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Diversity of airborne fungi in cultured and urban sites in Basra Province, Iraq

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Abstract. *Ameen MKM. 2024. Diversity of airborne fungi in cultured and urban sites in Basra Province, Iraq. Biodiversitas 25: 2870-2877.* Atmospheric aerosols consist of particles with diverse sizes, shapes, fungal particles are relatively prevalent. They are related to air pollution and several plant, animal, and human health effects. This study was conducted to compare the airborne fungal biodiversity between cultivated and urban areas in Basra Province, Southern Iraq. Results showed that a total of 1654 fungal colonies consisted of 26 genera and two sterile mycelium belonging to 32 species. These fungal isolates belonged to three groups, namely Ascomycota, Zygomycota and Basidiomycota. Among them, Ascomycota had the highest percentage frequency (90.6%), followed by Zygomycota (6.25%) and Basidiomycota (3.12%). The highest i.e., 0.91and 0.9 fungal diversity was found in Abu Al-Khaseeb 2 and Ad-Dayr, respectively, while the lowest was in urban areas and desert nature as Um Qasr, Al-Zubair 0.78 for each. The highest frequency 18.2 10.9 8.8, and 8.5% of fungal isolates were *Cladosporium herbarum*, *Aspergillus fumigatus*, *Aspergillus niger*, and *Penicillium* sp., respectively. The highest similarity was 0.77 observed between the airborne fungal communities at the Alseeba and Altannumah sites. From the results of this study, it was concluded that airborne fungi can be influenced by the type of terrain they inhabit. There was greater diversity in cultivated areas compared to urban and non-cultivated areas.

Keywords: Aerobiology, airborne fungi, cultivated areas, diversity, urban areas

INTRODUCTION

Air is the breath of life, essential for the sustenance and survival of all living beings on earth. Its presence is a fundamental necessity for the well-being and continuation of our world. Atmospheric aerosols consist of particles with diverse sizes, shapes, and sources, present in both outdoor and indoor air environments (Kalyoncu 2019). These particles are categorized into biological (fungal cells or spores, bacteria, viruses, pollens, protozoa, and algae), chemical, and physical groups (Kalyoncu 2019).

Fungi are one of the most diverse groups of life on the earth. They can live as saprobes, mutualists, endophytes, or pathogens in practically any terrestrial habitat. Indeed, the fungi kingdom is thought to have between one and five million species, with only about 5% of them being identified (Blackwell 2011). In the air, fungal particles are relatively prevalent. They are related to air pollution and several plant, animal, and human health effects (Kalyoncu 2019).

Exposure to fungi has caused various human health problems, including irritations, infections, allergies, and toxic effects, with toxigenic fungi suspected of causing more problems (Yamamoto et al. 2015; Jara et al. 2017; Atya et al. 2019; Wei et al. 2019). More than 80 fungal genera are associated with respiratory tract allergies symptoms (Frączek et al. 2017), and more than 600 fungal species are linked with significant human and animal infections, with many more species causing significant plant diseases (Fisher et al. 2016). The presence of several toxigenic fungi, according to an American Industrial Hygiene Association field guide, necessitates immediate risk management remedies (Odebode et al. 2020).

Fungal spores have caught the attention of researchers all over the world because due to their proven and prospective pathogenic and allergic capabilities, since of fungal spores has an impact on human health, as it can cause asthma and allergies, whether indoor or outdoor (Baxi et al. 2016; Alam et al. 2022). Airborne fungi play a significant role in spreading many plant diseases that result in substantial economic losses, among those airborne fungi causing economic losses. Several Botrytis species cause significant losses in various economically important horticultural and floral crops. For instance, *Botrytis cinerea* is known to infect tomato, grapevine, strawberry, and flax, resulting in substantial agricultural damage (Filinger and Elad 2016). Mango, banana, papaya, pineapple, and avocado are considered significant tropical fruits cultivated in tropical regions for local consumption, export, and as income sources for growers. These fruit crops are vulnerable to *Fusarium* infections both in the field and post-harvest, leading to root rot, vascular wilt, stem rot, and fruit rot. Among the *Fusarium* species most commonly linked to diseases in these major fruits are *F. oxysporum* and *F. solani*, prevalent particularly in tropical regions (Zakaria 2023). as well as their capacity to spread and survive in a wide range of environments (Grinn-Gofroń et al. 2020; Korneykova et al. 2020).

The fungal community of aerobic fungi can be affected by phytopathogenic fungi. Fungal species were are identified in different environments, from cultivated and uncultivated places and from some coastal areas (Chen et al. 2021). Up to now, the effects of various land cover types as potential sources of airborne spores have been rarely studied (Cudowski and Pietryczuk 2020). A number of studies on airborne fungi have been conducted in the Middle East region and Iraq's neighboring countries (Shams-Ghahfarokhi et al. 2014). As for Iraq, there are some studies, such as Al-Bader et al. (2018) analyzed the fungal community structure species found in air conditioner units contaminated with fungi at governmental hospitals in Erbil City, Iraq. Atya et al. (2019) assessed the indoor air quality, focusing on airborne fungi, in laboratories within Faculty and hospital buildings located in Thi-Qar Governorate, Southern Iraq. Saleem and Zefenkey (2023) conducted a study to uncover the fungal community associated with dust and its differences compared to its counterpart in the calm climate of Erbil City. Al-Bader and Zenfenkey (2023) conducted a review on airborne fungi in Iraq from 1995 to 2022 by analyzing the original articles on airborne fungi that have been conducted in Iraq. The objective of this study was to look investigate at the diversity and patterns of airborne mycoflora in outdoor habitats across Basra City, Iraq and compare the atmospheres of cultivated and non-cultivated areas.

MATERIALS AND METHODS

Sampling sites

Basra is Iraq's second largest city, with an area of 19070 km^2 and located on a latitude of 30°30' N and longitude of 47°50' E. It is characterized by its hot climate most of the year. Thirteen sites namely, Al-Zubair, Um Qasr, and Khor Al Zubair (desert area), Abu Al-Khaseeb 1, 2, Al-Seeba, At Tannumah, Al-Jazeera, Ad-Dayr, Al-Hartha, and Garmat Ali (agriculture area), Al-Maqil and Al Junaina (urban area) were chosen to collect samples of airborne fungi (Figure 1).

Air sampling

From October to December 2022, a total of 130 air samples were collected, using the settle plate method, from 13 sampling sites, 10 samples from each site, five of them in October and the another five in September for each area distance between each one to another 500 meters, in order to cover the largest possible area, as described by Shams-Ghahfarokhi et al. (2014). The selection of sampling sites was based on their representation of different areas within each location. For each site, plastic plates containing Malt Extract Agar (MEA) and Potato Dextrose Agar (PDA) in addition chloramphenicol were placed about one meter above the floor for a duration of 15 minutes. Subsequently, the plates transported to the laboratory for fungal isolation and identification. The experiment was done in triplicates.

Isolation and identification of airborne fungi

The plates were incubated at 27°C for 2-3 weeks to ensure the growth of all airborne fungi. Daily inspection was conducted to monitor any visible fungal growth. Each fungal colony was then introduced onto Malt Extract Agar (MEA) and Potato Dextrose Agar (PDA) media supplemented with chloramphenicol, and incubated at 27°C for 7 days. Following this, Petri dishes were initially inspected using a dissecting microscope (stereomicroscope) and then examined under a high-resolution light microscope to discern colonial characteristics and morphological structures. Morphological analysis was done using slide preparation in which samples were mounted in lactophenol. Fungal species were distinguished based on both micro- and macro-morphology, as well as color of colonies. Species identification was refined to the species level utilizing diverse mycological references (Ellis 1971; De Hoog and Guarro 1995; Domsch et al. 1993; Seifert et al. 2011; Kiffer and Morelet 2011; Campbell et al. 2013).

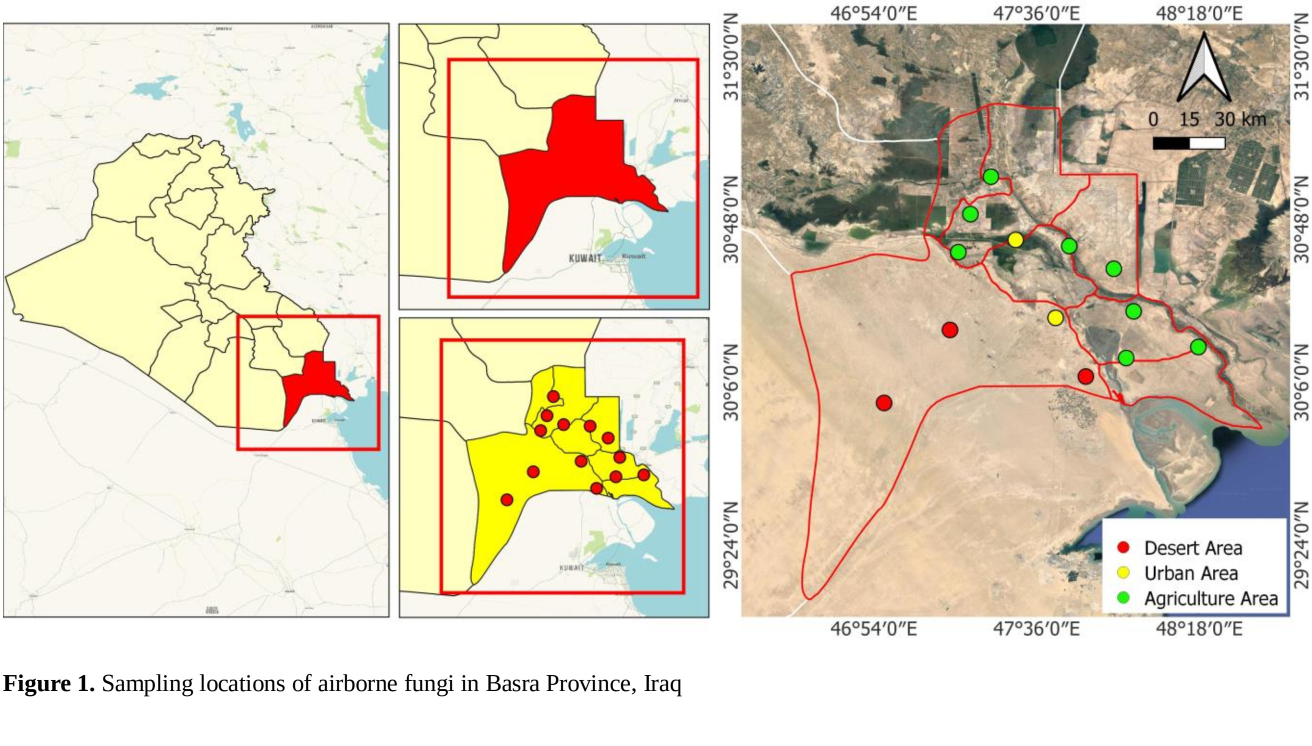

Figure 1. Sampling locations of airborne fungi in Basra Province, Iraq

Calculating fungal diversity and similarity

The fungal diversity indices were calculated by Simpson's Diversity Index (D):

$$D = 1 - \left[\frac{\sum ni(ni - 1)}{N(N - 1)}\right]$$

Where:

n_i : The number of organisms belonging to isolates *i*

N : The total of number of isolates

The value for Simpson's Diversity Index ranged between 0 to 1, the value near 1 indicate high level of biodiversity, while the value near 0 indicate low level of biodiversity.

The Marczewski-Steinhaus formula was employed to assess similarities among the airborne fungi communities collected from various sites under study.

$$S_{(1,2)} = \left[\frac{w}{(a + b - w)}\right]$$

Where:

S : Similarity of two mutually comparable airborne fungi communities

a : Number of isolates of fungi communities 1

b : Number of isolates of fungi communities 2

w : Number of fungi association isolates common for both associations (1 and 2)

(1,2): The fungal communities of sites 1 and 2

The convergence or divergence of two associations (r) is expressed by the formula:

$$r = 1 – S$$

RESULTS AND DISCUSSION

Identification of airborne fungi

The results showed that a total of 1654 fungal colonies were identified from 13 selected sites in Basra Province, including two sterile mycelium belonging to 26 genera and 32 species. Fungal isolates belonged to three groups, ascomycota, Zygomycota and Basidiomycota. The highest (90.6%) percentage of anamorphic status belonged to ascomycota, followed by Zygomycota (6.25%), and Basidiomycota (3.12%). The highest frequency i.e. 18.2%, 10.9%, 8.8%, and 8.5% of fungal isolates were recorded in *Cladosporium herbarum, Aspergillus fumigatus, Aspergillus niger*, and *Penicillium* sp., respectively. *Alternaria alternata* and *Aspergillus terrus* were ranged between 7.56 and 7.5 %, respectively, while lowest (0.7%) frequency was observed in *Monodictys cerebriformis* (Figure 2).

Additionally, fungal species that could be a potential plant pathogen were found to be more abundant in agricultural areas like Abu Al-Khaseeb, Al-Seeba, Al-Tannumah and Al-Jazeera compared to areas where desert climates prevail like Al-Zubayr and Umm Qasar (Table 1). Results showed that fungal species, like *A. alternata*, *Aurobasidium pullulans*, *Bipolaris australiensis*, *Bipolaris sorghicola*, *C. herbarum*, *Curvularia hominis*, *F. oxysporum*, *Helminthosporium velntinum*, *Stemphylium sarciniforme* and *Ulocladium* sp., were found from sampling sites. All these fungi can cause diseases in plants, whether they are economic crops, ornamental plants, or natural plants. Some of the isolated fungal species may be capable of decomposing organic matter and some of them may be responsible for human diseases.

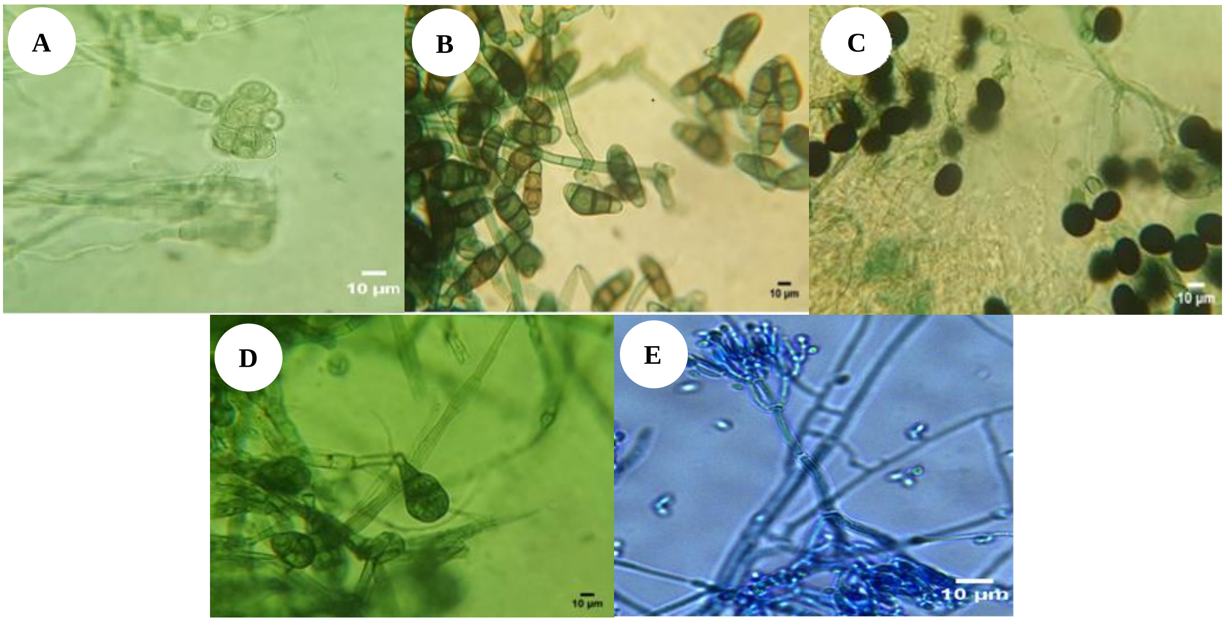

Figure 2. Airborne fungal species isolated from different sites in Basra Province, Iraq: A. *Monodictys cerebriformis*; B. *Curvularia hominis*; C. *Nigrospora oryzae*; D. *Alternaria alternata*; E. *Penicillium* sp.

Table 1. Number of colonies and frequency of fungal isolated from sites in Basra Province, Iraq

Fungal species	No. of colonies	Frequency (%)	Sites												
			Number of colonies at sites												
			Khor Al Zubair	Al-Jazeera	Al Zubayr	Al-Hartha	Abu Al-Khaseeb 1	Garmat Ali	Al Seeba	Abu Al-Khaseeb 2	Um Qasr	Al Junaina	Ad-Dayr	Al-Maqil	Altan-nauma
Acremonium sp.	48	2.9	-	12	-	-	11	-	-	11	-	-	-	14	-
Alternaria alternata	125	7.56	14	12	-	-	11	10	21	14	-	16	12	-	15
Aspergillus flavus	90	5.4	-	-	-	13	11	-	12	19	-	11	-	13	11
Aspergillus fumigatus	180	10.9	23	11	28	17	17	19	-	16	12	11	15	-	11
Aspergillus niger	145	8.8	-	11	22	15	12	15	11	12	13	12	11	-	11
Aspergillus oryzae	11	0.7	-	-	-	11	-	-	-	-	-	-	-	-	-
Aspergillus terrus	124	7.5	11	12	-	-	-	11	19	13	15	11	11	-	11
Aurobasidium pullulans	12	0.72	-	-	12	-	-	-	-	-	-	-	-	-	-
Baudoinia compniacensis	11	0.7	11	-	-	-	-	-	-	-	-	-	-	-	-
Bipolaris australiensis	11	0.7	-	-	-	-	-	11	-	-	-	-	-	-	-
Bipolaris sorghicola	11	0.7	-	-	-	-	-	-	-	-	-	-	-	-	11
Botrytis cinerea	11	0.7	-	-	-	-	-	-	-	-	-	-	-	11	-
Cladosporium herbarum	301	18.2	16	16	11	23	12	11	36	13	42	30	12	32	47
Curvularia hominis	11	0.7	-	-	-	-	-	-	-	-	-	-	-	-	11
Engyodontium album	11	0.7	-	-	-	11	-	-	-	-	-	-	-	-	-
Fusarium oxysporum	45	2.7	11	-	-	11	-	-	12	-	-	-	-	-	11
Helminthosporium velntinum	11	0.7	-	-	-	-	-	11	-	-	-	-	-	-	-
Monodictys cerebriformis	11	0.7	-	-	-	-	-	-	-	-	-	-	11	-	-
Monodictys putredinis	11	0.7	-	-	-	-	-	-	-	-	-	-	11	-	-
Mucor sp.	11	0.7	-	-	-	-	-	-	-	11	-	-	-	-	-
Myceliophthora lutea	11	0.7	-	-	-	-	-	11	-	-	-	-	-	-	-
Neotyphodium coenophialum	11	0.7	-	-	-	-	-	-	-	11	-	-	-	-	-
Nigrospora oryzae	12	0.72	-	-	-	-	-	-	-	-	-	-	12	-	-
Penicililum sp.	140	8.5	11	-	47	12	-	-	17	11	-	12	-	12	18
Rhizopus sp.	33	2	-	11	-	-	-	-	-	-	11	-	11	-	-
Scopulaiopsis brevicaulls	22	1.3	-	-	-	-	11	-	-	11	-	-	-	-	-
Stemphylium sarciniforme	11	0.7	-	-	-	-	11	-	-	-	-	-	-	-	-
Trichothecium roseum	29	1.7	-	-	-	-	-	-	12	-	-	-	-	-	17
Ulocladium sp.	11	0.7	-	11	-	-	-	-	-	-	-	-	-	-	-
Candida glabrata (Yellow yeast)	33	2	-	-	-	11	-	-	11	-	-	-	-	-	11
Rhodotorula mucilaginosa (Red yeast)	40	2.4	-	-	-	17	-	-	11	-	-	-	-	-	12
Candida albicans (Milky yeast)	53	3.2	12	-	12	-	11	-	-	-	18	-	-	-	-
Color mycelium	11	0.7	11	-	-	-	-	-	-	-	-	-	-	-	-
White mycelium	56	3.4	-	12	-	-	-	11	-	11	-	-	11	11	-
Total	1654		120	108	132	141	107	110	162	153	111	103	117	93	197

The highest number of fungal colonies were 197 and 162 noted from At Tannumah and Al seeba regions, respectively, and the lowest 99, 93 fungal colonies were recorded in urban areas, such as Garmat Ali and Al-Maqil, respectively, while the other ranged 103 for Al Junaina to 141 for Al-Hartha (Figure 3).

Diversity and similarity of airborne fungi

The urban areas were less diverse and had fewer colonies than areas where agricultural activities area were abundant. The highest fungal diversity was found in Abu Al-Khaseeb 2 and Ad-Dayr 0.91, 0.9, respectively where more agriculture activities were done, while the others ranged between 0.89-0.78 the lowest fungal diversity was recorded in urban areas and desert nature as Um Qasr, Al Zubayr 0.78 for each (Figure 4).

Qualitative similarity between fungal communities was calculated using the Jaccard similarity formula (Table 2). The highest similarity was 0.77 observed between the airborne fungal communities at Al Seeba and At Tannumah sites. Conversely, the lowest 0.09 similarity was noted between the airborne fungal communities at Um Qasr and Al-Maqil sites, while a moderate similarity was observed between the Al Junaina, which was an urban region. The two regions of Al Seeba and Abu Al Khaseeib 2, which were agriculture areas, similarities were 0.55 and 0.58, respectively. The remaining airborne fungal associations displayed comparable qualitative similarities, ranging from 0.14 for Garmat Ali and Al-Hartha to 0.58 for Al Junaina and Abu Al-Khaseeb 2 (Table 2).

When studying the coefficient of convergence and divergence between fungal communities, the convergence was found highest between At Tannumah and Al Seeba, and the greatest divergence was recorded between the fungal communities in the Al-Hartha and Ad-Dayr regions (Table 3).

Table 2. Qualitative similarity among fungal communities in thirteen analyzed regions in Basra Province, Iraq

Sites	Khor Al Zubair	Al-Jazeera	Al Zubayr	Al-Hartha	Abu Al-Khaseeb 1	Garmat Ali	Al Seeba	Abu Al-Khaseeb 2	Um Qasr	Al Junaina	Ad-Dayr	Al-Maqil
At Tannumah	0.38	0.29	0.36	0.35	0.29	0.29	0.77*	0.39	0.27	0.54	0.28	0.12
Al-Maqil	0.15	0.25	0.2	0.23	0.25	0.15	0.23	0.38	0.09	0.3	0.14	
Ad-Dayr	0.27	0.58*	0.23	0.1	0.27	0.46	0.25	0.38	0.45	0.42		
Al Junaina	0.45	0.45	0.4	0.31	0.45	0.45	0.55	0.58*	0.44			
Um Qasr	0.25	0.5	0.3	0.14	0.36	0.36	0.23	0.29				
Abu Al-Khaseeb 2	0.4	0.5	0.29	0.2	0.5	0.4	0.38					
Al Seeba	0.36	0.27	0.3	0.43	0.27	0.27						
Garmat Ali	0.29	0.5	0.25	0.12	0.29							
Abu Al-Khaseeb 1	0.2	0.38	0.25	0.19								
Al-Hartha	0.27	0.19	0.45									
Al Zubayr	0.25	0.25										
Al-Jazeera	0.36											

Note: *Significant value

Table 3. The coefficient values (r) among fungal communities in thirteen analyzed regions in Basra Province, Iraq

Sites	Khor Al Zubair	Al-Jazeera	Al Zubayr	Al-Hartha	Abu Al-Khaseeb 1	Garmat Ali	Al Seeba	Abu Al-Khaseeb 2	Um Qasr	Al Junaina	Ad-Dayr	Al-Maqil
	R value											
At Tannumah	0.62	0.71	0.64	0.65	0.71	0.71	0.23*	0.61	0.73	0.46	0.28	0.88
Al-Maqil	0.85	0.75	0.8	0.77	0.75	0.85	0.77	0.62	0.91	0.7	0.86	
Ad-Dayr	0.73	0.42*	0.77	0.9	0.73	0.54	0.75	0.62	0.55	0.58		
Al Junaina	0.55	0.55	0.6	0.69	0.55	0.55	0.45	0.42*	0.56			
Um Qasr	0.75	0.5	0.7	0.86	0.64	0.64	0.77	0.71				
Abu Al-Khaseeb 2	0.6	0.5	0.71	0.8	0.5	0.6	0.62					
Al Seeba	0.64	0.73	0.7	0.57	0.73	0.73						
Garmat Ali	0.71	0.5	0.75	0.88	0.71							
Abu Al-Khaseeb 1	0.8	0.62	0.75	0.81								
Al-Hartha	0.73	0.81	0.55									
Al Zubayr	0.75	0.75										
Al-Jazeera	0.64											

Note: * Significant value

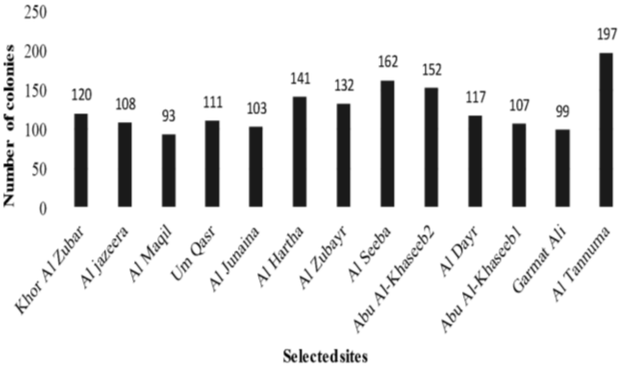

Figure 3. Number of total fungal colonies in selected sites at Basra Province, Iraq

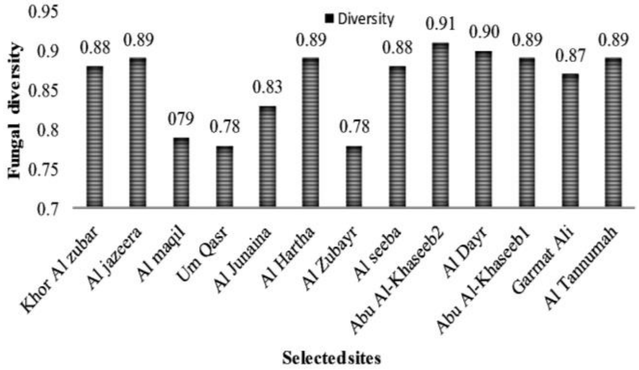

Figure 4. Fungal diversity in selected sites at Basra Province, Iraq

Discussion

Exposure to fungi has caused various human health problems, including irritations, infections, allergies, and toxic effects. Fungal communities of aerobic fungi can be affected by different environments, from cultivated and uncultivated places, up to now, the effects of various land cover types as potential sources of airborne fungal species spores have been rarely studied. The isolation results revealed that anamorphic fungi belonging to Ascomycota were found to be dominant in all regions. Anamorphic fungi, also known as asexually or mitotically sporulating fungi, are highly successful organisms (Wu and Diao 2022). They excel in producing diverse bioactive compounds, participating in post-harvest processes, and occupying a wide range of habitats. The melanin pigment present in some asexual fungal species, such as *Cladosporium*, *Bipolaris*, *Alternaria*, *Aurobasidium*, *Curvularia*, *Neotyphodium* and *Stemphylium* also plays an important role in their resistance to heat and ultraviolet radiation (Suthar et al. 2023). Their success can be attributed to their common and widespread nature, vital roles in ecosystems, and significant contributions to the human economy (Naranjo-Ortiz and Gabaldón 2019).

Airborne fungi rank as some of the most prevalent organisms in the natural environment and are associated with detrimental health effects on both humans and plants (Fisher et al. 2016). In the present study, *C. herbarum*, *A. fumigatus*, *A. niger*, and *Penicillium* sp. were identified as the predominant fungal species in the air of Basra Province. Moreover, their compositions differed between sampling sites. Weather factors can also influence the presence and spread of airborne fungi (Pyrri and Kapsanaki-Gotsi 2017). Our results were in accordance with other reports, which also identified these species as the most prevalent airborne fungi. Haas et al. (2014) reported that high concentrations of *Cladosporium* sp., *Penicillium* sp., and *Aspergillus* sp. were found in many regions of southern Austria. The median outdoor concentrations ranged between 100 and 940 cfu/m³ for culturable fungi, while for indoors, it ranged between 180 and 420 cfu/m³. Shams-Ghahfarokhi et al. (2014) investigated the distribution of airborne fungi in the outdoor environment in Tehran, out of a total of 6455 colonies, *Aspergillus* 31.3% was the most prominently isolated fungus, followed by *Cladosporium* 22.1%, *Penicillium* 13.8%, and *Alternaria* 12.2%. Saito et al. (2015), analyzed the transition of airborne fungi over 20 years in Sagamihara, and found that the most common fungi, excluding yeasts and sterile mycelium, were *Cladosporium*, *Alternaria*, *Penicillium*, *Ulocladium*, *Fusarium*, *Arthrinium*, *Epicoccum*, *Aureobasidium*, *Curvularia*, *Nigrospora*, and *Aspergillus*. In Borrego et al. (2022) studied the concentration and diversity of air- and dust-borne mycobiota in seven National Archive of the Republic of Cuba repositories, they found that the predominant genera were *Aspergillus*, *Cladosporium*, and *Penicillium*. Yang et al. (2023) conducted a survey of airborne fungi and their sensitization profile in Wuhan. Out of a total of 29 different fungal genera identified, the most prevalent fungi in this area were *Cladosporium*, *Alternaria*, *Aspergillus*, and *Penicillium*.

The increase in fungal colonies in cultivated areas generally exceeds that in urban areas. This could be attributed to the variety of crops, each susceptible to multiple fungal species. Moreover, agricultural plants create a conducive environment for fungal growth and reproduction, supported by organic-rich soils. These findings are aligned with prior research by Wan-Rou et al. (2018) who found an increase in airborne fungal colonies nearer rural areas compared to urban areas. Al-Shaarani et al. (2023) noticed an increase in the number of fungal colonies in areas close to cultivated areas, when studying airborne fungi at different sites in China. Haas et al. (2023) observed the effect of some factors, such as wind, humidity and regions on the concentration of airborne fungi, and found that areas with vegetation cover had a different concentration of fungal colonies than others.

The results of present study showed that the diversity of fungal communities and the number of colonies were higher in the air of cultivated environments than the air of uncultivated areas. Air sampling is efficient for capturing fungal diversity changes of not only soil-inhabiting fungi, such as ectomycorrhizal and saprotrophic fungi, but also wood-decaying fungi, lichens, endophytes, and plant pathogens. The results of this study led to the conclusion that urbanization can result in marked variation in fungal community composition already at the local scale, and that such variation can be detected more efficiently captured by air sampling than by soil sampling. Aerial fungal sampling can be applied globally with standardized methods (Schmidt et al. 2017; Piano et al. 2020). This is consistent with other studies, such as the study conducted by Odebode et al. (2020), who found that the abundance and diversity of airborne fungi communities are affected by various factors, including the wet season and the nature of the location, whether cultivated or uncultivated areas. Abrego et al. (2020) observed the effect of variation in human activity on air and soil fungi in different cities in Finland, results revealed that air fungi are more affected by variation than soil fungi. They also observed that different regions, whether urban, cultivated, or uncultivated land, have an impact on the variation in fungal community.

The results of present study exhibited that the aerial fungal communities to be highly sensitive to anthropogenic disturbance and thus be reliable bioindicator of ecosystem health. Identifying the particular stressors causing the marked variation in aerial fungal communities is an important avenue for future research (Fang et al. 2019).

The abundance and diversity of airborne fungi are influenced by the nature of the land. Cultivated areas, such as arable fields and grasslands, show higher abundance of fungi compared to non-cultivated areas like forests and natural habitats (Kacergius and Sivojiene 2023). Urban areas have significantly lower fungal diversity in both air and soil compared to natural areas (Abrego et al. 2020).

The presence of pepper plantations also affects the diversity of airborne fungi, with *Fusarium* sp., *Curvularia* sp., *Penicillium* sp., and *Trichoderma* sp. identified as potential pathogens (Rabae et al. 2020). Overall, the nature of land, whether cultivated or not, plays a crucial role in shaping the abundance and diversity of airborne fungi.

Results showed that the similarity of fungal communities appeared in some high value, as between Al-Seeba and At Tannumah, especially in some plant pathogenic species like *A. alternata*, *F. oxysporum* and *C. herbarum* due to the two sites having the same plants like date palm and other crop plants in addition to soil type and farming methods. This observation is supported by Zhai et al. (2018) also found the same type of cultivated plant affects the presence of specific airborne fungal species, especially are plant pathogens and are associated with disease. The similarity between the areas of Al Junaina, Al Seeba and Abu Al-Khaseeb 2 was moderate, this may be due to the transfer of spores of some fungal species, especially those that were pathogenic to plants, such as *A. alternata* and *C. herbarum* and the other fungal species that decompose organic matter, by wind or dust from the agricultural areas of Al Seeba and Abu Al-Khaseeb 2 to the urban area of Al Junaina. Our results were in accordance with Haas et al. (2023), who reported that geographic location and meteorological factors can affect the concentrations and quality of bioaerosols. The study examined three different geographical areas: urban, rural, and mountain regions. Possible correlations between particle counts and culturable fungal spore concentrations were investigated, revealing that some fungal species can be transported between these locations by wind, dust, or other factors.

From the results of present study, it can be concluded that airborne fungi were influenced by the type of terrain they inhabit. There was greater diversity in cultivated areas compared to urban and non-cultivated areas. Furthermore, plant-pathogenic fungi were closely linked to the presence of their respective plant families. In areas where plant species, environments, and agricultural practices were similar, fungal community were found to be higher. Weather factors may play a role in the presence and spread of types of air fungi, as wind, and heat have an influential role on these microscopic organisms, and their movement from one place to another, i.e. from cultivated areas to uncultivated areas, and vice versa as well.

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