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Aeromycobiota of the Mediterranean coastal area of Libya

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Abstract: The fungal airspora of the Mediterranean coastal area in Libya were assessed using the exposed plate method on two isolation media. The area of study covered 32 localities extending from Tripoli (West) to Amsaed (East) near the border area with Egypt, with a total length of 1500 Km. From 32 exposures, a total of 1502 fungal catches were collected on Czapek's agar plates, however only 1 catch of *Humicola fuscoatra* was recovered on 20 % NaCl Czapek's agar. These fungal propagules were classified into 60 species related to 28 genera. The most common aeromycobiota were *Alternaria* (found in 28 exposures matching 39.35 % of total catch), *Fusarium* (25 and 19.51 %), *Cladosporium* (15 and 16.31 %), *Ulocladium* (21 and 8.66 %) and *Aspergillus* (13 and 6.26 %). Of these genera, the most commonly encountered species were *Alternaria alternata* (20.4 % of the total catch), *Cladosporium sphaerospermum* (10.5 %), *C. cladosporioides* (5.7 %), *Ulocladium atrum* (6.9 %), *Fusarium solani* (5.7 %), *F. sambucinum* (5.5 %) and *Aspergillus niger* (5.1 %). It could be concluded that dematiaceous hyphomycetes greatly outnumbered hyaline ones. Also, many of the commonly reported species are well-documented as human, animal and plant pathogens, as well as many of them possess the ability to deteriorate stored products and spoil feed- and food-stuffs.

Key words: outdoor airspora, fungi, coastal area, Libya

Introduction

In the atmosphere many microbioparticles such as fungal spores, pollen grains and insect parts are present. Air is seldom free of fungal spores and the cosmopolitan distribution of fungi has been attributed to the fact that fungi occupy micro-environments which occur in various ecosystems and geographical areas (Richards 1956, Lacey 1975). Gregory (1973) and Moubasher (1993) supposed that airborne fungal spores are basically a contribution from vegetation rather than soil. Several others also supported this hypothesis, however, Burge (1985) stated that in natural outdoor environments, dead grasses, leaves, fallen fruits, tree bark, dead wood, and soil particles as well as animal and bird droppings and remains, provide adequate substrate materials for a wide variety of fungi.

Lacey (1981) compared the relative abundance of different spore types caught by internal traps in different climatic regions, from about 200 reports on the airspora in different parts of the world. He concluded that the number of fungal airspora and their types vary with time of day, weather, season, geographical location and the presence of local spore sources. Regional differences are mainly between minor components of the airspora which tend to increase in number and variety from cooler to warmer climatic zones.

It is well known that fungi require certain optimum conditions for each phase of their growth (Gregory 1973). Aeromycological researches from the Middle East area are scattered in several countries including Egypt (Abu-El-Souod 1974, Moubasher and Moustafa 1974, Abdul Wahid *et al*. 1996, Ismail *et al*. 2002, Abdel-Hameed *et al.* 2009, Abdel-Azeem and Rashad 2013), Kuwait (Moustafa 1975, Khan *et al*. 1999), Qatar (Al-Subai 2002), Saudi Arabia (Abdel-Hafez 1984), Yemen (El-Essawy *et al*. 1992), Turkey (Asan *et al*. 2004, Özkara *et al.* 2007), Iran (Hedayati *et al.* 2005, Nourian *et al.* 2007) and Jordan (Shaheen 1992, Al-Qura'n 2008).

The most abundant airborne fungal genera are *Cladosporium*, *Alternaria*, *Epicoccum*, *Stemphylium*, *Curvularia*, *Torula*, *Aspergillus* and *Penicillium* (Lacey 1981, Beaumont *et al*. 1985, El-Essawy *et al*. 1992, Tan *et al*. 1992, Abdel-Hafez *et al.* 1993, El-Said and Abdel-Hafez 1995, Ismail *et al.* 1999). The study of aeromycology is important in disease forecasting of man, animal and plant diseases (Gregory 1973, Burge 1985, Lacey and Crook 1988, Lynch and Hobbie 1988, Flannigan *et al.* 1991). Many fungal diseases of plants are spread by air. The deterioration of stored materials and the spoilage of foodstuffs are also induced by growth of fungi which reach them from the air. Some fungal spores are regarded as important causes of allergic diseases such as bronchial asthma and allergic rhinitis (Moubasher 1993), but the full implications are still not known (Lacey 1981).

Because of the importance of airborne fungal spores in initiating human, animal, and plant diseases, and because of the lack of information on the incidence, composition and distribution of outdoor fungal airspora in Libya, this investigation was designed as a preliminary survey to investigate the diversity of filamentous fungi in the air of the Mediterranean coastal area of Libya.

Materials and Methods

Sampling location

This investigation was carried out in 32 different localities in the Mediterranean coastal area of Libya in June 2010 (Fig 1). The temperature at these localities at the time of exposure fluctuated between 16º and 38ºC (Table 1).

The principal meteorological data recorded in the Mediterranean coastal area of Libya from seven stations on June 2010 are as follows: the annual average rainfall was 0.2 mm, the mean relative humidity ranged from 48 % to 76 % with a mean of 64.57 %, wind velocity ranged between 12.69 and 23.76 km/h with a mean of 16.27 km/h. The main wind direction throughout June was 010-350 (North) in Musrata, Beniena and Ejdabya stations, 100-08 (East) in Zwara and Al-Khums, 070-060 (East-East North) in Tripoli and from 340-330 (North-North-West) in Darna and the mean of minimum air temperature ranged from 20.2 °C to 22.6 °C with a mean of 21.4 ºC and the maximum air temperature ranged from 26.8 °C to 35.1 °C with a mean of 31.13 ºC.

Collection of samples

The exposure (sedimentation) plate method was used. Air sampling was carried out in a total of 32 air samples in the Mediterranean coastal area of Libya from Tripoli in the West to Amsaed in the East near the border area with Egypt (about 1500 km long). Five replicate agar plates of 9 cm diameter of modified Czapek's agar medium were exposed to the air for 15 minutes at the ground level. The plates were sealed, brought back to the laboratory then incubated at 28ºC for 7 – 21 days during which the developing fungi were identified and counted.

Two different agar media (modified Czapek's agar in which glucose (10 g/l) replaced sucrose and the same medium supplemented with 20% NaCl) were used. The composition of the modified Czapek's agar was as follow (g/liter): sodium nitrate 3.0, potassium dihydrogen phosphate 1.0, magnesium sulphate 0.5, potassium chloride 0.5, ferrous sulphate 0.01, glucose 10.0 and agar 15.0. Rose bengal (1/15000) and chloramphenicol (25 μg/ml) were added as bacteriostatic agents (Smith and Dawson 1944, Al-Doory 1980).

Identification of fungi

The identification of fungal genera and species were carried out on the basis of macroscopic and microscopic features following the descriptions given by Raper and Fennell (1965), Booth (1971), Ellis (1971, 1976), Pitt (1979), Moubasher (1993), Leslie and Summerell (2006), Domsch *et al.* (2007). Most of the isolated fungi were deposited in the culture collection of Assiut University Mycological Centre (AUMC), Assiut, Egypt.

Results and Discussion

A total of 1502 fungal catches were isolated from 32 exposures in the Mediterranean coastal area of Libya using the exposure plate method on Czapek's agar at 28 ºC. These fungal propagules were classified into 60 species related to 28 genera. The air of Al-Baryquah yielded the highest number of propagules while the air of Susah and Ras-Alhelal were fungi-free. The air temperature at the time of exposure in Al-Baryquah was 38 °C while that of both Susah and Ras-Alhelal was 20 °C. The widest spectrum of genera (11) and species (16 and 19) was recorded in Al-Khums and Musrata while the narrowest spectrum (1 genus and 1 species) was recorded in Shaha (Table 1). It is noteworthy that only 1 colony of *Humicola fuscoatra* was trapped on one plate exposed at site No. 6 (this site has a salt marsh soil nature) out of 160 plates of 20 % NaCl- Czapek's agar exposed at the 32 localities.

Alternaria (represented by 591 colonies) followed by *Fusarium* (293) and *Cladosporium* (245) were the most predominant fungi in the air. They were respectively isolated in 28, 25 and 15 exposures out of 32 investigated. These three genera were followed by *Ulocladium* (130) and *Aspergillus* (94), which appeared in 21 and 13 exposures respectively (Tables 1 and 2).

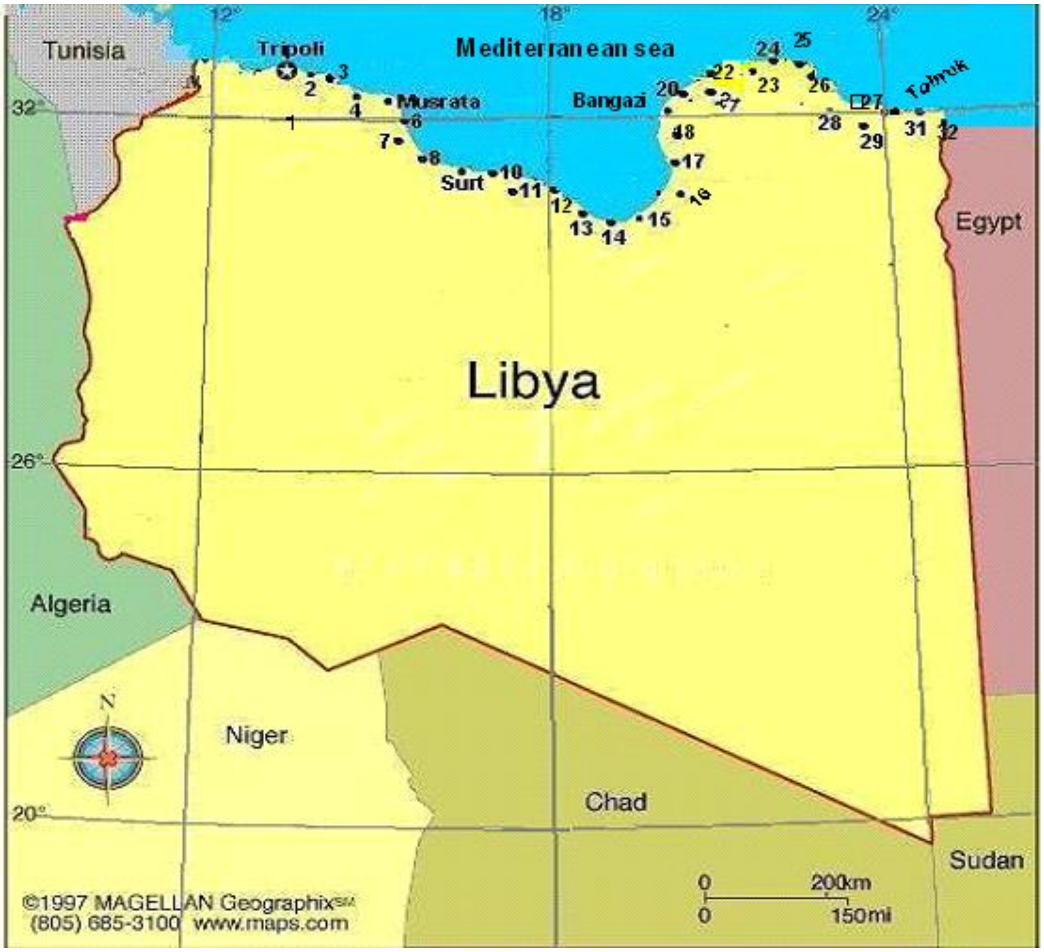

Fig 1: A map showing the different localities of the Mediterranean coastal area of Libya at which the air samplings were investigated.

In a study of fungal spore populations in the atmosphere of Kuwait, *Alternaria* occupied the first place in the order of percentage incidence, being represented by 18.3 % of the entire catch, followed by *Aspergillus* (17.1 %), *Penicillium* (14 %), *Cladosporium* (13.6 %), *Drechslera* (13.3 %) and *Ulocladium* (7.1 %) (Moustafa and Kamel 1976). These genera were also reported to be the most predominant in the atmosphere of Italy (Della Franca and Caretta 1984), Canada (Li and Kendrick 1995), Taiwan (Ho 1996), Saudi Arabia (Hasnain *et al.* 1998), Uganda (Ismail *et al.* 1999), Mali, West Africa (Kellogg *et al.* 2004), Helwan area, Egypt (Abdel-Hameed *et al.* 2009), Zarqa area, Jordan (Abu-Dieyeh *et al.* 2010), China (Li *et al.* 2010) Portugal (Oliveira *et al.* 2010), Spain (Reyes *et al.* 2009, Docampo *et al.* 2011), Nigeria (Ogunlana 1975, Uzochukwu and Nkpouto 2013), and Lake Manzala, Egypt (Abdel-Azeem and Rashad 2013).

Alternaria was on the top of the list of fungi isolated in 16 out of the 28 *Alternaria*-positive samples. Of the 2 identified *Alternaria* species, *A. alternata* yielded the largest number of propagules (306 out of 1502 catch representing 20.4 % of total catch). It was isolated from 25 out of 32 exposures. *A. chlamydospora* represented a minor proportion of total fungi (1.4 %) and was isolated only during 5 exposures (Table 2). *A. alternata* and *A. chlamydospora* were also reported to be the most common *Alternaria* species in most studies on the air of many countries e. g. in Egypt (Moubasher and Moustafa 1974, Ismail *et al.* 2002), Saudi Arabia (Abdel-Hafez 1984), Kuwait (Moustafa and Kamel 1976, Halwagy 1989), Sana'a city, Yemen (Abudallah 1997), Uganda (Ismail *et al*. 1999), and Jordan (Abu-Dieyeh et al. 2010).

Of the 3 *Cladosporium* species recorded, *C. sphaerospermum* followed by *C. cladosporioides* were represented in 11 and 8 exposures accounting for 10.5 % and 5.7 % of total fungi respectively. However *C. herbarum* occurred once in one exposure (Tables 1 & 2). These species were previously reported from the air in Western desert of Egypt (Ismail *et al*. 2002), Lake Manzala, Egypt (Abdel-Azeem and Rashad 2013), Zarqa area, Jordan (Abu-Dieyeh *et al*. 2010), Uganda (Ismail *et al.* 1999), Mali, West Africa (Kellogg *et al*. 2004), USA (Lacey 1981), and Turkey (Asan *et al*. 2004, Õzkara *et al.* 2007).

Among the 5 *Ulocladium* species caught, *U. atrum* (104 colonies) was the most common; it was caught in 19 exposures accounting for 6.9 % of total fungi. The remaining four *Ulocladium* species appeared in low numbers during two (*U. botrytis U. chartarum* and *U. tuberculatum*) or one exposure (*U. alternariae*). Some or all of these *Ulocladium* species were earlier caught from the atmosphere in Egypt (Ismail *et al.* 2002, Abdel-Hameed *et al*. 2009, Abdel-Azeem and Rashad 2013), Uganda (Ismail *et al.* 1999), Kuwait (Moustafa and Kamel 1976) and Jordan (Abu-Dieyeh *et al.* 2010).

Fusarium was isolated from 25 air samples and was the leading genus of airborne fungi collected from Al-Hesha and Gaminis.. Of the 9 identified *Fusarium* species, *F. solani* and *F. sambucinum* appeared in 14 and 15 exposures accounting for 5.7 % and 5.5 % of total fungi respectively. The remaining 7 species in the following order: *F. lateritium*, *F. equiseti*, *F. oxysporum*, *F. subglutinans*, *F. tricinctum*, *F. semitectum* and *F. verticillioides* were recovered from 1 to 7 exposures (Tables 1 & 2). Some of these species were previously reported from the air in many parts of the world (Ogunlana 1975, Ismail *et al.* 1999 & 2002, Abdel-Hameed *et al.* 2009, Abu-Dieyeh *et al.* 2010, Docampo *et al.* 2011, Abdel-Azeem and Rashad 2013, Uzochukwu and Nkpouto 2013) and from soil samples near iron and still factory, Misurata, Libya (Miltan *et al.* 2013). *Fusarium* species are incitants of serious plant diseases. *F. solani* is well documented as a pathogen of a number of legumes, and other plants where it is often associated with damping-off and wilt of *Vicia faba* (El-Helaly *et al.* 1966), cankers and dieback problems of trees (Nelsons *et al.* 1983).

Of the 7 *Aspergillus* species caught, *A. niger* was the most common. It was isolated in 12 exposures yielding 5.1 % of total fungi. *A. ochraceus* (from 4 exposures), *A. flavus* and *A. ustus* (2 exposures each) accounting collectively for 0.86 % of the total fungi. The remaining 3 species were isolated each from only one exposure (Tables 1 & 2). These species were reported earlier but in different frequencies and counts from the air in Italy (Della Franca and Caretta 1984), Egypt (Ismail *et al*. 2002, Abdel-Hameed *et al*. 2009, Abdel-Azeem and Rashad 2013), Uganda (Ismail *et al*. 1999), Mali (Kellogg *et al*. 2004), Nigeria (Ogunlana 1975), Jordan (Abu-Dieyeh *et al.* 2010) and Kuwait (Moustafa and Kamel 1976).

Penicillium (8 species, 9 exposures), *Papulaspora* (2 species, 6 exposures) and *Stemphylium* (1 species, 6 exposures) came behind the forementioned fungal genera in their frequency and counts. They accounted for 1.5 %, 1.5 % and 0.6 % of the total fungi, respectively. Of these, *Penicillium chrysogenum*, *Papulaspora irregularis* and *S. botryosum* were the most common species. Representative species of one or more the above three genera were also reported earlier from the air in Egypt (Ismail *et al.* 2002, Abdel-Hameed *et al.* 2010, Abdel-Azeem and Rashad 2013), Nigeria (Ogunlana 1975), Jordan (Abu-Dieyeh *et al.* 2010), Kuwait (Moustafa and Kamel 1976), Spain (Docampo *et al.* 2011), Canada (Li and Kendrick 1995), Taiwan (Ho 1996) and China (Li *et al.* 2010).

The remaining fungi were either caught during 4 exposures (*Trimmatostroma* sp.), 3 exposures (*Actinomucor elegans*, *Embellisia* sp., *Emericella* and *Phoma*), 2 exposures (*Cochliobolus, Microascus manginii, Phaeoacremonium, Torula* and unidentified ascomycete), or 1 exposure (*Acremonium strictum, Botryotrichum piluliferum, Cheatomium* sp., *Curvularia clavata, Humicola fuscoatra, Mucor* sp., *Stachybotrys bambusicola, Trichothecium roseum* and *Trichderma* sp.). They collectively accounted for 6.0 % of total fungi. Many of these fungi were reported from the air in many countries allover the world.

Conclusion: It is noteworthy that several fungal species trapped in the current study have been reported to be involved in plant, human and animal diseases, deterioration of stored products, spoilage of foodstuffs and in industrial processes (Lacey 1981, Burge 1985, Horner *et al.* 1994, De Hoog *et al.* 2000, Pitt and Hocking 2009). For example, inhalation of fungal spores and perhaps fungal metabolites can cause diseases in the respiratory system (such as bronchopulmonary aspergillosis, pulmonary mycotoxicosis and hypersensitivity). Spores of *Cladosporium* spp., *Alternaria* spp. (Hyde *et al.* 1956, Lynch and Hobbie 1988, Srivastava and Wadhwani 1992, Hasnain *et al.* 1998) and *Stachybotrys chartarum* (Le Bars and Le Bars 1985) have been reported to cause immediate allergic reaction type of hypersensitivity leading to allergenic rhinitis and bronchial asthma; and spores of *Aspergillus* (*A. fumigatus*, *A. flavus*, *A. niger*, *A. nidulellus* and *A. terreus*) and *Penicillium* are the cause of the delayed allergic reactions of hypersensitivity that cause alveolitis (pulmonary carcinoma) and breathlessness (Lynch and Hobbie 1988, Pitt 1994). Also, some are well-documented as pathogens of many plants as some of fusaria are associated with cankers and dieback problems of trees (Nelson *et al.* 1983), damping-off, root rot and wilt (Leslie and Summerell 2006). Species of *Alternaria* (e.g. *A. alternata*) can cause black rot of olive and citrus, black point of small cereals and black mold of several vegetables (Logrieco *et al.* 2003).

Table 1: Counts of colony forming units (CFUs per 5 plates) and percentage counts of the common fungal species isolated from the different locations investigated.

No	Place	Date	Time	Temp	NG	NS	Total	Common Species (CFU)	%
1	Tripoli	8.6.2010	5:30PM	35°C	6	10	104	*Alternaria alternata* (53)	50.96
								Aspergillus niger (13)	12.50
								Ulocladium tuberculatun (12)	11.54
								Alternaria. spp. (10)	9.62
								Emericella quadrilineata (9)	8.63
2	El-Garapolly	8.6.2010	6:37PM	26°C	8	9	81	*Alternaria alternata* (55)	67.90
								Fusarium solani (8)	9.88
								Cladosporium cladosporioides (7)	8.64
3	Alkhums	8.6.2010	8:15PM	23°C	11	16	118	*Cladosporium cladosporioides* (42)	35.59
								Cladosporium sphaerospermum (28)	23.73
								Alternaria alternata (13)	11.02
								Alternaria spp. (6)	5.08
								Embellisia spp. (6)	5.08
								Fusarium spp. (6)	5.08
4	Zleten	8.6.2010	9:20 PM	18°C	8	9	130	*Cladosporium sphaerospermum* (69)	53.08
								Alternaria spp. (36)	27.69
								Alternaria alternata (7)	5.38
								Fusarium spp. (6)	4.62
5	Musrata	9.6.2010	5:40AM	16°C	11	19	70	*Aspergillus niger* (18)	25.71
								Trimmatostroma spp. (7)	10
								Alternaria alternata (6)	8.57
								Cladosporium sphaerospermum (6)	8.57
								Ulocladium artum (5)	7.14
6	Taworgha	9.6.2010	6:30AM	20°C	4	4	24	*Alternaria* spp. (10)	41.67
								Alternaria alternata (7)	29.17
7	Al-Heasha	9.6.2010	7:34AM	20°C	5	10	50	*Fusarium sambucinum* (11)	22
								Alternaria alternata (10)	20
								Fusarium equiseti (8)	16
								Cladosporium sphaerospermum (6)	12
								Cladosporium cladosporioides (5)	10
8	Al-Weshka	9.6.2010	8:25AM	25°C	6	6	43	*Alternaria alternata* (26)	60.47
								Fusarium sambucinum (8)	18.60
9	Surt	9.6.2010	9:41AM	30°C	5	5	23	*Aspergillus niger* (9)	39.13
10	Al-Gordabyia	9.6.2010	10:12AM	30°C	5	5	112	*Alternaria* spp. (52)	46.43
								Aspergillus niger (17)	15.18
								Fusarium solani (16)	14.29
								Botryotrichum piluliferum (12)	10.71
								Trichoderma spp. (8)	7.14
								Fusarium oxysporium (7)	6.25

11	Ehrawa	9.6.2010	11:26AM	37°C	6	8	102	*Alternaria* spp. (42)	41.18
								Fusarium solani (17)	16.67
								Ulocladium artum (15)	14.71
								Fusarium tricinctum (9)	8.82
								Aspergillus niger (6)	5.88
								Fusarium sambucinum (6)	5.88
12	Benjawad	9.6.2010	12:25 AM	37°C	3	3	9	*Alternaria alternata* (4)	44.44
								Fusarium sambucinum (4)	44.44
13	Ras-Alonof	9.6.2010	1:32PM	37°C	8	9	95	*Ulocladium artum* (37)	38.95
								Alternaria spp. (12)	12.63
								Fusarium sambucinum (10)	10.53
								Papulaspora irregularis (10)	10.53
								Alternaria alternata (7)	7.37
								Cladosporium sphaerospermum (6)	6.32
14	Al-Eggilah	9.6.2010	2:28PM	38°C	5	9	52	*Alternaria alternata* (14)	26.92
								Fusarium oxysporum (9)	17.31
								Fusarium sambucinum (9)	17.31
								Ulocladium artum (7)	13.46
								Alternaria chlamydospora (5)	9.62
15	Al-Braquah	9.6.2010	3:28PM	38°C	4	6	168	*Alternaria* spp. (61)	36.31
								Fusarium lateritium (35)	2083
								Cladosporium sphaerospermum (23)	13.69
								Fusarium solani (22)	13.10
								Fusarium sambucinum (14)	8.33
								Alternaria alternata (12)	7.14
16	Ejdabya	9.6.2010	4:47PM	33°C	9	15	57	*Alternaria* spp. (11)	19.30
								Cladosporium cladosporioides (11)	19.30
17	Shat-Elbdein	9.6.2010	5:29PM	30°C	9	14	53	*Cladosporium cladosporioides* (12)	22.64
								Alternaria alternata (7)	13.21
								Alternaria spp. (7)	13.21
18	Geminis	9.6.2010	6:39PM	30°C	4	4	14	*Fusarium equiseti* (6)	42.86
19	Benghazi	9.6.2010	7:11PM	30°C	3	4	11	*Alternaria alternata* (5)	45.45
20	Farzogha	9.6.2010	6:39PM	28°C	4	4	11	*Papulaspora immersa* (4)	36.36
								Alternaria alternata (3)	27.27
21	Al-Marj	9.6.2010	9:20PM	22°C	4	4	22	*Alternaria alternata* (11)	50
								Ulocladium artum (5)	22.72
22	50km-before Al-Beida	9.6.2010	10:15PM	20°C	4	6	38	*Alternaria alternata* (12)	31.58
								Ulocladium artum (10)	26.32
								Alternaria spp. (6)	15.79
								Ulocladium botrytis (5)	13.16
23	Al-Beida	10.6.2010	9 : 15AM	20°C	3	3	8	*Aspergillus niger* (3)	37.50
								Fusarium solani (3)	37.50
24	Shahat	10.6.2010	10:10AM	20°C	1			*Mucor* sp. (1)	100
25	Susah	10.6.2010	11:00AM	20°C				- - (0)	0
26	Ras-Alhelal	10.6.2010	12:00AM	20°C				- - (0)	0
27	Darnah	10.6.2010	12:40AM	24°C	5	6	17	*Alternaria alternata* (5)	29.41
								Alternaria chlamydospora (5)	29.41
28	Al-Temimy	10.6.2010	1:35PM	27°C	3	3	5	*Aspergillus niger* (3)	60
29	Ein-Elghazal	10.6.2010	2:30PM	29°C	3	3	13	*Cladosporium sphaerospermum* (11)	84.62
30	Tobruk	10.6.2010	3:40PM	26°C	5	7	51	*Alternaria alternata* (27)	52.94
								Fusarium subglutinons (10)	19.61
31	Cambut	10.6.2010	4:35PM	26°C	6	6	14	*Alternaria alternata* (8)	57.14
								Cladosporium sphaerospermum (2)	14.29
32	Amsaed	10.6.2010	5:40PM	26°C	3	3	6	*Alternaria alternata* (4)	66.66

Table 2: Total catch (TC per 160 plates) and their percentages (% TC), incidences (I, out of 32 exposures) and their percentages (% I) of all fungi recovered during this investigation.

Taxa	TC	TC %	I	I %
Acremonium strictum W. Gams	1	0.07	1	3.13
Actinomucor elegans (Eidam) C. R. Benjamin & Hesseltine	4	0.27	3	9.38
Alternaria (Total)	591	39.35	28	87.50
A. alternata (Fries) Keissler	306	20.37	25	78.13
A. chlamydospora Mouchacca	15	1.43	5	15.63
Alternaria spp.	270	17.8	19	59.38
Aspergillus (Total)	94	6.26	13	40.63
A. flavus Link	4	0.27	2	6.25
A. niger van Tieghem	76	5.06	12	37.50
A. ochraceus Wilhelm	5	0.33	4	12.50
A. petrakii Voros	1	0.07	1	3.13
A. sydowii (Bainier & Sartory) Thom & Church	1	0.07	1	3.13
A. ustus (Bainier) Thom & Church	4	0.26	2	6.25
A. versicolor (Vuillemin)Tiraboschi	3	0.20	1	3.13
Botryotrichum piluliferum Saccardo & Marchal	12	0.80	1	3.13
Cheatomium sp.	1	0.07	1	3.13
Cladosporium (Total)	245	16.31	15	46.88
C. cladosporioides (Fresenius) de Vries	86	5.73	8	25.00
C. herbarum (Persoon) Link	1	0.07	1	3.13
C. sphaerospermum Penzig	158	10.52	11	34.38
Cochliobolus (Total)	2	0.13	2	6.25
C. hawaiiensis Alcorn	1	0.07	1	3.13
Cochliobolus sp.	1	0.07	1	3.13
Curvularia clavata Jain	1	0.07	1	3.13
Embellisia sp.	11	0.73	3	9.38
Emericella (Total)	16	1.07	3	9.38
E. dentata (Sandhu & Sandhu) Horie	1	0.07	1	3.13
E. quadrilineata (Thom & Raper) Benjamin	13	0.87	2	6.25
E. rugulosa (Thom & Raper) Benjamin	2	0.13	1	3.13
Fusarium (Total)	293	19.51	25	78.13
F. equiseti (Corda) Saccardo	26	1.73	7	21.88
F. lateritium Nees	37	2.46	2	6.25
F. oxysporum Schlechtendal	20	1.33	4	12.50
F. sambucinum Fuckel	82	5.46	15	46.88
F. semitectum Berk & Ravenel	3	0.20	1	3.13
F. solani (Martius) Saccardo	85	5.67	14	43.75
F. subglutinans (Wollenweber & Reinking) Nelson *et al.*	11	0.73	2	6.25
F. tricinctum (Corda) Saccardo	9	0.60	1	3.13
F. verticillioides (Saccardo) Nirenberg	1	0.07	1	3.13
Fusarium spp.	19	1.27	5	15.63
Humicola fuscoatra Traaen	1	0.07	1	3.13
Microascus manginii (Loubière) Curzi	4	0.27	2	6.25
Mucor sp.	1	0.07	1	3.13
Papulaspora (Total)	23	1.53	6	18.75
P. immersa H.H. Hotson	5	0.33	2	6.25
P. irregularis Hotson	18	1.20	4	12.50
Penicillium (Total)	22	1.47	9	28.13
P. chrysogenum Thom	10	0.67	5	15.63
P. citrinum Thom	1	0.07	1	3.13
P. expansum Link	4	0.27	2	6.25
P. griseofulvum Dierckx	3	0.20	2	6.25

P. janthinellum Biourge	2	0.13	1	3.13
Penicillium spp.	2	0.13	2	6.25
Phaeoacremonium (Total)	2	0.13	2	6.25
P. parasiticum (Ajello *et al.*) W. Gams *et al.*	1	0.07	1	3.13
Phaeoacremonium sp.	1	0.07	1	3.13
Phoma (Total)	5	0.33	3	9.38
P. herbarum Westendorp	1	0.07	1	3.13
Phoma sp.	4	0.27	2	6.25
Rhizopus sp.	2	0.13	2	6.25
Stachybotrys bambusicola Rifai	2	0.13	1	3.13
Stemphylium botryosum Wallr.	9	0.60	6	6.25
Torula (Total)	5	0.33	2	6.25
T. graminis Desm.	3	0.20	1	3.13
Torula sp.	2	0.13	1	3.13
Trichothecium roseum (Pers.: Fr.) Link	1	0.07	1	3.13
Trichoderma sp.	8	0.53	1	3.13
Trimmatostroma sp.	14	0.93	4	12.50
Ulocladium (Total)	130	8.66	21	65.63
U. alternariae (Cook) Simmons	2	0.13	1	3.13
U. atrum Preuss	104	6.92	19	59.38
U. botrytis Preuss	7	0.47	2	6.25
U. chartarum (Preuss) Simmons	4	0.27	2	6.25
U. tuberculatun Simmons	13	0.87	2	6.25
Undentified ascomycete	2	0.13	2	6.25
Total	1502	100%	30	93.75
Number of genera	28			
Number of species	60			

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References

Abdel-Azeem AM and Rashad HM (2013): Mycobiota of outdoor air that can cause asthma: a case study from Lake Manzala, Egypt. Mycosphere 4(4): 1092-1104.

Abdel-Hafez SII (1984): Survey of air-borne fungus spores at Taif, Saudi Arabia. Mycopathologia 88: 39-44.

Abdel-Hafez SII, Moubasher AH and Barakat A (1993): Seasonal variations of fungi of outdoor air and sedimented dust at Assiut region, Upper Egypt. Grana 32:115-121.

Abdel-Hameed AA, Khoder MI, Yuosra S, Osman AM and Ghanem S (2009): Diurnal distribution of airborne bacteria and fungi in the atmosphere of Helwan area, Egypt. Science of the Total Environment 407(24): 6217-6222.

Abdullah QYM (1997): Studies on fungal air-spora in the atmosphere of the city of Sana'a, Republic of Yemen. M.Sc. Thesis, Biology Department, Faculty of Science, Sana'a University, Yemen, 152 pp.

Abu-Dieyeh MH, Barham R, Abu-Elteen K, Al-Rashidi R and Shaheen I (2010): Seasonal variation of fungal spore populations in the atmosphere of Zarqa area, Jordan. Aerobiologia 26(4): 263-276.

Abdul Wahid OA, Moustafa AF, Moustafa AM (1996): Fungal population in the atmosphere of Ismailia City. Aerobiologia 12: 249-255.

Abu-El-Souod SM (1974): Studies on fungus-air-spora in Egypt. Ph.D. Thesis, Faculty of Science, Assiut University, Egypt.

Al-Doory Y (1980): Laboratory Medical Mycology. Lea Febiger, Philadelphia, pp. 240-367.

Al-Qura'n S (2008): Analysis of airborne pollen fall in Tafileh, Jordan, 2002–2003. World Applied Sciences Journal 4(5): 730-735.

Al-Subai AA (2002): Air-borne fungi at Doha, Qatar. Aerobiologia 18(3-4): 175-183.

Asan A, Ilhan S, Sen B, Erkara I, Filik C and Cabuk A (2004): Airborne fungi and actinomycetes concentrations in the air of Eskisehir City (Turkey). Indoor and Built Environment 13: 63–74.

Beaumont F, Kauffman HF, Van-der Mark TH, Sluiter HJ and de Vries K (1985): A volumetric aerobiological survey of conidial fungi in the North-East Netherlands. Seasonal patterns and the influence of meteorological variables. Allergy 40: 173–180.

Booth C. (1971): The Genus *Fusarium*. Commonwealth Mycological Institute, Kew, Surrey, UK.

Burge HA (1985): Fungus allergens. Clinical Review of Allergy 3: 319–329.

De Hoog GS, Guarro J, Gene J and Figueras MJ (2000): Atlas of clinical fungi. Centraalbureau voor Schimmelcultures Utrecht, the Netherlands, 2nd edition, 1126 pp.

Della Franca P and Caretta G (1984): Keratinophilic fungi isolated from the air at Pavia. Mycopathologia 85: 65-68.

Docampo S, Trigo MM, Recio M, Melgar M, Garcia-Sanchez J and Cabezudo B (2011): Fungal spore content of the atmosphere of the Cave of Nerja (southeren Spain): Diversity and origin. Science of the Total Environment 407: 835-843.

Domsch KH, Gams W and Anderson T-H (2007): Compendium of soil fungi. 2nd edition, IHW-Verlag, Eching.

El-Essawy AA, Abdel-Kader MIA, Abou El-Hawa ME and Aly ASE (1992): Studies on mycoflora of air of Sana'a Governorate, Yemen Republic. Egyptian Journal of Applied Science 7: 607-616.

El-Helaly AF, Ibrahim IA, Assawah MW, Elarosi HM, Abo-El-Dahab MK, Michail SH, Abd-El-Rehim MA, Wasfy EH, and El-Goorany MA (1966): General survey of plant diseases and pathogenic organisms in the U. A. E. (Egypt) until 1965. Research Bulletin No. 15, Journal of Agricultural Research, Faculty of Agriculture, Alexandria University Press, Alexandria, Egypt, (pp. 154).

Ellis MB (1971): Dematiaceous Hyphomycetes. Commonwealth Mycological Institute, Kew, Surrey, England, 608 pp.

Ellis MB (1976): More Dematiaceous Hyphomycetes. Commonwealth Mycological Institute, Kew, Surrey, England, 507 pp.

El-Said AHM and Abdel-Hafez SII (1995): Seasonal variations of airborne fungi above banana fields in Qena, Upper Egypt. Cryptogamie Mycologie 16:101-109.

Flannigan B, McCabe EM and McGarry F (1991): Allergenic and toxigenic micro-organisms in houses. Journal of Applied Bacteriology, Symposium Supplement 70: 61S-73S.

Gregory PH (1973): Microbiology of the atmosphere. 2nd ed., Aylesbury, London. Leonard Hill, 377 PP.

Halwagy MH (1989): Seasonal airspora af three sites in Kuwait-1977–1982. Transactions of the British Mycological Society 93:208–213.

Hasnain SM, Al-Frayh A, Gad-el-Rab MO and Al-Sedairy S (1998): Airborne *Alternaria* spores: Potential allergic sensitizers in Saudi Arabia. Annals of Saudi Medicine 18(6): 497–501.

Hedayati M, Mayahi S, Aghili R and Goharimoghadam K (2005): Airborne fungi in indoor and outdoor of asthmatic patients' home, living in the city of Sari. Iranian Journal of Allergy, Asthma and Immunology 4(4): 189-191.

Ho H-M (1996): The outdoor fungal airspora in Hualien (I): The agar plate method. Taiwania 41(1): 67-80.

Homer WE, Lehrer SB, Salvaggio JE, Banks DE,Weissmman DN (1994): Fungi. Indoor air pollution: an allergy perspective. Immunology and Allergy Clinics of North America 14: 551–566.

Hyde HA, Richards M and Williams DA (1956): Allergy to mould spores in Britain. British Medical Journal 1(4972): 886-890.

Ismail MA, Chebon SK and Rebecca Nakamya (1999): Preliminary surveys of outdoor and indoor aeromycobiota in Uganda. Mycopathologia 148: 41-51.

Ismail MA, Abdel-Hafez SII and Moharram AM (2002): Aeromycobiota of western desert of Egypt. African Journal of Science and Technology 3(1): 1-9.

Kellogg CA, Griffin DW, Garrison VH, Kealy Peak K, Royall N, Smith RR and Shinn EA (2004): Characterization of aerosolized bacteria and fungi from desert dust events in Mali, West Africa. Aerobiologia 20: 99-110.

Khan ZU, Khan M, Chandy R and Sharma PN (1999): *Aspergillus* and other moulds in the air of Kuwait. Mycopathologia 146: 25-32.

Lacey J (1975): Air-borne spores in pastures. Transactions of the British Mycological Society 64: 265-281.

Lacey J (1981): Aerobiology of conidial fungi. In: Cole GT, Kendrick WB (eds.), Biology of condidial fungi. New York, Academic Press Inc. 273–416.

Lacey J and Crooke B (1988): Review: Fungal and actinomycetes spores as pollutants of the workplace and occupational allergens. Annals of Occupational Hygiene 32(4):515-533.

Le Bars J and Le Bars P (1985): Etude du nuage de spores de *Stachybotrys atra*. contaminant de pailles: Risques d'Inhalation. Bulletin de Societé Francaise de Mycologie Medicale 14: 321-324.

Leslie JF and Summerrell BA (2006): The *Fusarium* Laboratory Manual. Blackwell Publishing, Ames, Iowa, USA, pp. 388.

Li D-W and Kendrick B (1995): A year-round outdoor aeromycological study in Waterloo, Ontario, Canada. Grana 34: 199-207.

Li L, Lei C and Liu Z-G (2010): Investigation of airborne fungi at different altitudes in Shenzhen University. Natural Science 2(5): 505-514.

Logrieco A., Bottalico A., Mule G., Morreti A., and Perrone G. (2003): Epidemiology of toxigenic fungi and their associated mycotoxins for some Mediterranean crops. – In: Xu X, Bailey JA and Cooke BM (eds.), Epidemiology of mycotoxin-producing fungi, Dordrecht, pp. 654–667.

Lynch JM and Hobbie JE (1988): Aerial dispersal and development of microbial communities. Blackwell Scientific Publications, London, pp. 207–237.

Miltan AB, Alrayes HM, Alremally AM, Almedaham AM, Oaen SO and Alderwish MN (2013): The effects of the dust emitted from Kasr Ahmed-Misurata iron and still factory in Libya. Digital Proceeding of the ICOEST' 2013, Cappadocia, Ozdemir C, Sahinkaya S, Kahpei E and Oden (editors), Nevsehir, Turkey, June 18-21, pp. 656-664.

Moubasher AH and Moustafa AF (1974): Airborne fungi at Assiut, Egypt. Egyptian Journal of Botany 17: 135–149.

Moubasher AH (1993): Soil fungi of Qatar and other Arab countries. Doha, Qatar. The Scientific and Applied Research Centre, University of Qatar, 566 pp.

Moustafa AF (1975): Osmophilous fungi in the salt marshes of Kuwait. Canadian Journal of Microbiology 21: 1573-1580.

Moustafa AF and Kamel SM (1976): Studies on fungal spore populations in the atmosphere of Kuwait. Mycopathologia 59: 29–35.

Nelson PE, Toussoun TA and Marasas WFO (1983): *Fusarium* species: an illustrated manual for identification. Pennsylvania: Pennsylvania State University Press, pp. 193.

Nourian AA, Badali H, Khodaverdi M, Hamzehei H and Mohseni S (2007): Airborne mycoflora of Zanjan-Iran. International Journal of Agriculture & Biology 9(4): 628–630.

Ogunlana EO (1975): Fungal air spora at Ibadan, Nigeria. Applied Microbiology 29(4): 458-463.

Oliveira M, Ribeiro H, Delgado L, Fonseca J, Castel-Branco MG and Abreu I (2010): Outdoor allergenic fungal spores: Comparison between an urban and a rural area in Northern Portugal. Journal of Investigational Allergology and Clinical Immunology 20(2): 117-128.

Õzkara A, Ocak I, Korcan S and Konuk M (2007): Determination of fungal air spora in Afyonkarahisar, Turkey. Mycotaxon 102: 199–202.

Pitt JI (1979): The genus *Penicillium* and its teleomorphic states *Eupenicillium* and *Talarormyces*. London, Academic Press, 634 pp.

Pitt JI (1994): The current role of *Aspergillus* and *Penicillium* in human and animal health. Journal of Medical and Veterinary Mycology 32: 17–32.

Pitt JI, and Hocking AD (2009): Fungi and Food Spoilage, 3rd edition, Blackie Academic and Professional, London, 519 pp.

Raper K, Fennell Dl (1965): The genus *Aspergillus*. Baltimore: Williams & Wilkins, 686 pp.

Reyes ES, de la Cruz DR, Merino ES and Sanchez JS (2009): Meteorological and agricultural effects on airborne *Alternaria* and *Cladosporium* spores and clinical aspects in Valladolid (Spain). Annals of Agricultural and Environmental Medicine 16: 53-61.

Richards M (1956): A census of mould spores in the air over Britain in 1952. Transactions of the British Mycological Society 39:431-441.

Shaheen I (1992): Aeromycology of Amman area, Jordan. Grana 31: 223–228.

Smith NI and Dawson VT (1944): The Bacteriostatic action of rose bengal in media used for the plate counts of fungi. Soil Science 58: 467-471.

Srivastava AK and Wadhwani K (1992): Dispersion and allergenic manifestation of *Alternaria* airspora. Grana 31: 61–66.

Tan TK, Teo TS, Tan H, Lee BW and Chong A (1992): Variation in tropical airspora in Singapore. Mycological Research 96(3): 221-224.

Uzochukwu OV and Nkpouto U (2013): Airborne fungi in the indoor and outdoor environments of a higher institution in Nigeria. International Journal of Advanced Biological Research 3(1): 9-12.