

Seasonal variation of fungal spore populations in the atmosphere of Zarqa area, Jordan

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Abstract Fungi are among the most important aeroallergens. The aim of this study was to provide aeromycological baseline information about Zarqa area, Jordan, for the first time. During the entire survey and from 170 settle plate exposures, a total of 735 mould- and 274 yeast colony-forming units (CFU) were collected. mould colonies were assigned to 35 genera and 59 species. The highest abundance was attributed to *Cladosporium* with a percentage of 29.1% of the total colony count followed by *Fusarium* 20%, *Alternaria* 7.7%, *Ulocladium* 6.5% *Penicillium* 4.2% and then *Aspergillus* 3.6%. *Cladosporium* showed one peak in October while *Aspergillus* and *Penicillium* peaked in September. *Fusarium* peaked in May and August and *Alternaria* in March and July. However, *Ulocladium* showed almost the same abundance from March to June and then in September and

December. A double peak in total colony count and fungal diversity was found, the first was in March and the second in November–December. Significant differences of total fungal colony counts favouring the 1500 hours collection time over that at 1000 hours were found between November and January while no such significant differences were obtained between February and April. Our results also indicated differences in species composition between the two periods in different months. Spores of the three abundant species, *Cladosporium*, *Fusarium* and *Alternaria*, might favour high release in the 1500 hours period during winter while having a similar incidence during the two periods in the spring months.

Keywords Fungal spores · Aeromycology · Airborne · Aerobiology · Jordan

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1 Introduction

Fungal spores constitute a significant fraction of airborne bioparticles. The airborne fungal spores have important health implications for allergy and asthma sufferers. Therefore, extensive studies on spatial and temporal distribution of airborne fungal spores have been conducted in different parts of the world.

According to Lacey (1981), airborne fungal spores are originally created from plant, animal, and soil sources; however, some authors believed that airborne

spores are mainly a contribution from vegetation rather than soil (Gregory 1973; Moubasher 1993). The number of fungal airspora and their diversity vary with time of day, weather, season, geographical location and the presence of local spore sources (Lacey 1981). The greatest number of airborne spores was found to be in temperate and tropical regions and the least in desert (Lacey 1981). Some species of fungi such as *Cladosporium cladosporioides*, *C. herbarum*, *Penicillium brevicompactum*, *P. chrysogenum*, *Aspergillus candidus*, *A. niger* and *A. versicolor* can provoke extreme allergic reactions in humans (Simeray et al. 1995), and these bioaerosols may cause eye and sinus irritation, sore throat, headache, fatigue and dizziness (Buttner et al. 2001). Mould growth may contribute to sick-building syndrome as well as to allergy and other environmental health problems (Singh 2001). Fungal propagules can serve as infective agents of plant diseases and, moreover, airborne fungi cause spoilage of foods and are responsible for many adverse health effects; the mycotoxins which they produce may affect humans and animals.

Aeromycological research from the Middle East area is limited and scattered; in Egypt (Saad 1958; Zaky 1960; Moustafa 1971; Moubasher and Moustafa 1974; Abdel-Hafez et al. 1986; Abdul Wahid et al. 1996; Ismail et al. 2002), in Israel (Ben-Meir-Gleuck 1952; Barkai-Golan 1959, 1961; Barkai-Golan and Clazer 1962; Bashan et al. 1991), in Kuwait (Moustafa 1975; Moustafa and Al-Musallam 1976; Khan et al. 1999), in Qatar (Al-Subai 2002), in Saudi Arabia (Abdel-Hafez 1984; Abdel-Hafez and Shoreit 1985; Hasnain et al. 2005), in Yemen (El-Essawy et al. 1992), in Turkey (Colakoglu 1996; Sarica et al. 2002; Sakiyan and Inceoglu 2003; Asan et al. 2004; Özkara et al. 2007) and in Iran (Hedayati et al. 2005; Nourian et al. 2007). In Jordan, aerobiological studies are scarce (Al-Eisawi and Dajani 1987, 1988; Al-Qura'n 2008) with only a single article published about aeromycology of the Amman area (Shaheen 1992). While the Amman area is located in a semi-arid Mediterranean bioclimatic zone, Zarqa is located in an arid Mediterranean region and bordered by both Mediterranean and Saharo-Arabian regions. Therefore, plant elements of the three regions are present and can contribute to the aeromycoflora of the Zarqa area. This study represents the first investigation of air-borne fungal spore population of the Zarqa area, Jordan, and represents a baseline for future studies.

2 Materials and methods

2.1 Study site

Jordan is about 100 km from the south-eastern coast of the Mediterranean Sea (approx. 29–33°N, 35–39°E) and has a land area of about 89,200 km², of which arable land is less than 5%. The present study was conducted at the campus of The Hashemite University, Zarqa (32°04'N, 36°12'E; altitude 550–650 m) that lies 40 km east of Amman (the capital of Jordan). The mean annual precipitation is approximately 115 mm, falling mainly between October and April. The recorded temperature ranges between 0.0°C in December and/or January to around 40°C in July and/or August. The mean minimum temperature in winter is 2.7°C and the mean maximum temperature in summer is 34.3°C. The prevailing wind is northwest with a mean monthly wind speed ranged between 2.0 and 7.8 knots. According to bioclimatic classification, the area is specifically classified as arid Mediterranean, while for vegetation type it is typically Irano-Turanian (steppe) region (Zohary 1962; Al-Eisawi 1985). The area is mainly of rocky limestone hills, flat plains and broad wadis. The natural vegetation is mainly of bushes like *Salsola baryomosa*, *Noaea mucronata*, *Hamada scoparia*, *Anabasis syriaca* and *Artemisia herba-alba*. *Retama reatum* shrubs represent the climax vegetation in hilly areas. Recently, the area became highly populated due to the construction of many housing projects, university campuses, and investment activities for industrial, commercial and service purposes.

The region is highly industrialised with more than 52% of Jordanian industries located in Zarqa. These include the main Oil Refinery, King Hussain Thermal Power Plant and other chemical industries. Moreover, Kherbit El-Samra, the main wastewater treatment plant in the country that treats about 80% of municipal and industrial wastewater, and Al-Rusaifa Landfill which is considered as the largest landfill in Jordan, are located within the region.

New agricultural projects accompanied the above development. In the Hashemite University campus and since 8–15 years ago, olive trees had been planted in the plains and low slopes covering around 100 ha. Ornamental shrubs/trees are also planted on the hill slopes, along roads, and near buildings which include *Pinus*, *Casuarina*, *Cupressus*, *Eucalyptus* and

Ceratonia. A variety of ruderal annuals and weeds are mainly grown under and between ornamental and olive trees. The dominant weed species are *Diploaxis eruroides*, *Eruca sativa*, *Sonchus oleraceus*, *Mulva neglecta* and *Chenopodium album*.

2.2 Sampling methods

Sampling was made using a gravitational method through a Petri dish directly on the roof of the building of the Department of Biology and Biotechnology, The Hashemite University Campus, which is about 7 m high. Preliminary tests showed that sampling between 1000 and 1200 hours and an exposure time of 15 min were very appropriate as it gave adequate colony counts. One Petri dish (9 cm diameter) containing Sabouraud's dextrose agar was exposed on the roof of the above-mentioned building for 15 min on each of 3 days a week (alternate days) at 1000 hours from the beginning of January 2008 to the end of January 2009. A total of 170 exposures were made for the entire study. After sampling, the plates were incubated at $25 \pm 2^\circ\text{C}$ for 6–8 days. The fungal colonies grown for each species were counted and the total colony count was also recorded. For identification purposes, fungal colonies were isolated and purified on Sabouraud's dextrose agar and/or 1% glucose-Czapek's agar + 0.05% yeast extract and then incubated for 5 days. Identification (at specific level, if possible) was based on the macro- and microscopic features following the keys and description given by Booth (1971), Domsch et al. (1980), Kozakiewicz (1989), Moubasher (1993), Pitt and Hocking (1997), Barnett and Hunter (1999) and Samson et al. (2002).

To study diurnal variations in fungal populations, One Petri dish (9 cm diameter) containing Sabouraud's dextrose agar was exposed for 15 min at 3-h intervals: 1000, 1300 and 1500 hours on each of the last 10 days from February to April 2008 and November 2008 to January 2009 (a total of 10 exposures for each interval per month). Then, the same conditions of collection, incubation, isolation and identification of fungal colonies were applied as mentioned above. Since the differences between 1300 and 1500 hours data (colony count and species composition) were negligible, the 1300 hours data are not presented. Sørensen's similarity coefficient (Sørensen 1948) was applied to compare the

similarities in species composition (including species identified at specific level and other taxa) between morning and afternoon data of each month (the results of 10 exposures) as follows: Sørensen's similarity coefficient = $2C/A + B$, where A and B are the species numbers in the 1000 and 1500 hours exposures, respectively, and C is the number of species shared by the two exposures.

Significance in monthly total colony counts between morning and afternoon exposures were tested using paired *t* test (SigmaStat) at $P = 0.05$.

2.2.1 Meteorological data

Daily meteorological data were supplied by the Weather Record Department at Zarqa weather station.

3 Results

From the 170 exposures that have been conducted, a total of 735 mould- and 274 yeast colony-forming units (CFU) were recovered during the entire study. Mould colonies were assigned to 35 genera and 59 species. However, certain colonies were only identified to the genus level, e.g. *Penicillium*, and others were marked as unknowns (Table 1). Figure 1 represents the nine major genera obtained during the study as they represent more than three-quarters of total colony count obtained from the entire study (Table 1). The greatest total colony count was attributed to *Cladosporium* with 29.1% followed by *Fusarium*, *Alternaria*, *Ulocladium* and then *Penicillium* with 20.0, 7.7, 6.5 and 4.2%, respectively (Table 1; Fig. 2). *Cladosporium* and *Fusarium* occurred in every month of the entire study (13 months), followed by *Alternaria* (12 months), *Penicillium* and *Ulocladium* (11 months) and *Aspergillus* (10 months) (Table 1). *Cladosporium cladosporioides* achieved the highest percentage of total colony count and prevailed for 9 out of 13, while *C. macrocarpum* had the second highest percentage with 12 months prevalence and *C. tenuissimum* was the third with 7 months prevalence (Table 1). During the entire year of 2008, different peaks of monthly colony count percentage were obtained for the major genera (Fig. 2). *Cladosporium*, showed one peak in October while *Aspergillus* and *Penicillium* peaked in September. *Fusarium* peaked in May and August in addition to January 2009 and

Table 1 Total count and occurrence of airborne fungi recovered from the air of Zarqa area, Jordan

Genera and species	No. of colonies	Colony count as % of total ^a	Monthly occurrence ^b
MOULDS	735		
<i>Absidia</i>	1	0.1	1
<i>Absidia corymbifera</i> (Cohn) Saccardo & Trotter	1	0.1	1
<i>Acremonium</i>	5	0.7	2
<i>Acremonium strictum</i> W. Gams	5	0.7	2
<i>Alternaria</i>	57	7.7	12
<i>Alternaria alternata</i> (FR.) Keissler	12	1.6	6
<i>Alternaria chlamydospora</i> Mouchacca	12	1.6	7
<i>Alternaria phragmospora</i> V. Emden	15	2.0	3
<i>Alternaria tenuissima</i> (Kunze) Wilt.	18	2.5	6
<i>Aspergillus</i>	27	3.6	10
<i>Aspergillus alutaceus</i> Berk. & Curtis	1	0.1	1
<i>Aspergillus candidus</i> Link	1	0.1	1
<i>Aspergillus flavus</i> Link	6	0.8	4
<i>Aspergillus niger</i> (V. Tiehem) Blochw	11	1.5	8
<i>Aspergillus parasiticus</i> Speare	2	0.3	2
<i>Aspergillus terreus</i> Thom	3	0.4	1
<i>Aspergillus versicolor</i> (Vuill.) Tiraboschi	2	0.3	1
<i>Aspergillus wentii</i> Wehmer	1	0.1	1
<i>Aurobasidium</i>	10	1.3	3
<i>Aurobasidium pullulans</i> (de Bary) Arnaud	10	1.3	3
<i>Byssochlamys</i>	3	0.4	2
<i>Byssochlamys fulva</i> Ollivier & Smith	3	0.4	2
<i>Cladosporium</i>	216	29.1	13
<i>Cladosporium cladosporioides</i> (Fres) de Vries	57	7.8	9
<i>Cladosporium herbarum</i> (Pers.) Link	27	3.7	9
<i>Cladosporium macrocarpum</i> Preuss	48	6.6	12
<i>Cladosporium oxysporum</i> Berk. & M.A. Curtis	17	2.3	6
<i>Cladosporium sphaerospermum</i> Penzig	27	3.7	10
<i>Cladosporium tenuissimum</i> Cooke	40	5.5	7
<i>Cochliobolus</i>	5	0.7	1
<i>Cochliobolus australiensis</i> (Tsuda & Ueyama) Alcorn	5	0.7	1
<i>Emericella</i>	2	0.3	1
<i>Emericella variegata</i> Berkeley & Broome	2	0.3	1
<i>Emericellopsis</i>	2	0.3	2
<i>Emericellopsis minima</i> Stolk	2	0.3	2
<i>Epicoccum</i>	10	1.3	4
<i>Epicoccum nigrum</i> Link	10	1.4	4
<i>Eurotium</i>	1	0.1	1
<i>Eurotium chevalieri</i> Mangin	1	0.1	1
<i>Fennellia</i>	2	0.3	1
<i>Fennellia flavipes</i> Wiley & Simmons	2	0.3	1
<i>Fusarella</i>	6	0.8	3
<i>Fusarella aegyptica</i> Mouchacca	6	0.8	3

Table 1 continued

Genera and species	No. of colonies	Colony count as % of total ^a	Monthly occurrence ^b
<i>Fusarium</i>	148	20.0	13
<i>Fusarium acuminatum</i> Ellis & Everhart	14	1.9	6
<i>Fusarium avenaceum</i> (Corda: Fr.) Sacc.	8	1.1	4
<i>Fusarium lateritium</i> (Nees) Link	12	1.6	6
<i>Fusarium chlamydosporum</i> Wollenweber & Reinking	32	4.4	9
<i>Fusarium equiseti</i> (Corda) Sacc.	5	0.7	3
<i>Fusarium moniliforme</i> (A. Braun) Wollenweber	23	3.2	5
<i>Fusarium oxysporum</i> Schlecht.: Fr.	24	3.3	8
<i>Fusarium pallidoroseum</i> (Cooke) Sacc.	30	4.1	10
<i>Geomyces</i>	2	0.3	2
<i>Geomyces pannorum</i> (Link) Sigler & Carmichael	2	0.3	2
<i>Geosmithia</i> sp.	3	0.4	1
<i>Geotrichum</i>	12	1.6	5
<i>Geotrichum candidum</i> Link	12	1.6	5
<i>Graphium</i> sp.	8	1.1	1
<i>Humicola</i>	10	1.3	6
<i>Humicola fuscoatra</i> Traaen	2	0.3	1
<i>Humicola insolens</i> Cooney & Emerson	8	1.1	5
<i>Microascus</i> sp.	3	0.4	1
<i>Moniliella</i>	21	2.8	5
<i>Moniliella acetoabutens</i> Stolk Dakin	13	1.8	3
<i>Moniliella suaveolens</i> (Lindner) v. Arx	8	1.1	3
<i>Monoascus</i>	5	0.7	3
<i>Monoascus ruber</i> v. Tieghem	5	0.7	3
<i>Mucor</i>	4	0.5	2
<i>Mucor racemosus</i> Fres.	4	0.5	2
<i>Paecilomyces</i> sp.	19	2.6	5
<i>Penicillium</i> spp.	31	4.2	11
<i>Phoma</i>	18	2.4	5
<i>Phoma</i> sp.	12	1.7	2
<i>Phoma glomerata</i> (Corda) Wollenw. & Hochapfel	3	0.4	2
<i>Phoma herbarum</i> Westend.	3	0.4	2
<i>Pleospora</i>	9	1.2	3
<i>Pleospora tarda</i> Simmons	9	1.2	3
<i>Pseudallescheria</i>	3	0.4	2
<i>Pseudallescheria boydii</i>	3	0.4	2
<i>Rhizopus</i>	6	0.8	4
<i>Rhizopus arrhizus</i> Fischer	1	0.1	1
<i>Rhizopus oryzae</i> Went & Prinsen-Geerligs	3	0.4	3
<i>Rhizopus stolonifer</i> (Ehrenb.) Lind	2	0.3	1
<i>Scopulariopsis</i>	1	0.1	1
<i>Scopulariopsis candida</i> (Gueguen) Vuill.	1	0.1	1
<i>Thanatephorus</i>	6	0.8	4

Table 1 continued

Genera totals are in bold

^a Calculated as a percentage of the total count of colonies recovered from the entire study (i.e. a total of 735 colonies from 170 exposures = days)

^b Number of months of occurrence out of 13 months

^c Yeast was not included in the total colony count %

Genera and species	No. of colonies	Colony count as % of total ^a	Monthly occurrence ^b
<i>Thanatephorus cucumeris</i> (Frank) Donk	6	0.8	4
<i>Thermomyces</i> sp.	2	0.3	2
<i>Ulocladium</i>	48	6.5	11
<i>Ulocladium atrum</i> Preuss	8	1.1	7
<i>Ulocladium botrytis</i> Preuss	8	1.1	4
<i>Ulocladium chartarum</i> (Preuss) Simmons	22	3.0	7
<i>Ulocladium consortiale</i> (Thum) Simmons	1	0.1	1
<i>Xeromyces</i>	9	1.2	4
<i>Xeromyces bisporus</i> L.R. Fraser	9	1.2	4
UNKNOWN	26	3.6	13
YEASTS ^c	274		13

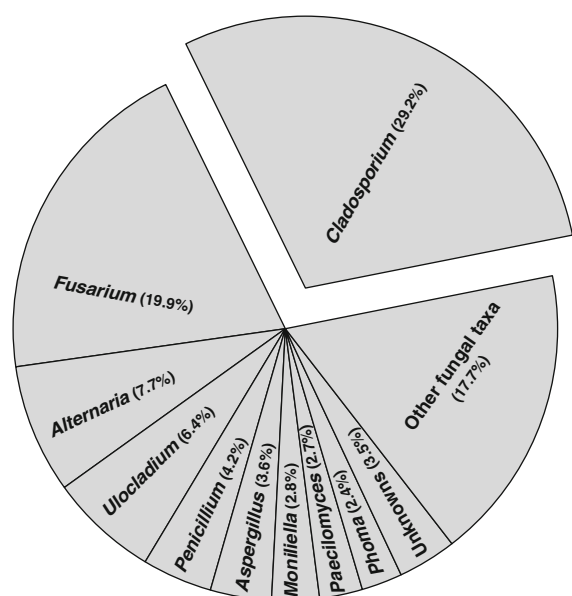


Fig. 1 Relative contributions (% of total colony count) of the major airborne fungi in the air of the Zarqa area, Jordan

Alternaria in March and July. However, *Ulocladium* showed almost similar abundance from March to June and then in September and December (Fig. 2).

The seasonal fluctuations of total fungal colony count and species diversity are best described as a double peak phenomenon, the first was in March and the second in November–December (Fig. 3).

Diurnal variations were studied in two different periods from February to April 2008 (months with moderate temperature) and from November 2008 to January 2009 (cold months); other months of the year are relatively dry and very hot (the mean maximum

temperature ranged from 30 to 38°C and with 0 mm rainfall). Total colony count and number of colonies for each of the four most abundant species (based on % colony count data of Table 1) were reported for each month at 1000 and 1500 hours and presented in Table 2. The total colony count was significantly higher ($P = 0.05$) at 1500 than at 1000 hours in November, December and January. Other months showed no significant difference between the two collection periods (Table 2). *Cladosporium* and *Fusarium*, the two most abundant species, were also lower in colony count at 1000 than at 1500 hours in November, December and January. Using a similarity index to calculate the similarity coefficient for species composition obtained in the two periods indicated that March, November and December had the highest similarity coefficient while February was the least in species similarity between the 1000 and 1500 hours fungal collections (Table 2).

4 Discussion

Based on bioclimatic and vegetation type, Jordan is divided into four bioclimatic regions: the Mediterranean (including the Amman area), the Irano-Turanian (including the Zarqa area), the Saharo-Arabian and the Sudanian regions. The Zarqa area is specifically classified as arid Mediterranean with typically Irano-Turanian (steppe) vegetation (Zohary 1962; Al-Eisawi 1985). However, the Amman area is classified as semi-arid Mediterranean with about a fourfold increase of the average annual rainfall (400–500 mm) and mean

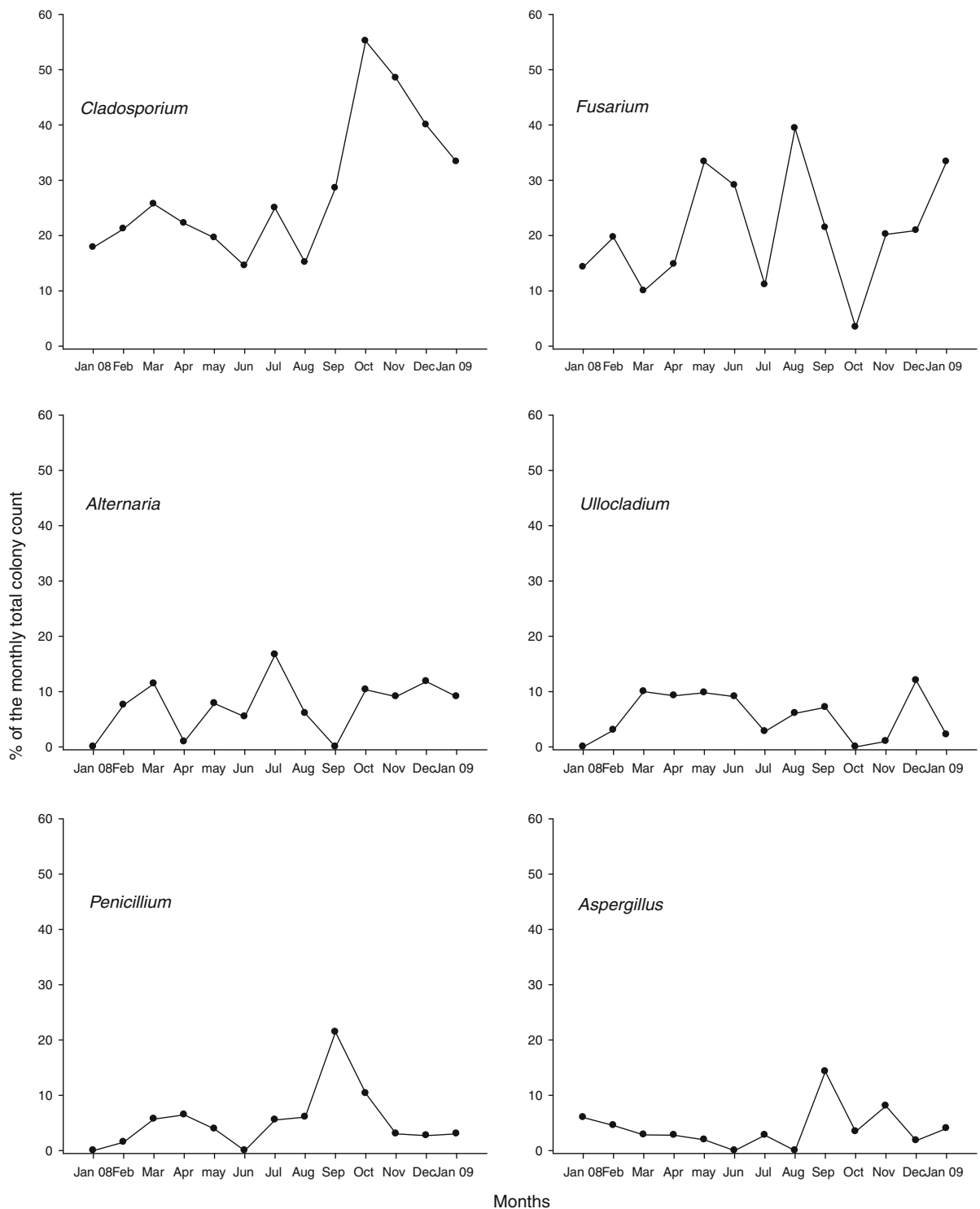


Fig. 2 Seasonal variations in monthly abundance (% of the monthly total colonies) of the major fungal genera recovered from the air of the Zarqa area, Jordan

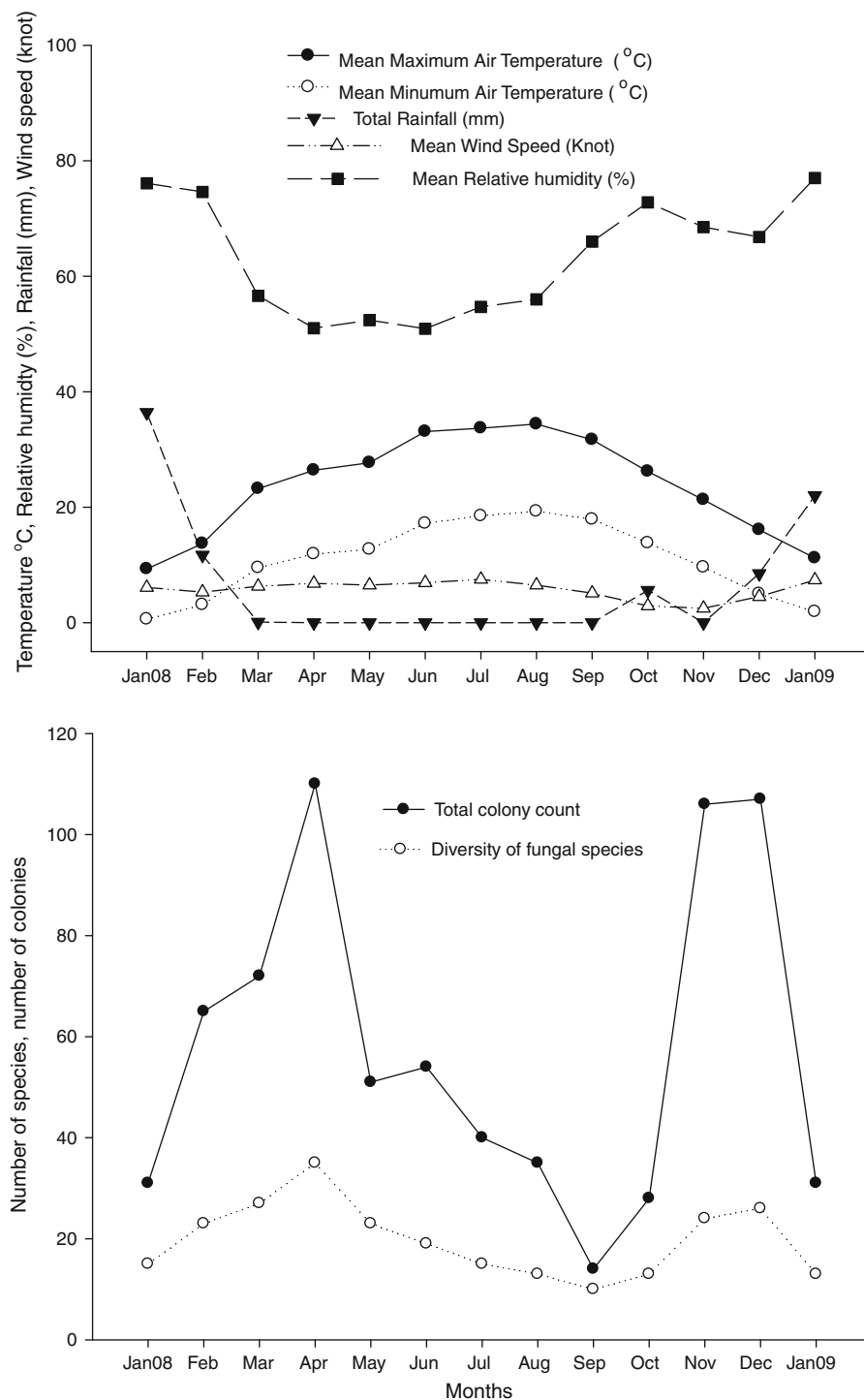


Fig. 3 Seasonal variations in total monthly colony count and number of fungal species reported each month in relation to metrological parameters

Table 2 Diurnal variations (1000 vs 1500 hours) in colony count and species composition of air-borne fungi in the Zarqa area, Jordan

	Time (hours)	Feb	Mar	Apr	Total	Nov	Dec	Jan	Total
Total colony count	10.00 am	17	14	19	50	14*	26*	17*	53
	03.00 pm	18	21	17	56	35	39	30	104
<i>Cladosporium</i>	10.00 am	5	4	7	16	6	11	5	22
	03.00 pm	2	6	7	15	17	15	10	42
<i>Fusarium</i>	10.00 am	7	7	0	14	3	4	7	14
	03.00 pm	5	6	2	13	9	12	8	29
<i>Alternaria</i>	10.00 am	2	0	0	2	1	3	3	7
	03.00 pm	2	1	0	3	0	3	0	3
<i>Ulocladium</i>	10.00 am	0	0	2	2	0	1	2	3
	03.00 pm	2	1	4	7	3	0	1	4
Total no of species	10.00 am	9	8	9	26	9	13	7	29
	03.00 pm	9	12	10	31	14	11	9	34
QS ^a		0.222	0.6	0.316		0.521	0.666	0.375	

*Significant difference in total colony count between morning and afternoon exposures according to paired *t* test at *P* = 0.05

^a Sørensen's similarity coefficient = $2C/A + B$, where A and B are the species numbers in the 1000 and 1500 hours samples, respectively, and C is the number of species shared by the two groups of samples

maximum temperature 1–2°C lower. Despite the differences in the bioclimate and vegetation between Zarqa and Amman, our results coincide with that for the Amman area (Shaheen 1992) in the fact that *Cladosporium* is the largest constituent of the airspora. Not only that but October is also the month of the highest incidence of *Cladosporium*. This may be explained by the fact that Zarqa is the closest city to Amman. In addition to that, the vegetation is intruded between the two bioclimatic regions and so some elements of one region can be encountered in the other (Zohary 1962; Al-Eisawi 1985). In several aeromycological studies, *Cladosporium* was considered as one of most, if not the most, abundant aerospora reported all over the world (Lacey 1981; El-Essawy et al. 1992; Shaheen 1992; El-Said and Abdel-Hafez 1995; Ismail et al. 2002; Al-Subai 2002; Asan et al. 2004; Hedayati et al. 2005; Oliveira et al. 2005; Nourian et al. 2007; Özkara et al. 2007). According to Shaheen (1992), the abundance of *Cladosporium* throughout the year may be attributed to the structural features of the spores such as small size, thin exine and smooth wall which favour and facilitate the transport of airborne spores. Other authors have indicated that *Cladosporium* spores are the dominant airspora in hot climates (Takahashi 1997; Sen and Asan 2001; Al-Subai 2002; El-Morsy 2006).

In the present study, *Cladosporium* (29.1%), *Fusarium* (20%), *Alternaria* (7.7%), *Ulocladium* (6.5%), *Penicillium* (4.2%) and *Aspergillus* (3.6%) represent more than two-thirds of the whole fungal collections. Except for *Fusarium*, these genera were also dominant in the air of Kuwait (Moustafa and Kamel 1979), Saudi Arabia (Abdel-Hafez 1984), Amman, Jordan (Shaheen 1992), Qatar (Al-Subai 2002) and the eastern desert of Egypt (Ismail et al. 2002). The common factor among all the above regions or countries is the arid climate while the common factor among the above-mentioned fungal spores is that they are mostly dark-coloured. Al-Subai (2002) presented a good discussion about the prevalence of dark-coloured spores in hot climate atmospheres since they are more resistant to desiccation (Nicot 1960; Ranzoni 1968; Moubasher and Mazen 1972), strong light (Nicot 1960) and ultra-violet radiation (Durrell and Shields 1960).

Fusarium was the second most abundant species in our findings with a total contribution of 20% divided between 8 identified species (Fig. 2; Table 1). Although *Fusarium* was reported to be one of the most abundant species in the atmosphere of Tel-Aviv, Israel (Kessler 1953, 1958), other reports indicated the inconsistency of *Fusarium* in hot climate regions (Moustafa and Kamel 1979; Shaheen 1992; Al-Subai 2002). In the Amman area, it was described as an

irregularly present species over the year (Shaheen 1992), but this was based on spore trapping methodology and not on viable cultures. *Fusarium* is better detected on open plates rather than spore trapping (Mitakakis and Guest 2001), and airborne spore counts for *Fusarium* are rarely high; this is because *Fusarium* species do not grow well at low water activity levels and will usually colonise very damp or wet materials, in addition, airborne microconidia and chlamydospores of *Fusarium* are difficult to identify for air samples analysed by direct microscopy, and only the macroconidia of some species may be reported (Nelson et al. 1994). It is therefore possible that *Fusarium* spores were grouped with other unidentified spores in most of studies conducted using spore traps. In agriculture, *Fusarium* is known to cause diseases of many economically important crop plants (Nelson et al. 1994), therefore the continuous drip irrigation of olive plantations (a total area of ~ 100 ha) found inside the university campus and also the several agricultural plots around Kherbit El-Samra (the largest wastewater treatment plant in Jordan which is 6–7 km distant from the campus) may contribute to *Fusarium* abundance and its frequent incidence in the atmosphere of the Zarqa area.

Studies showed that some of the airborne fungi have seasonality which might be different between different regions and/or countries. Certain peaks reported in this study (*Cladosporium*: October; *Aspergillus* and *Penicillium*: September; *Fusarium*: May, August and January; *Alternaria*: March and July; Fig. 2) may partially match one or more of the previous studies; however, we presume that this issue is hardly comparable as it is greatly affected by several regional and local factors. For example, in Amman, Jordan, the peaks were reported as follows: *Cladosporium*: October; *Alternaria*: July; *Penicillium* and *Asperigillus*: January to March (Shaheen 1992). In Doha, Qatar, the peaks were: *Cladosporium*: September and December; *Alternaria*: July and September; *Ulocladium*: May and July; *Penicillium*: July and August; *Asperigillus*: July and December (Al-Subai 2002). In Melbourne, Australia, Mitakakis and Guest (2001) noticed the seasonality of spore levels of *Cladosporium* and *Alternaria* sp. which peaked in spring and summer. In Derby, UK, Corden and Millington (2001) determined that *Alternaria* sp. spores peak in August but occasionally in late July or early September. Bandyopadhyay et al. (1991) found

a positive correlation between heavy rainfall and *Fusarium* sp. concentration. It is clear from the literature that the ecology of an area, the climatic factors, the vegetation and the microclimate (s) as well as human activities may have a major influence on seasonality of airspora.

Many researchers have reported significant effects of meteorological factors on the concentration of aerospora (Agarwal and Shivpuri 1969; Di Giorgio et al. 1996; Bandyopadhyay et al. 1991; Asan et al. 2004); however, other researchers contradicted the above findings (Mitakakis et al. 1997; Zoppas et al. 2006). In the present study, a regular association can be deduced for both fungal parameters with air temperature (Fig. 3). It is difficult to separate out the individual effects of different meteorological parameters, since fungi react simultaneously to a combination of factors (Azco' n-Bieito and Talo' n 2000). Far from considering correlations with a certain climatic parameter, the climatic year of the Zarqa area can be divided into two periods which can be repeatedly overlapped: the first is the rainfall temperate period including October to March and the second is the dry high temperature period including May to September. Moreover, the vegetation and mainly the annuals are flourishing between January and March. Therefore, the first peak of spore colony count and species diversity was March (Fig. 3). This is easily explained as it comes after the 2 months of the highest rainfall and moderate temperature, January and February, so the soil is moistened enough and the vegetation is in its maximum growth and diversity. Basically, soil and vegetation are considered the main sources contributing to airborne fungal spores (Moustafa 1971; Gregory 1973; Abdel-Gawad 1984; Moubasher and Al-Subai 1987). The second peak was in the November–December period (Fig. 3). This peak is also due to the conditions following the rainfall encountered in October and also to the relatively moderate temperature and humid climate. Even though rainfall was too low (5.6 mm, average of 10 years) but still enough to moisten the soil and to cause perennial shrubs and bushes to thrive, and in consequence fungal growth to flourish after the extended dry hot conditions from May to September. The gradual drop of fungal spore count and diversity started from May continuing to the trough in September, which may support the above conclusion. Usually, winter and rainy months have maximum frequency and concentration of fungal

spores due to the favourable growth and sporulation conditions for fungi and the availability of suitable substrates (Kakde et al. 2001). In Amman, and based on spore trapping methodology, Shaheen (1992) found a multi-peak system with October as the month of highest fungal spore count with no peak occurring in the winter months (November–March). The discrepancy in seasonality of fungal spore count between the Amman and Zarqa areas could be attributed to variations in the atmospheric conditions, vegetation density and diversity, type of soil and climatic conditions as well as the different methodology used. In dry and desert environments in Kuwait, close to the Zarqa climatic pattern, the monthly total number of fungi showed marked seasonal periodicity with the greatest number of colonies occurring in March–April and November (Moustafa and Kamel 1979). In Qatar, two peaks were recognised in July and December (Al-Subai 2002).

The months of fungal spore abundance were studied for diurnal periodicity (Table 2). We found that significant differences of total fungal colony counts were favouring the 1500 over the 1000 hours collection period between November and January while no such significant differences were obtained between February and April. Our results also indicate differences in species composition between the two periods in different months. The greatest similarities in species composition between the two periods occurred in March and December while the least occurred in February (Table 2). The three abundant species *Cladosporium*, *Fusarium* and *Alternaria* might favour to be released more at 1500 hours during winter while having a similar incidence during the two periods in the spring months. Gregory (1973) described *Cladosporium* and *Alternaria* as a daytime spora group with spores being found in maximum numbers during late morning and early afternoon. Decreasing the relative humidity in the morning is responsible for the presence of many spores in the air (Hirst 1959). Pady et al. (1969) suggested that *Cladosporium* spores that are produced at night are mature by the morning but are removed only by dry air flow. This may explain the lack of significant differences in periodicity of spore counts during February to April as well as the significant differences in periodicity during winter months as cold and humid air were encountered during early mornings. Other reports showed that *Cladosporium* peaked either in the afternoon (Pawsey 1964;

Moustafa 1971), midday (Sreeramulu and Ramalingam 1966; Al-Subai 2002) or night time (Panzer et al. 1957). However, the normal diurnal periodicity of a certain spore type could be reversed in different seasons and this might be due to the temperature effect as reviewed by Hyde (1973).

In this study, *Cladosporium*, *Fusarium*, *Alternaria*, *Ulocladium*, *Penicillium* and *Aspergillus* are the commonest fungal spores in the atmosphere of the Zarqa area. All of the above fungi have been reported to be aeroallergens. *Aspergillus* and *Penicillium* spores are the most widespread aeroallergens in the world (Asan et al. 2004). Myszkowska et al. (2002) noted that some 4–7% of the European population shows sensitivity to *Alternaria* and *Cladosporium* spores. *C. cladosporioides*, the most common reported species in this study (Table 1), has been reported to be the agent causing phaeohyphomycosis along with other species of *Cladosporium* (Kantarcioglu et al. 2002). *C. herbarum*, the second most common reported in this study, is often the major contributor to inhalant allergy and allergic asthma in humans (Cosentino et al. 1995). *Alternaria* is known to be allergenic and is one of the most common fungi worldwide that contribute to severe asthma (Downs et al. 2001); specifically, *Alternaria alternata* allergens have long been considered to cause significant respiratory allergies and serious cases of respiratory arrest (O'Hollaren et al. 1991; Vijay et al. 1989). *Aspergillus niger* is well known to cause many health problems such as extrinsic alveolitis, allergic bronchopulmonary aspergillosis, keratitis, endophthalmitis, primary cutaneous aspergillosis and necrotising otitis in humans (Severo et al. 1997). In addition to being aeroallergens, the above fungi may produce mycotoxins or other fungal metabolites that are carried by airborne dust and reach humans through skin contact (Sarica et al. 2002). According to our knowledge, no specific data are available about sensitivity of Jordanian population to the above common fungi so future investigations are needed to examine the effects of mould exposures on related health problems.

Our study revealed the existence of a rich population of airborne fungi in the atmosphere of the Zarqa area which is varied in species composition, abundance and seasonal fluctuation than in the Amman area. However, it must be considered that the culture methods used revealed only a portion of the airborne micro-organisms because some fungi

cannot grow at all in culture media and some of them may lose viability due to competition from other fungi, thus the air of the Zarqa area may be even richer in fungi. Therefore, a complimentary study using volumetric spore trapping techniques should be considered for further research.

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