



Summer airborne mycoflora of Timișoara (Romania) and relationship to meteorological parameters

Nicoleta Ianovici

To cite this article: Nicoleta Ianovici (2017) Summer airborne mycoflora of Timișoara (Romania) and relationship to meteorological parameters, Grana, 56:6, 424-435, DOI: 10.1080/00173134.2016.1271823

To link to this article: <https://doi.org/10.1080/00173134.2016.1271823>



Published online: 17 Feb 2017.



Submit your article to this journal [↗](#)



Article views: 91



View related articles [↗](#)



View Crossmark data [↗](#)



Summer airborne mycoflora of Timișoara (Romania) and relationship to meteorological parameters

NICOLETA IANOVICI

Faculty of Chemistry, Biology, Geography, Department of Biology–Chemistry, West University of Timișoara, Timișoara, Romania

Abstract

The present aeromycological investigation was undertaken to study atmospheric fungal spores in Timișoara (western Romania). This study was carried out using a Hirst type volumetric sampler. The study revealed the existence of a rich airborne mycoflora. The atmospheric fungal spores were classified and evaluated into three groups ('major', 'minor' and 'sporadic') depending upon their catch percentage in the air. *Cladosporium/Fusarium/Leptosphaeria*-group, *Alternaria*, *Helminthosporium* airborne fungal spores and airborne fungal fragments regularly recorded (frequency 100% of days). *Cladosporium* accounted for 81.09% of the outdoor fungal spores. The airborne fungal fragments have been identified as abundant in our geographic area. Spearman's correlations were applied to meteorological parameters and airborne fungal spore concentrations. In addition, correlations were calculated between the fungal spore concentrations and the meteorological variables from the previous day. A total of eleven weather factors were selected for this investigation. Following Spearman's correlations, I identified two patterns of behaviour: most of the airborne fungal spores prefer cloudiness, lower near-surface soil temperature, lower atmospheric pressure, higher relative humidity and precipitation (pattern A) while other spore concentrations favour increased sunshine, higher near-surface soil temperature and dry conditions (pattern B). The behaviour of some fungal spores during the warm season has proven unclear (pattern C). This study demonstrates the need for investigations throughout the year and the evaluation with complementary statistical methods, regarding the correct interpretation of airborne mycoflora relationships with meteorological parameters.

Keywords: *atmospheric fungal spores, allergenic fungal spores, Cladosporium, Romania, fungal behaviour patterns*

Aeromycological sampling attempts to quantify phytopathogenic and non-phytopathogenic atmospheric fungal spores (Sarica Okten et al. 2005; Ianovici et al. 2011). Biologists have shown a great interest in biomonitoring atmospheric fungal spores in outdoor and indoor environments due to their constant frequency in the air and the increase of respiratory allergies caused by their allergens (Simon-Nobbe et al. 2008; Almaguer et al. 2014). Fungal allergens belonging to over 80 fungal genera produce allergies and immunotoxic diseases (Horner et al. 1995; Ianovici & Tudorică 2009). As well as spores, other structures such as hyphal fragments and conidiophores are also dispersed in the atmosphere (Comtois 1990).

The distribution of atmospheric fungal spores changes from country to country and even within

regions of the same country. The duration of the phenological stages for each fungi species is variable. The release and dispersion of fungal spores in the atmosphere are the result of the direct or indirect action of many factors, e.g. anthropogenic, biological (the availability of substrates to be colonised by the fungi, daily sporulation rhythm), ecological (local vegetation and land use) meteorological, phenological (seasonal variations) and physical (movement of the atmosphere, turbulence, convection) (Ianovici 2008; Pakpour et al. 2015). The relationship between weather and fungal spore concentrations has been recognised by many authors in different parts of the world, e.g. Poland (Myszkowska et al. 2002; Kasprzyk 2008; Grinn-Gofron et al. 2011), Greece (Damialis et al. 2015b), Turkey (Celenk

Correspondence: Nicoleta Ianovici, Faculty of Chemistry, Biology, Geography, Department of Biology–Chemistry, West University of Timișoara, Pestalozzi Street, No. 16, Timișoara 300115, Romania. E-mail: nicole_ianovici@yahoo.com

(Received 8 February 2016; accepted 20 October 2016)

et al. 2007), Spain (Vélez-Pereira et al. 2015), Denmark (Skjøth et al. 2012), Italy (Rizzi-Longo et al. 2009), Austria (Ebner et al. 1989), Sweden (Hjelmroos 1993), Finland (Kurkela 1997), Portugal (Oliveira et al. 2010), Croatia (Peternel et al. 2004), Slovakia (Ščevková et al. 2015), UK (Sadyś et al. 2015), France (Sindt et al. 2016), Lithuania (Mikaliūnaitė et al. 2009), Estonia (Saar 2007), Australia (Stennett & Beggs 2004), Chile (Ibáñez et al. 2001), Brasil (De Antoni Zoppas et al. 2006), Argentina (Nitiu & Mallo 2011), Mexico (Rocha-Estrada et al. 2013), Colombia (Alzate Guarín et al. 2015), Cuba (Almaguer et al. 2014), Canada (Li & Kendrick 1995), USA (Dixit et al. 2000), South Africa (Berman 2011), Nigeria (Uzochukwu & Nkpouto 2013), Kuwait (Halwagy 1994), Egypt (Ismail et al. 2002), Israel (Helfman et al. 2011), Qatar (Al-Subai 2002), Saudi Arabia (Hasnain et al. 2005), Yemen (El-Essawy et al. 1992), Iran (Nourian et al. 2007), Jordan (Abu-Dieyeh et al. 2010), India (Das & Gupta-Bhattacharya 2012), Japan (Takahashi 1997), Singapore (Lim et al. 1998) and Taiwan (Ho et al. 2005). Studies on the presence of spores in the atmosphere of Timișoara (Romania) were started by Ianovici and Faur in 2001 using a Hirst (1952) volumetric sampler (Ianovici & Faur 2003). Further work has focused on quantifying atmospheric concentrations and temporal variations of selected airborne fungal spore types and not on the whole spectrum. The effect of climate on airborne spore concentrations in Romania is less well known (Ianovici 2016a, 2016b). The biomonitoring of fungal spores in Romania revealed the summer as the most favourable season for the occurrence of airborne fungal spores (Ianovici et al. 2011).

The aim of this study was to identify the atmospheric fungal spores present in an urban area in western Romania and to study their association with meteorological factors.

Material and methods

Airborne fungal spore samples were obtained daily during July 2008. The sampler was located on a building approximately 20 m above ground level (West University of Timișoara). The sampling site is above the adjacent buildings and the circulation of the air currents was unobstructed in all directions. This area is completely urbanised with buildings several meters in height mixed with low buildings and abundant vegetation. Fungal spores were sampled by using a 7-day volumetric trap of the Hirst (1952) design. The suction rate of the volumetric air sampler was maintained at 10 l/min. The counting of spores was included in the counting procedure of pollen grains. The slides were exam-

ined by light microscopy (LM) weekly. Specific fungal spores were counted with 400× magnification and identification was performed based on their morphological characteristics. The fungal spores were observed on the surface of four horizontal bands, and counts were done at 2-h intervals. A correction factor is used to determine the atmospheric concentration of fungal spores, which is a product of the area of slide, field of view of the microscope and volume of air sampled. Concentrations were expressed as the number of airborne fungal spores per cubic metre of air (AFS/m³).

Timișoara lies to the south-east of the Pannonian Basin and is situated in the western part of Romania at 86 meters above sea level (45° 46' N, 21° 15' E). The River Bega passes through the city. The climate is temperate continental moderate with slight sub-mediterranean influences. The characteristic vegetation is anthropogene forest steppe which defines the Banat Plain. The total surface area of the Timișoara Municipality is 12 926.83 ha. The surface of agricultural land comprises arable land, pastures, hay-fields, vineyards and orchards. The surface of non-agricultural land comprises forests, waters, constructions, roads and unproductive land. The urban flora is mainly composed of exotic trees and shrub species that are cultivated for ornamental purposes in streets, avenues, parks and cemeteries. Some of the plants are used for ornamental purposes and do not represents the local flora such as Pinaceae and Taxaceae/Cupressaceae. Herbaceous vegetation occurs spontaneously in open areas or it is cultivated in parks and private gardens (Ianovici et al. 2009, 2013b; Ianovici 2016b).

The statistical analysis was carried out using the SPSS software package. Spearman's correlation test was performed in order to identify the major variables likely to influence the dynamic of the airborne fungal spores. P values < 0.05 were accepted as significant. Correlations were examined between daily average airborne fungal spore concentrations and some daily meteorological parameters (daily mean temperature expressed in °C; near-surface soil temperature expressed in °C; relative humidity in %; mean wind speed expressed in m/s; daily maximum wind speed expressed in m/s; atmospheric pressure in mbar; sunshine hours in h; cloudiness in tenths; quantities of precipitations in l/m²). Wind direction was not included in the study. The number of days with potential to trigger allergic reactions was selected on the basis of literature data (Targonski et al. 1995; Rapiejko et al. 2004).

In the region, the highest relative humidity values were recorded in the first month of the year, with minimum values being reached in the summer months. In Timișoara, the lowest temperatures

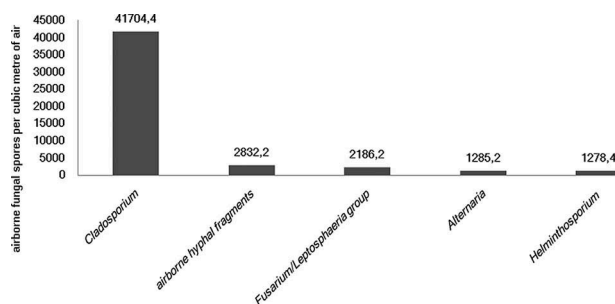


Figure 1. Totals of major spores in the air recorded from Timișoara monitoring station.

were recorded in the first months of the year, with the maximum temperatures being reached in July. The weather in Timișoara in middle of summer (July) was warm (with mean average temperature of 21.9 °C), with average relative humidity of 60.8%, with sunny days and low rainfall. The meteorological data for Timișoara were obtained from the records of the National Meteorological Administration (Table I).

Results

Qualitative and quantitative characterization of airborne mycoflora

A total of 85 fungal types/taxa were recorded in the outdoor air during the study: Basidiomycota (5 spore types); Oomycota (1 spore type – *Peronospora*); Ascomycota (35 spore types). Other fungal spore types that were identified in air samples included the anamorphs (44 genera). The broken hyphae or conidiophores were recorded as airborne fungal fragments. Distinguishing the conidia of *Drechslera* and *Exserohilum* using an optic microscope is difficult; they were therefore considered as belonging to the *Drechslera*-type. The *Fusarium/Leptosphaeria*-group-type included spores of *Melanomma* and *Phaeosphaeria*. Xylariaceae spores were recorded as one pooled taxon. *Aspergillus/Penicillium* type was not quantified. Some spore types could not be identified.

Our results show the presence of a large number of fungal spore types. The richness of the spore types varied throughout the investigated period. The maximum number of spores types was registered on 4 July (28 types) and the minimum recorded on 1 July and 2 July (11 types). Airborne fungi were grouped into 'major', 'minor' and 'sporadic' types depending on their catch percentage in the air (Figures 1, 2). *Cladosporium*, *Alternaria*, *Fusarium/Leptosphaeria*-group, *Helminthosporium*-type spores and airborne fungal fragments were trapped most frequently (100% of the days). The minor fungal spores of Xylariaceae, *Peronospora*, *Epicoccum*, *Capronia*, *Para-*

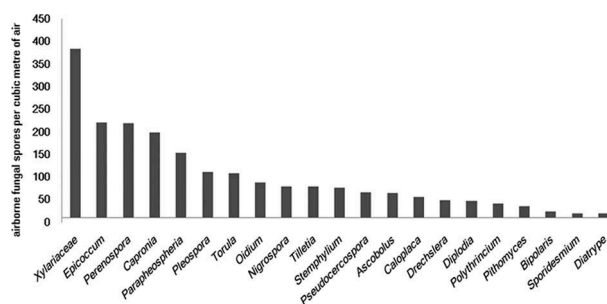


Figure 2. Totals of minor spores in the air recorded from Timișoara monitoring station.

pheosphaeria, *Pleospora*, *Torula*, *Oidium*, *Nigrospora*, *Tilletia*, *Stemphylium*, *Pseudocercospora*, *Ascochola*, *Calopogon*, *Drechslera*, *Diplodia*, *Polythrincium*, *Pithomyces*, *Bipolaris*, *Sporidesmium* and *Diatrype* occurred in low concentrations. Minor components included less frequent types (greater frequency of 12%) but stable components of Aeromycota. The remaining types of spores are sporadic presence in the atmosphere.

The spore concentration obtained during the period studied was 51 578 AFS/m³ (Figure 3). The day with the highest total concentration of spores was 18 July (3224 AFS/m³). *Cladosporium* was the most prevalent fungal spore type during summer in the air samples from the Timișoara site (41 704 AFS/m³). The threshold concentration of 2000 AFS/m³ that is associated with the occurrence of allergic reactions was exceeded on a 6 days. The peak of the *Cladosporium* spore concentrations was observed on 2 July (3216 AFS/m³). The air concentration of *Alternaria* spores exceeded the threshold level of 80 AFS/m³ on only 2 days (4 July and 30 July). The peak of the *Alternaria* spore concentrations was observed on 4 July (108 AFS/m³).

Correlations between airborne fungal spores and environmental factors from the same sampling day (SSD)

Spearman's test was used for analysis. The relation between airborne fungal spore concentrations and meteorological variability were given in Tables II–IV. The 25 major and minor fungal spore types, airborne hyphal fragments and daily total spores were subjected to the analyses. A positive significant correlation between fungal spore concentrations and minimum temperature occurred for only two spore types (*Bipolaris*, *Pithomyces*). The *Pseudocercospora* spore level showed a significant negative correlation with minimum temperature and maximum temperature.

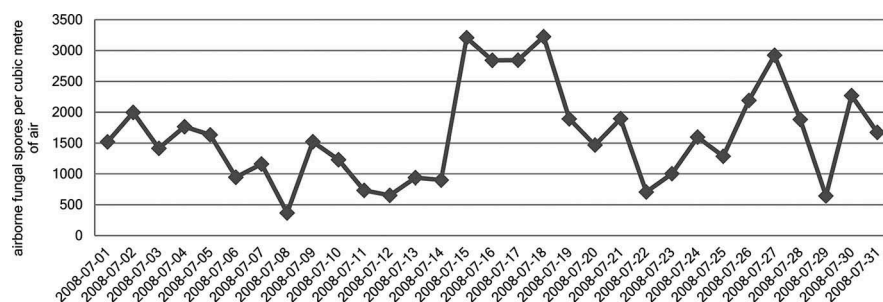


Figure 3. Daily concentrations of airborne total fungal spores.

Torula, *Pithomyces* and *Oidium* spore levels showed a significant positive correlation with maximum temperature.

In the present work, the *Fusarium*/*Leptosphaeria*-group, *Capronia*, *Pseudocercospora* and *Polythrincium* spores presented a significant negative correlation with mean daily average temperature. The results have shown that level of *Torula* and *Bipolaris* spores is significant positive affected by daily mean temperature. A positive and statistically significant correlation was observed between the airborne fungal fragments and *Torula* spores and the near-surface soil temperature. More notable was the significant negative relationship between near-surface soil temperature and concentrations of *Fusarium*/*Leptosphaeria*-group, *Capronia*, *Parapheosphaeria*, *Pleospora*, *Pseudocercospora*, *Ascobolus* and *Polythrincium*. In the case of airborne fungal fragments and *Torula*, significant negative correlation coefficients were obtained with daily average relative humidity. *Fusarium*/*Leptosphaeria*-group, *Xylariaceae*-group, *Capronia*, *Parapheosphaeria*, *Pleospora*, *Pseudocercospora*, *Ascobolus* and *Polythrincium* revealed significant positive correlations.

Significant negative correlations were observed between the airborne fungal fragments, *Helminthosporium*, *Torula* and *Sporidesmium* spores and precipitation. For this same factor, the correlations were significant and positive in the case of *Fusarium*/*Leptosphaeria*-group, *Capronia*, *Pleospora* and *Polythrincium*. In the present work, *Fusarium*/*Leptosphaeria*-group, *Capronia*, *Parapheosphaeria*, *Pleospora* and *Pseudocercospora* spores presented a significant negative correlation with sunshine hours. The results show that levels of *Helminthosporium* and *Torula* spores were significantly positively correlated with sunshine hours. For *Torula* spores was negative correlation detected between concentrations and cloudiness. A positive and statistically significant correlation was found for *Fusarium*/*Leptosphaeria*-group, *Parapheosphaeria* and *Pleospora* spores concentrations. In the present study, I found only a negative correlation between atmospheric pressure and *Parapheosphaeria* spores counts. In relation to daily average wind

speed, the correlation was significant and positive in the case of airborne fungal fragments.

Correlations between the airborne fungal spores and environmental factors from the previous day (PD)

I have chosen the meteorological parameters on the day before to the appearance of airborne fungal spores to see if it confirms the statistical data on the same day sampling. Weak negative correlations were observed in the case of maximum temperature and minimum temperature a day earlier. In the present study, only *Capronia* and *Polythrincium* spores presented a significant negative correlation with mean temperature on the previous day. *Fusarium*/*Leptosphaeria*-group, *Capronia* and *Polythrincium* had a significant negative correlation with near-surface soil temperature. A positive and statistically significant correlation was observed between the airborne fungal fragments and *Torula* spores.

Cladosporium, *Fusarium*/*Leptosphaeria*-group, *Xylariaceae*-group, *Capronia*, *Parapheosphaeria*, *Nigrospora*, *Polythrincium* and daily total fungal spores showed a significant strong positive correlation with daily average relative humidity on the day before sampling. Airborne fungal fragments and *Torula* spores were negatively correlated. *Fusarium*/*Leptosphaeria*-group, *Capronia* and *Ascobolus* were the components of the aeromycoflora to show a significant positive correlation with quantities of precipitations falling on the day before sampling but *Torula* were negative significantly correlated.

Torula, *Oidium* and airborne fungal fragments were positive correlated significantly with sunshine hours on the day before sampling. The strongest negative correlations were demonstrated by *Fusarium*/*Leptosphaeria*-group, *Capronia*, *Pleospora*, *Pseudocercospora*, *Ascobolus* and *Polythrincium*. A positive and statistically significant correlation was found between the cloudiness and *Capronia* spore concentrations. Atmospheric concentrations of *Torula* and *Oidium* spores were negatively correlated with cloudiness. In the present study, I found a negative correlation between atmospheric pressure and airborne

Nigrospora spore concentrations, whereas there was a significant positive correlation between atmospheric concentrations of *Torula* and *Helminthosporium* spores and atmospheric pressure. In relation to daily average wind speed, the correlation was significant and negative only in the case of the Xilariaceae-group.

According to the Spearman's correlations with meteorological factors, the major and minor fungal spores can be divided after two patterns: (I) Airborne fungal fragments, *Torula*, *Pithomyces*, *Helminthosporium*, *Bipolaris*, *Sporidesmium* and *Oidium* presented positive correlations with temperature, atmospheric pressure and sunshine but negative correlations with relative humidity, rainfall and cloudiness, in general, I noticed a weak correlation between wind speed and airborne fungal spore concentrations (Table II); (II) *Cladosporium*, *Fusarium*/Leptosphaeria-type, Xylariaceae-type, *Polythrincium*, *Capronia*, *Parapheosporia*, *Pleospora*, *Nigrospora*, *Pseudocercospora*, *Ascobolus* and daily total spores presented a contrary behaviour (Table III). *Stemphylium*, *Drechslera*-type, *Diplodia*, *Epicoccum*, *Perenospora*, *Diatrype*, *Tilletia*, *Caloplaca* and *Alternaria* did not exhibit the clear behaviour during period of study (pattern C; Table IV).

Discussion

Most of the fungal spores in the current study have been reported in the atmospheres of different microhabitats all over the world. Most of them have been reported to be aeroallergens. However, they differ greatly in their concentrations and frequencies. The commonest and important are the spores of the artificial group of Fungi imperfecti (anamorphic or conidial fungi). More infrequent identified are Basidiomycotina and Ascomycotina spores (Kasprzyk & Konopińska 2006). In this study, the anamorphs fungi were the largest contributors of the airborne mycoflora. These results are comparable to those from previous studies: in the middle of summer, richness of the fungal spore types is much greater than at any other time of the year (Ianovici 2008; Ianovici & Tudorică 2009).

In this study, *Cladosporium*, *Fusarium*/Leptosphaeria-group, *Alternaria*, *Helminthosporium* and hyphal fragments are the major fungal components in the atmosphere of the Timișoara area. *Cladosporium* and *Alternaria* spores were found to be most abundant in Timișoara. *Cladosporium* constitutes 81.09% of the airborne spore load. It is known that *Cladosporium* is the most common taxon in outdoor air worldwide irrespective of the climate (Bensch et al. 2012).

The variability of meteorological factors at different stages of fungal reproduction could lead to mod-

Table I. Mean monthly meteorological conditions (2008).

Month	daily mean temperature (°C)	maximum temperature (°C)	minimum temperature (°C)	quantities of precipitations (l/m ²)	daily average relative humidity (%)	sunshine hours (h)	atmospheric pressure (mbar)	daily mean wind speed (m/s)	daily max. wind speed (m/s)	nebulosity (tenths)	near-surface soil temperature (°C)
JANUARY	0.9	5.7	-2.4	0.7	80.2	2.9	1013.6	1.7	2.6	6.13	0.6580
FEBRUARY	3.7	10.1	-0.9	0.3	72.3	4.3	1016.3	1.8	3	5.44	3.7586
MARCH	7.7	12.9	3.6	2	67	4	997.5	2.4	3.7	7.21	8.0419
APRIL	12.4	18.7	7	1.5	66	5.9	999.7	2.3	3.2	6.46	14.7266
MAY	17.8	25	11.3	1.6	63.2	7.9	1003.8	2.1	3.2	5.14	23.0612
JUNE	21.6	28.1	15.7	5.2	66.1	8.3	1003.8	1.7	2.3	5.44	25.8133
JULY	21.9	29.1	15.4	1.5	60.8	8.2	1002.6	1.9	2.6	4.72	27.1419
AUGUST	22.6	30.9	15.6	0.8	57.8	9	1003.4	1.7	2.5	2.87	27.5645
SEPTEMBER	15.4	21.7	11.2	1.7	70.6	4.7	1005.7	1.6	2.4	6.33	17.3633
OCTOBER	12.3	20.3	7.3	0.6	75.2	5.5	1009	1.6	2.6	4.61	13.0871
NOVEMBER	7.1	13.4	2.7	1.8	73.4	4.4	1007.3	1.9	2.8	5.27	7.3033
DECEMBER	3.6	7	0.7	1.8	78.3	1.7	1009.5	2.1	2.8	7.83	3.2322

ifications of the biodiversity and fungal behaviour patterns (Damialis et al. 2015a). In my study, temperature and humidity were found to be the most important influence on airborne spore concentrations. This observation was consistent with previous reports (Wu et al. 2000; Marchiso & Airaudi 2001). The results of the Spearman's correlation test showed that the atmospheric fungal spore concentration is not significantly affected by the wind speed. These meteorological variables can modulate the response of different species of fungi. On the one hand, airborne concentrations of some fungal spores are significantly correlated with some meteorological factors in the same day. On the other hand, these same fungal spores can be strongly correlated with other factors from the day before sampling (Rodríguez-Rajo et al. 2005; Fernández-González et al. 2009, 2012). The same meteorological variable may have different influences on different parts of the cycle. Each weather variable has a range in which it affects the fungal spore's development, release and dispersal. Release mechanisms of fungal spores are numerous and vary from species to species. Some fungi require rather humid conditions whereas others favour dry and windy conditions for spore release (Sesartic & Dallafior 2011). Overall, the correlations were less significant when data is restricted to the period of airborne spores being released (Iano-vici 2016a). However, my study, according to Spearman's correlation analysis, indicated that increases in airborne fungal fragments of *Torula*, *Pithomyces*, *Helminthosporium*, *Bipolaris*, *Sporidesmium* and *Oidium* were correlated with higher temperatures, sunshine and lower relative humidity, while *Cladosporium*, *Fusarium/Leptosphaeria*-type, *Xylariaceae*-type, *Polythrincium*, *Capronia*, *Parapheospheria*, *Pleospora*, *Nigrospora*, *Pseudocercospora*, *Ascobolus* and daily total spores increased at higher relative humidity, cloudiness and lower temperature.

Airborne fungal fragments were found to be correlated with several meteorological factors (the sum of precipitation, daily average relative humidity, and daily average wind speed). In other studies, airborne fungal fragments have been shown to become airborne at significantly higher concentrations than conidia in simulated aerosolization experiments (Górny & Ławniczek-Wałczyk 2012). Incorporating hyphal concentrations with those of conidia in epidemiologic investigations has improved the association with asthma severity. One study has demonstrated that airborne fungal hyphae commonly function as sources of aeroallergens (Green et al. 2005).

In the present work, the daily total fungal spore concentrations did not present a significant positive correlation with meteorological parameters (except

Table II. Coefficients of correlation between the major and minor fungal spore concentrations and the main meteorological parameters by using the Spearman correlation test (Pattern A).

		near-surface soil temperature (°C)	mean daily average temperature (°C)	maximum temperature (°C)	minimum temperature (°C)	quantities of precipitations (l/m ²)	daily average relative humidity (%)	sunshine hours (h)	atmospheric pressure (mbar)	daily average wind speed (m/s)	daily max. wind speed (m/s)	nebulosity (tenths)
airborne fungal fragments	PD	0.443*	0.233	0.292	0.237	-0.305	-0.537**	0.370*	0.236	0.188	0.159	-0.259
	SSD	0.424*	0.346	0.293	0.316	-0.441*	-0.674**	0.309	0.230	0.391*	0.335	-0.308
<i>Torula</i>	PD	0.470**	0.178	0.245	-0.076	-0.375*	-0.258	0.654**	0.496**	-0.121	-0.099	-0.587**
	SSD	0.519**	0.581**	0.543**	0.273	-0.358*	-0.516**	0.460**	0.203	0.008	0.002	-0.423*
<i>Helminthosporium</i>	PD	0.158	0.049	0.068	0.013	-0.040	-0.067	0.286	0.360*	-0.035	-0.047	-0.116
	SSD	0.272	0.127	0.019	0.093	-0.466**	-0.347	0.369*	0.185	0.102	0.084	-0.296
<i>Oidium</i>	PD	0.354	0.141	0.266	-0.086	-0.224	-0.223	0.441*	0.318	-0.287	-0.214	-0.452*
	SSD	0.287	0.301	0.390*	0.090	0.018	-0.153	0.176	0.288	0.129	0.109	-0.207
<i>Bipolaris</i>	PD	0.103	0.092	0.158	-0.033	-0.046	-0.031	0.183	0.072	0.080	0.106	-0.164
	SSD	0.261	0.392*	0.300	0.424*	-0.290	-0.329	0.060	-0.135	0.084	0.137	-0.115
<i>Sporidesmium</i>	PD	0.118	0.199	0.243	0.039	-0.225	-0.048	0.141	-0.202	-0.310	-0.270	-0.086
	SSD	0.144	0.329	0.265	0.287	-0.360*	-0.154	0.149	-0.113	0.025	0.060	-0.253
<i>Pithomyces</i>	PD	0.146	0.163	0.278	-0.096	-0.254	0.034	0.154	0.017	-0.093	0.038	-0.288
	SSD	0.072	0.353	0.457**	0.476**	-0.150	-0.066	0.085	-0.031	-0.314	-0.240	-0.070

Note: **, correlation is significant at the 0.01 level; *, correlation is significant at the 0.05 level; SSD, meteorological parameters in same sampling day; PD, meteorological parameters in previous day.

Table III. Coefficients of correlation between the major and minor fungal spore concentrations and the meteorological parameters by using the Spearman correlation test (Pattern B).

		near-surface soil temperature (°C)	mean daily average temperature (°C)	maximum temperature (°C)	minimum temperature (°C)	quantities of precipitations (l/m ²)	daily average relative humidity (%)	sunshine hours (h)	atmospheric pressure (mbar)	daily average wind speed (m/s)	daily max. wind speed (m/s)	nebosity (tenths)
<i>Cladosporium</i>	PD	-0.297	-0.118	-0.141	0.010	0.188	0.442*	-0.132	0.034	-0.075	0.025	0.244
	SSD	-0.057	0.115	-0.060	0.084	-0.320	0.086	0.033	-0.101	-0.243	-0.155	-0.046
<i>Fusarium/Leptosphaeria</i> -type	PD	-0.391*	-0.230	-0.078	-0.141	0.358*	0.537**	-0.499**	-0.342	0.006	0.170	0.351
	SSD	-0.746**	-0.393*	-0.320	0.016	0.580**	0.744**	-0.623**	-0.190	-0.030	0.025	0.569**
<i>Xylariaceae</i> -type	PD	-0.311	-0.054	-0.062	-0.139	0.175	0.587**	-0.013	-0.028	-0.373*	-0.246	0.082
	SSD	-0.224	0.029	0.006	0.000	0.086	0.460**	-0.019	0.083	-0.191	-0.082	0.022
<i>Polythrincium</i>	PD	-0.422*	-0.397*	-0.324	-0.230	0.344	0.545**	-0.422*	-0.074	-0.050	-0.011	0.238
	SSD	-0.610**	-0.385*	-0.281	-0.216	0.362*	0.600**	-0.270	-0.105	-0.204	-0.145	0.146
<i>Capronia</i>	PD	-0.398*	-0.453*	-0.251	-0.317	0.490**	0.500**	-0.505**	-0.117	-0.224	-0.045	0.366*
	SSD	-0.617**	-0.384*	-0.243	-0.244	0.437*	0.713**	-0.377*	-0.111	-0.173	-0.115	0.187
<i>Paraphaeosporia</i>	PD	-0.241	-0.223	-0.101	-0.395*	0.231	0.445*	-0.242	-0.330	-0.038	0.128	0.049
	SSD	-0.415*	-0.118	0.006	0.195	0.285	0.426*	-0.460**	-0.398*	-0.195	-0.032	0.413*
<i>Pleospora</i>	PD	-0.261	-0.266	-0.189	-0.217	0.319	0.351	-0.432*	-0.263	-0.049	0.123	0.224
	SSD	-0.475**	-0.316	-0.195	-0.092	0.394*	0.543**	-0.564**	-0.320	-0.030	0.083	0.445*
<i>Nigrospora</i>	PD	-0.303	-0.214	-0.214	-0.190	0.180	0.376*	-0.259	-0.400*	-0.349	-0.346	0.080
	SSD	-0.186	-0.328	-0.219	-0.216	0.143	0.313	-0.151	-0.314	-0.168	-0.087	0.032
<i>Pseudocercospora</i>	PD	-0.317	-0.335	-0.306	-0.140	0.298	0.206	-0.472**	-0.281	-0.068	-0.058	0.377*
	SSD	-0.452*	-0.559**	-0.505**	-0.376*	0.324	0.521**	-0.459**	-0.295	0.011	-0.018	0.347
<i>Ascochilus</i>	PD	-0.280	-0.223	-0.107	-0.031	0.534**	0.209	-0.399*	-0.013	0.019	0.064	0.410*
	SSD	-0.378*	-0.346	-0.228	-0.306	0.346	0.416*	-0.201	0.129	0.147	0.192	0.156
daily total spores	PD	-0.241	-0.107	-0.086	-0.020	0.154	0.430*	-0.091	0.011	-0.092	0.035	0.186
	SSD	-0.098	0.140	-0.033	0.170	-0.334	0.063	0.001	-0.128	-0.149	-0.067	-0.054

Note: **, correlation is significant at the 0.01 level; *, correlation is significant at the 0.05 level; SSD, meteorological parameters in same sampling day; PD, meteorological parameters in previous day.

Table IV. Coefficients of correlation between the major and minor fungal spore concentrations and the meteorological parameters by using the Spearman correlation test (Pattern C).

		near-surface soil temperature (°C)	mean daily average temperature (°C)	maximum temperature (°C)	minimum temperature (°C)	quantities of precipitations (l/m ²)	daily average relative humidity (%)	sunshine hours (h)	atmospheric pressure (mbar)	daily average wind speed (m/s)	daily max. wind speed (m/s)	nebulosity (tenths)
<i>Peronospora</i>	PD	-0.024	0.029	0.074	-0.083	-0.007	0.216	0.212	0.080	-0.218	-0.093	-0.088
	SSD	-0.066	0.255	0.172	0.131	-0.083	0.102	0.086	-0.008	0.100	0.168	0.030
<i>Diatrype</i>	PD	-0.176	-0.153	-0.142	-0.354	-0.027	0.278	-0.120	-0.352	-0.203	-0.108	-0.026
	SSD	-0.188	0.021	-0.065	0.141	-0.259	0.157	-0.149	-0.254	-0.072	-0.085	0.050
<i>Stemphylium</i>	PD	-0.038	-0.095	-0.018	0.035	0.122	0.128	-0.118	0.176	0.062	0.158	0.076
	SSD	-0.113	-0.150	-0.031	-0.034	0.016	0.036	0.082	0.256	-0.034	-0.053	-0.140
<i>Drechslera</i>	PD	-0.236	-0.286	-0.196	-0.055	0.065	0.286	-0.073	-0.006	-0.004	0.018	0.050
	SSD	-0.065	-0.125	-0.058	0.064	-0.085	-0.009	0.076	0.170	0.118	0.152	-0.046
<i>Caloplaca</i>	PD	-0.052	-0.154	-0.009	0.086	0.147	-0.003	-0.112	0.086	-0.084	0.049	0.152
	SSD	-0.054	0.022	0.096	0.021	-0.104	-0.026	0.055	0.213	-0.254	-0.224	-0.192
<i>Tilletia</i>	PD	0.190	-0.091	0.083	-0.112	-0.065	-0.153	0.237	0.076	-0.254	-0.180	-0.223
	SSD	0.082	0.183	0.304	0.126	-0.210	-0.218	0.084	0.074	0.069	0.136	-0.223
<i>Alternaria</i>	PD	0.030	-0.183	-0.041	-0.129	-0.042	0.028	0.099	0.193	0.023	0.118	-0.058
	SSD	0.040	0.065	0.150	0.154	-0.239	-0.148	0.141	0.262	0.192	0.221	-0.204
<i>Diplodia</i>	PD	-0.031	-0.207	-0.118	0.020	0.171	-0.083	-0.131	0.113	0.021	0.070	0.152
	SSD	0.072	-0.026	0.047	-0.096	-0.215	-0.161	0.132	0.105	-0.145	-0.097	-0.269
<i>Epicoccum</i>	PD	0.012	0.046	0.030	0.104	-0.229	0.132	0.060	0.125	-0.049	0.050	-0.070
	SSD	0.009	0.125	0.215	0.092	-0.157	-0.038	0.273	0.316	-0.112	-0.071	-0.236

Note: **, correlation is significant at the 0.01 level; *, correlation is significant at the 0.05 level; SSD, meteorological parameters in same sampling day; PD, meteorological parameters in previous day.

relative humidity on the day before sampling). Also, in many other studies, no significant associations were found between meteorological conditions and the total fungal spore concentrations. This finding could partly help to explain the lack of association in the reporting of health effects and total fungal spore concentrations observed (Osborne et al. 2006).

It is possible that other non-measured parameters may have some influence on spore release. Fungi react simultaneously to a combination of climate factors (Grinn-Gofroń & Bosiacka 2012). Fungal spores and asexual conidia are adapted to resist in the stressful conditions characteristic of the summer, with absence of rain, high temperatures and strong sunlight (Seong et al. 2008; Elvira-Rendueles et al. 2013). The exceedance of the higher temperature limit for growth may kill some fungi, whereas temperatures below the lower growth limit are less lethal. Fungi are living organisms that multiply rapidly under favourable conditions and may colonise organic material when water is available in sufficient quantity (Eduard 2009). Lyon et al. (1984) suggested that adequate moisture is probably the most important factor in spore production. Some authors (Ebner et al. 1989; Hawke & Meadows 1989) have stated that the significance of the correlation with humidity depends on the type of spores.

The classification in 'dry' and 'wet' types of spores is based on the predominant meteorological conditions that are required for production, release and dispersal of fungal spores. These terms have not been used to characterise the pattern of spores in this study. For example, the correlations seem to indicate that *Cladosporium* spores favoured 'wet' conditions the previous day. Increased levels in the air of *Cladosporium* spores after light rain have previously been reported (Sadyś et al. 2015). In July 2008, the rains were few and relative humidity was low compared with the previous month. On the other hand, the largest contribution to the total variation of *Cladosporium* spore concentrations in the same sampling day was daily mean temperature and maximum temperature. The *Fusarium/Leptosphaeria*-type is described as 'wet' (Dawidziuk et al. 2012). Differences in the results from the other studies are caused by differences in the various methodologies applied, such as the differences in sampler type, sampling height, statistical analysis and also by duration of the season included in the analysis (Khattab & Levetin 2008; Ianovici et al. 2013a).

The growth, sporulation and dispersal of airborne spores are evidently highly sensitive to changes in the weather (Rodríguez-Rajo et al. 2005). The distribution of fungal spores in the atmosphere has a varying nature and is determined by a combination of many environmental and biological factors. My study illustrated the

difficulty in interpretations relating the associations between meteorological variables and airborne spore concentrations. Short sampling durations only provide a snapshot of airborne mycoflora. Obviously, it is necessary to investigate multiannual dynamics of spore concentrations that can conclusively illustrate the relationship with meteorological parameters. It is documented that the season of occurrence of airborne mycoflora is related to the phenology of vegetation (Awad 2005). The area around Timișoara is an agricultural region with large-scale plantings of crops. It is also known that in this area the use of agricultural practices and the land management has changed, which constitute the habitat of the fungi (Ianovici 2011; Ianovici et al. 2013b).

My present study has an important contribution for determination of levels and types of atmospheric fungal spores in Romania. Comparison of my research results with those presented in the literature shows that the atmospheric fungal spores frequently present in Timișoara are cosmopolitan, spread in different climatic zones. Most of these atmospheric fungal spores are a potential danger to public health. Monitoring of these aeroallergens may be useful for patients, clinicians and the general public in the Romania. Based on my results, clinicians should consider the atmospheric fungal spores described herein as a possible cause of allergic symptoms during periods of warm summer weather. The threshold concentrations of aeroallergens, for the induction of clinical symptoms, are practically unknown in our country. It is recommended that the testing of allergic patients to include these types of fungal spores.

Conclusions

The value of this study is to help in the identification of the various components of the outdoor environment. My study revealed the existence of a rich airborne mycoflora of Timișoara. *Cladosporium* is the leading allergenic fungi observed in the climate and is an important source of aeroallergens. The meteorological parameters who affecting the concentration of spores in the atmosphere were not defined precisely, but I described two opposite patterns of behaviour in the summer period.

Disclosure statement

No potential conflict of interest was reported by the author.

References

- Abu-Dieyeh MH, Barham R, Abu-Elteen K, Al-Rashidi R, Shah-reen I. 2010. Seasonal variation of fungal spore populations in

- the atmosphere of Zarqa area, Jordan. *Aerobiologia* 26: 263–276. doi:10.1007/s10453-010-9162-2.
- Almaguer M, Aira M-J, Rodríguez-Rajo FJ, Rojas T. 2014. Temporal dynamics of airborne fungi in Havana (Cuba) during dry and rainy seasons: Influence of meteorological parameters. *International Journal of Biometeorology* 58: 1459–1470. doi:10.1007/s00484-013-0748-6.
- Al-Subai AAT. 2002. Air-borne fungi at Doha, Qatar. *Aerobiologia* 18: 175–183. doi:10.1023/A:1021344307205.
- Alzate Guarín F, Quijano Abril MA, Alvarez A, Fonnegra R. 2015. Atmospheric pollen and spore content in the urban area of the city of Medellín, Colombia. *Hoehnea* 42: 9–19. doi:10.1590/2236-8906-52/2013.
- Awad AH. 2005. Vegetation: A source of air fungal bio-contaminant. *Aerobiologia* 21: 53–61. doi:10.1007/s10453-004-5878-1.
- Bensch K, Braun U, Groenewald JZ, Crous PW. 2012. The genus *Cladosporium*. *Studies in Mycology* 72: 1–401. doi:10.3114/sim0003.
- Berman D. 2011. Climate change and aeroallergens in South Africa. *Current Allergy & Clinical Immunology* 24: 65–71.
- Celenk S, Bicakci A, Erkan P, Aybeke M. 2007. *Cladosporium* Link ex Fr. and *Alternaria* Nees ex Fr. spores in the Atmosphere of Edirne. *Journal of Environmental Biology* 1: 127–130.
- Comtois P. 1990. Indoor and mold aerosols. *Aerobiologia* 6: 165–176. doi:10.1007/BF02539110.
- Damialis A, Mohammad AB, Halley JM, Gange AC. 2015a. Fungi in a changing world: Growth rates will be elevated, but spore production may decrease in future climates. *International Journal of Biometeorology* 59: 1157–1167. doi:10.1007/s00484-014-0927-0.
- Damialis A, Vokou D, Gioulekas D, Halley JM. 2015b. Long-term trends in airborne fungal-spore concentrations: A comparison with pollen. *Fungal Ecology* 13: 150–156. doi:10.1016/j.funeco.2014.09.010.
- Das S, Gupta-Bhattacharya S. 2012. Monitoring and assessment of airborne fungi in Kolkata, India, by viable and non-viable air sampling methods. *Environmental monitoring and assessment* 184: 4671–4684. doi:10.1007/s10661-011-2294-1.
- Dawidziuk A, Kaczmarek J, Podlesna A, Kasprzyk I, Jedryczka M. 2012. Influence of meteorological parameters on *Leptosphaeria maculans* and *L. biglobosa* spore release in central and eastern Poland. *Grana* 51: 240–248. doi:10.1080/00173134.2011.649016.
- De Antoni Zoppas BC, Valencia-Barrera RM, Vergamini Duso SM, Fernández-González D. 2006. Fungal spores prevalent in the aerosol of the city of Caixas do Sul, Rio Grande do Sul, Brazil, over a 2-year period. *Aerobiologia* 22: 119–126. doi:10.1007/s10453-006-9022-2.
- Dixit A, Lewis W, Baty J, Crozier W, Wedner J. 2000. Deuteromycete aerobiology and skin-reactivity patterns – A two year concurrent study in Corpus Christi, Texas, USA. *Grana* 39: 209–218. doi:10.1080/00173130051084368.
- Ebner MR, Haselwandter K, Frank A. 1989. Seasonal fluctuations of airborne fungal allergens. *Mycological Research* 92: 170–176. doi:10.1016/S0953-7562(89)80008-5.
- Eduard W. 2009. Fungal spores: A critical review of the toxicological and epidemiological evidence as a basis for occupational exposure limit setting. *Critical Reviews in Toxicology* 39: 799–864. doi:10.3109/10408440903307333.
- El-Essawy AA, Abd El-Kader MIA, Abou El-Hawa ME, Aly ASE. 1992. Studies on mycoflora of air of Sana'a governorate Yemen Republic. *Egyptian Journal of Applied Science* 7: 607–616.
- Elvira-Rendueles B, Moreno J, Garcia-Sanchez A, Vergara N, Martinez-Garcia MJ, Moreno-Grau S. 2013. Air-spore in Cartagena, Spain: Viable and non-viable sampling methods. *Annals of Agricultural and Environmental Medicine* 20: 664–671.
- Fernández-González M, Rodríguez-Rajo FJ, Jato V, Aira MJ, Ribeiro H, Oliveira M, Abreu I. 2012. Forecasting ARIMA models for atmospheric vineyard pathogens in Galicia and Northern Portugal: *Botrytis cinerea* spores. *Annals of Agricultural and Environmental Medicine* 19: 255–262.
- Fernández-González M, Rodríguez-Rajo FJ, Jato V, Aira MJ. 2009. Incidence of fungals in a vineyard of the denomination of origin Ribeiro (Ourense– north-western Spain). *Annals of Agricultural and Environmental Medicine* 16: 263–271.
- Górny RL, Ławniczek-Wałczyk A. 2012. Effect of two aerosolization methods on the release of fungal propagules from a contaminated agar surface. *Annals of Agricultural and Environmental Medicine* 19: 279–284.
- Green BJ, Sercombe JK, Tovey ER. 2005. Fungal fragments and undocumented conidia function as new aeroallergen sources. *Journal of Allergy and Clinical Immunology* 115: 1043–1048. doi:10.1016/j.jaci.2005.02.009.
- Grinn-Gofroń A, Bosiacka B. 2012. The advanced statistical methods in aerobiological studies. *Acta Agrobotanica* 65: 69–74. doi:10.5586/aa.2012.023.
- Grinn-Gofron A, Strzelczak A, Wolski T. 2011. The relationships between air pollutants, meteorological parameters and concentration of airborne fungal spores. *Environmental Pollution* 159: 602–608. doi:10.1016/j.envpol.2010.10.002.
- Halwagy MH. 1994. Fungal airspora of Kuwait City, Kuwait, 1975–1987. *Grana* 33: 340–345. doi:10.1080/00173139409429022.
- Hasnain SM, Fatima K, Al-Frayh A, Al-Sedairy S. 2005. Prevalence of airborne basidiospores in three coastal cities of Saudi Arabia. *Aerobiologia* 21: 139–145. doi:10.1007/s10453-005-4184-x.
- Hawke PR, Meadows ME. 1989. Winter airspora spectra and meteorological conditions in Cape Town, South Africa. *Grana* 28: 187–192. doi:10.1080/00173138909427430.
- Helfman I, Waisel Y, Kutiel H. 2011. Relationship between weather conditions and release of allergen pollen and spores to the air in Haifa. *Geography Research Forum* 31: 24–38.
- Hirst JM. 1952. An automatic volumetric spore trap. *The Annals of Applied Biology* 39: 257–265. doi:10.1111/j.1744-7348.1952.tb00904.x.
- Hjelmroos M. 1993. Relationship between airborne fungal spore presence and weather variables: *Cladosporium* and *Alternaria*. *Grana* 32: 40–47. doi:10.1080/00173139309436418.
- Ho HM, Rao CY, Hsu HH, Chiu YH, Liu CM, Chao HJ. 2005. Characteristics and determinants of ambient fungal spores in Hualien, Taiwan. *Atmospheric Environment* 39: 5839–5850. doi:10.1016/j.atmosenv.2005.06.034.
- Horner WE, Helbling A, Salvaggio JE, Lehrer SB. 1995. Fungal allergens. *Clinical Microbiology Reviews* 8: 161–179.
- Ianovici N. 2011. Approaches on the invasive alien taxa in Romania – *Ambrosia artemisiifolia* (ragweed) II. *Annals of West University of Timișoara, ser. Biology* 14: 93–112.
- Ianovici N. 2016a. Atmospheric concentrations of selected allergenic fungal spores in relation to some meteorological factors, in Timișoara (Romania). *Aerobiologia* 32: 139–156. doi:10.1007/s10453-016-9427-5.
- Ianovici N. 2016b. Methods of biological monitoring in urban conditions: Quantification of airborne fungal spores. *Annals of West University of Timișoara, ser. Biology* 19: 87–100.
- Ianovici N, Dumbravă-Dodoacă M, Filimon MN, Sinitean A. 2011. A comparative aeromycological study of the incidence of allergenic spores in outdoor environment. *Analele Universității din Oradea, Fascicula Biologie* 18: 88–98.
- Ianovici N, Faur A. 2003. Preliminary study of some atmospheric fungi in Timișoara, The 5th International Symposium “Young people and multidisciplinary research”, Section Environmental Protection, Timisoara, Romania, 6–7 November, 624–629.

- Ianovici N, Novac ID, Vlădoiu D, Bijan A, Ionaşcu A, Sălăşan B, Rămuş I. 2009. Biomonitoring of urban habitat quality by anatomical leaf parameters in Timişoara. *Annals of West University of Timişoara, ser. Biology* 12: 73–86.
- Ianovici N, Tudorică D. 2009. Aeromycoflora in outdoor environment of Timişoara City (Romania). *Notulae Scientia Biologicae* 1: 21–28.
- Ianovici N. 2008. Preliminary survey of airborne fungal spores in urban environment. *Scientific Papers, Agronomy Series* 51: 84–89.
- Ianovici N, Maria C, Răduţoiu MN, Haniş A, Tudorică D. 2013a. Variation in airborne fungal spore concentrations in four different microclimate regions in Romania. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca* 41: 450–457.
- Ianovici N, Panaitescu Bunu C, Brudiu I. 2013b. Analysis of airborne allergenic pollen spectrum for 2009 in Timişoara, Romania. *Aerobiologia* 29: 95–111. doi:10.1007/s10453-012-9266-y.
- Ibáñez V, Rojas G, Roure J. 2001. Airborne fungi monitoring in Santiago, Chile. *Aerobiologia* 17: 137–142. doi:10.1023/A:1010833101583.
- Ismail MA, Abdel-Hafez SII, Moharram AM. 2002. Aeromycobiota of Western Desert of Egypt. *African Journal of Science and Technology* 3: 1–9.
- Kasprzyk I, Konopińska A. 2006. Comparative analysis of the concentration of fungal spores in the air of Lublin and Rzeszów (Eastern Poland). *Acta Agrobotanica* 59: 143–150. doi:10.5586/aa.2006.069.
- Kasprzyk I. 2008. Aeromycology. Main research fields of interest during the last 25 years. *Annals of Agricultural and Environmental Medicine* 15: 1–7.
- Khattab A, Levetin E. 2008. Effect of sampling height on the concentration of airborne fungal spores. *Annals of Allergy, Asthma & Immunology* 101: 529–534. doi:10.1016/S1081-1206(10)60293-1.
- Kurkela T. 1997. The number of *Cladosporium* conidia in the air in different weather conditions. *Grana* 36: 54–61. doi:10.1080/00173139709362591.
- Li D-W, Kendrick B. 1995. A year-round study on functional relationships of airborne fungi with meteorological factors. *International Journal of Biometeorology* 39: 74–80. doi:10.1007/BF01212584.
- Lim SH, Chew FT, Dali SDBM, Tan TW, Lee BW, Tan TK. 1998. Outdoor airborne fungal spores in Singapore. *Grana* 37 (4): 246–252. doi:10.1080/00173139809362674.
- Lyon EL, Framer CL, Eversmeyer MG. 1984. Variation of air-spores in the atmosphere due to weather conditions. *Grana* 23: 177–181. doi:10.1080/00173138409427713.
- Marchiso VF, Airaudi D. 2001. Temporal trends of the airborne fungi and their functional relations with the environment in a suburban site. *Mycologia* 93: 831–840. doi:10.2307/3761749.
- Mikaliūnaitė R, Kazlauskas M, Veriankaitė L. 2009. Prevalence peculiarities of airborne *Alternaria* genus spores in different areas of Lithuania. *Scientific Works of the Lithuanian Institute of Horticulture and Lithuanian University of Agriculture. Sodininkystė ir Daržininkystė* 28: 135–143.
- Myszkowska D, Stępańska D, Krystyna K, Porębski G. 2002. The relationship between airborne pollen and fungal spore concentrations and seasonal pollen allergy symptoms in Cracow in 1997–1999. *Aerobiologia* 18: 153–161. doi:10.1023/A:1020603717191.
- Nitiu DS, Mallo AC. 2011. Variaciones en la estacionalidad de polen y esporas fúngicas en la atmósfera de la Ciudad de la Plata (Argentina). *Boletín de la Sociedad Argentina de Botánica* 46: 297–304.
- Nourian AA, Badali H, Khodaverdi M, Hamzehei H, Mohseni S. 2007. Airborne mycoflora of Zanjan, Iran. *International Journal of Agriculture & Biology* 9: 628–630.
- Oliveira M, Ribeiro H, Delgado L, Fonseca J, Castel-Branco MG, Abreu I. 2010. Outdoor allergenic fungal spores: Comparison between an urban and a rural area in Northern Portugal. *Journal of Investigational Allergology & Clinical Immunology* 20: 117–128.
- Osborne M, Reponen T, Adhikari A, Cho SH, Grinshpun SA, Levin L, Bernstein DI, LeMasters G. 2006. Specific fungal exposures, allergic sensitization, and rhinitis in infants. *Pediatric Allergy and Immunology* 17: 450–457. doi:10.1111/j.1399-3038.2006.00414.x.
- Pakpour S, Li DW, Klironomos J. 2015. Relationships of fungal spore concentrations in the air and meteorological factors. *Fungal Ecology* 13: 130–134. doi:10.1016/j.funeco.2014.09.008.
- Peternel R, Čulig J, Hrga I. 2004. Atmospheric concentrations of *Cladosporium* spp. and *Alternaria* spp. Spores in Zagreb (Croatia) and effects of some meteorological factors. *Annals of Agricultural and Environmental Medicine* 11: 303–307.
- Rapiejko P, Lipiec A, Wojdas A, Jurkiewicz D. 2004. Threshold pollen concentration necessary to evoke allergic symptoms. *International Reviews Allergology Clinical Immunology* 10: 91–94.
- Rizzi-Longo L, Pizzulin-Sauli M, Ganis P. 2009. Seasonal occurrence of *Alternaria* (1993–2004) and *Epicoccum* (1994–2004) spores in Trieste (NE Italy). *Annals of Agricultural and Environmental Medicine* 16: 63–70.
- Rocha-Estrada A, Alvarado-Vázquez MA, Hernández-Piñero JL, De León-Alanís DD, Guzmán-Lucio MA. 2013. Diversidad polínica en la atmósfera del área metropolitana de Monterrey, N. L., octubre 2004 a marzo 2005. *Revista Mexicana de Biodiversidad* 84: 1063–1069.
- Rodríguez-Rajo FJ, Iglesias I, Jato V. 2005. Variation assessment of airborne *Alternaria* and *Cladosporium* spores at different bioclimatic conditions. *Mycological Research* 109: 497–507.
- Saar M. 2007. Seasonality in quantity of atmospheric fungal aerosol in Tartu (Estonia). *Folia Cryptog. Estonica* 43: 57–67.
- Sadyš M, Kennedy R, West JS. 2015. Potential impact of climate change on fungal distributions: Analysis of 2 years of contrasting weather in the UK. *Aerobiologia* 32: 127–137.
- Sarica Okten S, Asan A, Tungan Y, Ture M. 2005. Airborne fungal concentrations in east patch of Edirne City (Turkey) in autumn using two sampling methods. *Trakya University Journal Sciences* 6: 97–106.
- Ščevková J, Dušička J, Mičieta K, Somorčík J. 2015. The effects of recent changes in air temperature on trends in airborne *Alternaria*, *Epicoccum* and *Stemphylium* spore seasons in Bratislava (Slovakia). *Aerobiologia* 32: 69–81.
- Seong KY, Zhao X, Xu JR, Guldener U, Corby Kistler H. 2008. Conidial germination in the filamentous fungus *Fusarium graminearum*. *Fungal Genetics and Biology* 45: 389–399.
- Sesartic A, Dallaflor TN. 2011. Global fungal spore emissions, review and synthesis of literature data. *Biogeosciences* 8: 1181–1192.
- Simon-Nobbe B, Denk U, Poll V, Rid R, Breitenbach M. 2008. The spectrum of fungal allergy. *International Archives of Allergy and Immunology* 145: 58–86.
- Sindt C, Besancenot JP, Thibaudon M. 2016. Airborne *Cladosporium* fungal spores and climate change in France. *Aerobiologia* 32: 53–68.
- Skjøth CA, Sommer J, Frederiksen L, Gosewinkel Karlson U. 2012. Crop harvest in Central Europe causes episodes of high airborne *Alternaria* spore concentrations in Copenhagen. *Atmos Chemical Physical Discussions* 12: 14329–14361.

- Stennett PJ, Beggs PJ. 2004. *Alternaria* spores in the atmosphere of Sydney, Australia, and relationships with meteorological factors. *International Journal of Biometeorology* 49: 98–105.
- Takahashi T. 1997. Airborne fungal colony forming units in outdoor and indoor environments in Yokohama, Japan. *Mycopathologia* 139: 23–33.
- Targonski PV, Persky VW, Ramakrishnan V. 1995. Effect of environmental molds on risk of death from asthma during the pollen season. *The Journal of Allergy and Clinical Immunology* 95: 955–961.
- Uzochukwu OV, Nkpouto U. 2013. Airborne fungi in the indoor and outdoor environments of a higher institution in Nigeria. *International Journal of Advanced Biological Research* 3: 9–12.
- Vélez-Pereira AM, De Linares C, Delgado R, Belmonte J. 2015. Temporal trends of the airborne fungal spores in Catalonia (NE Spain), 1995–2013. *Aerobiologia* 32: 23–37.
- Wu PC, Su HJ, Lin CY. 2000. Characteristics of indoor and outdoor airborne fungi at suburban and urban homes in two seasons. *The Science of the Total Environment* 253: 111–118.