/mg dry soil in every 40 samples). Concerning this category, fungal populations are strongly influenced by the diversity and composition of the plant community and in return, affect plant growth through mutualism, pathogenicity, and their effect on nutrient availability and cycling [57-59]. Moreover, fungi participate in nitrogen fixation, hormone production, biological control against root pathogens, and protection against drought [60-62]. They also play an important role in the stabilization of soil organic matter and the decomposition of residues [63].

Aspergillus was the most dominant genus on the two media used based on frequency of occurrence (100 % & 94 % of the samples tested) accounting (74.22 % & 65.13 % of gross count) on Czapek's glucose and potato-dextrose agar media, respectively. The genus was represented by 30 species + 4 varieties. *A. niger, A. ficuum, A. fumigatus* and *A. terreus* were the most dominant species on the two tested media with high frequencies of occurrence and variable degree of counts. The data are in full agreement with results obtained from agricultural soil in Upper Egypt that *Aspergillus* (29 sp. + 3 var., 97.5% of the samples) was the superior genus based on number of isolated species and frequency of occurrence. *A. niger* and *A. terreus* had the highest counts and frequencies (high occurrence) [64,65]. Concerning the previous studies of soil fungi isolated from agricultural soil, the previous four *Aspergillus* species were detected in variable degrees of counts and frequencies [66-72].

Mucor occupied the second order among isolated fungi on potato-dextrose agar medium with high occurrence (41samples out of 50 tested), accounting 176998 colonies as 14.60% of gross fungi count and represented by 3 species namely; *M. circinelloides* (40 samples, high occurrence & 157664 colonies as 13% of fungal count), *M. hiemalis* (6 samples, low occurrence& 19334 colonies as1.59%) and *M. racemosus* (2, rare & 2999 as 0.24%). Whilst, on Czapek's-glucose agar medium, *Mucor* retarded to fifth place after *Trichoderma* with low occurrence in 11 samples out of 50 tested with 16333 colonies accounting 1.15% of fungal gross count, and represented by 2 species only; *M. circinelloides* (11 samples, low occurrence &15666 colonies as 1.11% of fungal cross count) and *M. hiemalis* (only one sample, rare occurrence & 667 colonies as 0. 04%). The results are in harmony with Mucorales isolated from cultivated soil in Upper Egypt, 8 species of 5 genera were isolated and identified of which *Mucor racemosus*, *M. hiemalis, Circinella simplex*, and *Syncephalastrum racemosum* had low frequencies (10-17.5% of the samples) with low counts (collectively, 1.75 of total fungal count), whereas, *Cunninghamella* and *Rhizopus* (2 species, each) were rare (5 - 7.5%) and very low in count (0.45%) [44]. With respect to Mucorales (Zygomycetes), most species are saprobic fungi with ruderal characteristics, including rapid growth, prolific spore production and ability to use only relatively simple fixed carbon compounds [73-75]. The Mucorales can degrade organic matters [76] and safe hydrocarbons (aliphatic and aromatic) biodegradation [77]. On the contrary, fungi of order Mucorales cause mucormycosis, a rare but highly fatal fungal infection. They can cause cutaneous, rhino-orbital, pulmonary, rhinocerebral, and disseminated bloodstream infections [78]. Recently these fungi have been frequently reported to infect the COVID- 19 patients as black fungi [79]. In addition, these results are in agreement with that obtained from agricultural soils in different places around the world [80-82].

Concerning *Fusarium,* it was represented by 11 species and one variety, ranked the second order on Czapek's-glucose and the third order on potato-dextrose agar medium according to frequencies of occurrence (39 & 40 samples out of 50 tested) and gross total count (43997 and 3.12 % & 50331 colonies/gm dry weight soil and 4.15% of total count) on Czapek's-glucose and potato-dextrose agar media respectively. *F. solani* was the superior species isolated in moderate frequencies of occurrence (13 & 12 samples) accounting (23002 and 1.89% & 18999 and 1.34% of total count) on potato-dextrose and Czapek's-glucose agar media, respectively. *F. moniliforme* and *F. moniliforme* var. *subglutinans* were appeared in low occurrence (6 – 11 samples) only on Czapek's-glucose and in rare occurrence on the other medium. Whilst, the other 9 *Fusarium* species were isolated in rare occurrence (1 - 5 samples) on the two media used. The results are in harmony with that obtained from cultivated soil in Upper Egypt that *Fusarium* (67.5% of the samples and 6.56 of gross fungal count) had the third place of isolated filamentous fungi 43. As well as, *Fusarium* is a cosmopolitan genus of filamentous fungi that involves many toxin-producing plant pathogens of agricultural importance. In addition to mycotoxin producers and opportunistic human pathogens [79]. The genus was dominant in cultivated soils in Egypt and India [64,66-68]. Also, *F. oxysporum, F. solani* and *F. moniliforme* were associated with peanut damping off and wilting the seedling of many plants [83], also had pathogenicity effects on peanut seed germination. It is worthy for mention that, *F. oxysporum* is ranked the fifth out of top plant pathogens of scientific economic importance [84,85].

Talaromyces (6 & 5 species) occupied the third place on Czapek's-glucose agar and the fourth order on potato-dextrose agar among isolated fungal genera, appeared in moderate frequencies of occurrence from cultivated soil samples tested represented (74999 colonies, 5.32% of gross count & 20 samples and 34998, 2.88% & 19) on the two media used, respectively. Of which, 2 species (*T. purpurgenus* and *T. luteus*) were appeared in low frequencies of occurrence (11 & 8 samples of each on both media) and with variable degrees of count (15333 colonies & 1.08% of total count and 9998 colonies & 0.88% for *T. purpurgenus*) and (38000 colonies and 2.69% of gross count and 18667 colonies &1.53% for *T. luteus*), respectively on both media used. The other *Talaromyces* species were isolated in rare frequencies of occurrence. As well as, *T. Stipitatus* was completely missed on potato-dextrose agar medium. These results are in full agreement with that obtained from cultivated soil in Upper

Egypt, that ten species and one variety of *Talaromyces* were isolated, of which, *T. duclauxs* and *T. funiculosus,* were isolated in moderate frequencies (27.5 - 37.5% of the samples), while *T. purpurogenus* was in low frequency (12% of the samples), while the others were recorded in rare frequencies [44].

Trichoderma was represented by three species namely; *T. koningii, T. ressei* and *T. viride,* ranked the fourth order on Czapek's glucose agar and the fifth place on potato-dextrose agar among isolated fungi. It was isolated in moderate occurrence in 17 samples out of 50 tested with 78666 colonies accounting 5.58% of gross total fungi on Czapek's-glucose agar, while, it recovered with low occurrence in10 samples accounting 103000 colonies as 8.49% on potato-dextrose agar medium. This result was in harmony with that obtained from cultivated soil in Upper Egypt that *Trichoderma* (4 species) was low in frequency (15% of the samples) and deficient in count (0.52% of gross counts) [44]. Also, this genus has been known since at least 1920 for its ability to act as a biocontrol agent against plant pathogens. Recent advances demonstrated the effects of *Trichoderma* on plants, inducing systemic or localized resistance. The genus colonizes the root epidermis and outer cortical layers and releases bioactive molecules that increase plant growth and nutrient uptake, in addition to induction of pathways for resistance in plants. As well as, *Trichoderma* species produce a rich mixture of antifungal enzymes, including chitinases and ß-1, 3 glucanase which are synergistic with each other and with other antifungal enzymes to act as biocontrol against mycoparasitism [86]. Many species of *Trichoderma* produce several secondary metabolites, including trichoviridin, gliotoxin, viridin, harzianic acid, etc. that possess antibiotic activity and when combined with various cell wall-degrading enzymes produce inhibitory effect against plant pathogens [87,88]. *Trichoderma* species are used also as both biofertilizer and biofungicide [89].

Eurotium was represented by four species and one variety namely; *E. chevalieri, E. amstelodami, E. repens, E. rubrum* and *E. chevalieri* var. *intermedius,* ranked the fifth order on Czapek's glucose agar and the sixth place on potato-dextrose agar among isolated fungi. It appeared in moderate occurrence in 14 samples out of 50 tested with 29001 colonies accounting 2.05% of gross total fungi on Czapek's-glucose agar, while it was recovered with low occurrence in11 samples accounting 12665 colonies representing 1.04% of fungal total count on potato-dextrose agar medium. *E. chevalieri* had only appeared in low occurrence in 9 samples accounting 23668 comprising 1.67% of gross fungal count on Czapek's-glucose agar medium, while other isolated *Eurotium* species appeared in rare occurrence on both media used. Eurotium species have been isolated from soil and these species produce many extrolites such as flavoglaucin, auroglucin, isotetrahydroauroglaucin, neoechinulins (A, B and E), echinulin, preechinulin, epiheveadride and queslin [90].

Penicillium ranked the sixth order on Czapek's glucose agar and retarded to the eighth place on potato-dextrose agar among isolated fungi. It was appeared in low frequencies of occurrence (8 & 6 cases out of 50 tested) on both media, respectively. It was represented by four species and one variety namely; *P. citrinum, P. cyclopium, P. nigricans, P. tardum* and *P. cyclopium* var. *echinulatum.*These results are in full agreement with that obtained from different cultivated soils in Upper Egypt, that 24 *Penicillium* species were isolated, of which *P. citrinum* (11 cases out of 40 tested with moderate occurrence) and *P. asperum* (5 cases with low occurrence) were the most predominant, while the other 22 species were appeared in rare occurrence [44].

Emerciella ranked the seventh order on both media. It appeared in low frequencies of occurrence (6 & 8 cases out of 50 tested) among isolated fungi on both media, respectively. It was represented by one species; *E. nidulans* and one variety; *E. nidulans* var. *dentatus.* These results are in harmony with that otained from cultivated soils in Upper Egypt that *Emerciella nidulans* appeared only in low occurrence (5 samples), while *E. heterothallicus* (3 cases out of 40 tested), *E. nidulans* var. *latus* (3 cases) and *E. nidulans* var. *echinulata* (2 cases) were isolated in rare frequencies [44].

Paecilomyces ranked the eighth order among isolated fungi in low frequencies occurrence (6 cases out of 50 tested) on Czapek's-glucose agar, while appeared in rare (one case only) on potato-dextrose agar medium. It was represented by two species *P. fusisporus* and *P. variotii* on the first medium and by *P. variotii* only on the second medium. These results were in agreement with that obtained from cultivated soils in Upper Egypt, that *Paecilomyces lilacinus, P. variotii and P. terricola* were isolated in rare frequencies [44]. As well as, *Paecilomyces lilacinus* is a saprophytic soil fungus and can be found in a wide range of habitats. It has a high frequency of occurrence in tropics and subtropics and can be found in most agricultural soils [91].

4. Conclusion

Fungal community of agricultural soil in Sohag governorate, Upper Egypt is varied and differed according to its chemical content, pH value and total dissolved salts which affect on its fertility and crop productivity. So, studying soil microorganisms diversity is very interested and important in using in biofertilization, biocontrol and antagonism activity against plant pathogens. Therefore, fungal community must be taken into consideration to increase soil fertility and resistant plant pathogens with ecofriendly techniques which lead to soil protection and increase healthy organo-crops productivity to support the economy.

Data availability statement

The data used to support the findings of this study are available from the corresponding author upon request.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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