

Selected airborne allergenic fungal spores and meteorological factors in Szczecin, Poland, 2004–2006

Agnieszka Grinn-Gofroń · Aneta Mika

Received: 3 January 2008 / Accepted: 2 April 2008
© Springer Science+Business Media B.V. 2008

Abstract Airborne fungal spore concentrations in Szczecin, Poland, were studied between 2004 and 2006 with the objective of determining a seasonal variation in the concentrations of selected fungal spore types in relation to meteorological parameters. The presence of spores of five taxa, namely, *Cladosporium*, *Ganoderma*, *Alternaria*, *Leptosphaeria* and *Didymella*, was recorded using a volumetric method (Hirst type). Fungal spores were present in the air in large numbers during the summer, with the highest concentrations recorded mainly in June, July and August. The peak concentrations of two of the studied spore types, *Ganoderma* and *Alternaria*, occurred in August, while the concentrations of *Cladosporium*, *Leptosphaeria* and *Didymella* spores were the highest in July. Multiple regression analysis was performed for three fungal seasons—2004, 2005 and 2006. Spore concentration was found to be positively correlated with the minimum temperature. For some spore types, there was also a significant correlation between concentrations, relative humidity and rain.

Keywords Allergenic fungal spores · Meteorological parameters · Poland · Seasonal variation

1 Introduction

Fungal spores of specific taxa are very often implicated in respiratory allergy symptoms (D’Amato et al. 1997; Rapiejko et al. 2004) and have been reported to be responsible for many of the hospital admissions related to asthma attacks or even acute respiratory failure (Bush and Prochnau 2004). Such respiratory diseases are particularly well documented for children and young adults (Bush and Prochnau 2004). There are many reports of airborne spores (particularly *Alternaria*, *Cladosporium*, *Didymella* and *Ganoderma*) as highly allergic agents in Poland (Corden 2005; Gawel et al. 1996; Myszkowska et al. 2002; Rapiejko et al. 2004), which is accordance with results reported for other countries (Corden and Millington 1994; D’Amato et al. 1997; Resano et al. 1998; Tarlo et al. 1979).

The differences between dry-air spora and wet-weather spora are well known. Dry-spora include mainly *Cladosporium*, *Alternaria* and smut spores (Hjelmroos 1993). Although many other types can be categorized as dry-air spora, these three types are the most prominent in the Szczecin area. They are also well-known allergens (Corden 2005). A potential

A. Grinn-Gofroń (✉)
Department of Plant Taxonomy and Phytogeography,
University of Szczecin, Wąska 13, 71-415 Szczecin,
Poland
e-mail: agofr@univ.szczecin.pl

A. Mika
Polish Physical Society, Szczecin, Poland

allergen threat occurs when the concentration of *Cladosporium* spores reaches 2800 per 1 m³ of air or that of *Alternaria* spores reaches 80 spores per 1 m³ of air (Rapiejko et al. 2004).

Wet-spores, belonging to Ascomycetes and Basidiomycetes, are released into the atmosphere by processes related to high humidity conditions and rain. Ascospore concentrations will increase during and after rainstorms (Bush 1989), whereas basidiospores have a more diurnal pattern that corresponds to the diurnal rhythm of relative humidity (Hasnain 1993; Li and Kendrick 1994; Tarlo et al. 1979).

Basidiospores, *Ganoderma* in particular, have been shown to elicit an allergic response in some patients (Cutten et al. 1988). In addition, *Didymella* ascospores are a recognized trigger of late summer asthma (Richardson 1996). The conclusive establishment of a relationship between meteorological conditions and fungal spore concentrations would represent a major benefit to patients diagnosed with fungal spore allergies. Such knowledge would allow allergy patients to take preventative measures prior to the manifestation of the predicted high concentrations of particular allergens, thereby reducing needless suffering.

The study reported here was conducted to determine the potential influence of different factors on the various allergenic fungal components of the air spora of the Szczecin region.

2 Materials and methods

The taxa analyzed belong to the class of Deuteromycetes, with the exception of *Ganoderma* (Basidiomycotina) and *Didymella* (Ascomycotina). Numerous studies have confirmed the high frequency and concentration of these spore types in the air (Calderon et al. 1995; Diaz et al. 1998; Kasprzyk et al. 2004; Levetin 1991; Mitakakis and Guest 2001; Stępańska and Wołek 2005). These taxa were chosen for study on the basis of their dominance in fungal aeroplankton populations and documented involvement in triggering respiratory allergy symptoms.

The analysis of the spore count and spore fall distribution was carried out using data collected in Szczecin in 2004–2006. The air sampling was carried out using a VPPS Lanzoni 2000 spore trap (Lanzoni, Bologna, Italy) set for 7 days of sampling onto

Melinex tape. The sampler was located 21 m above ground level, approximately 5 km from the city centre (53°26'26'' N, 14°32'50' E). Sampler drums were changed weekly, and the tapes cut into 48-mm segments representing the previous 7 days. Concentrations were presented as spores per cubic metre of air.

Spore data were analyzed to determine the start, end and duration of the season using the 90% method. The start of the season was defined as the date when 5% of the seasonal cumulative spore count was trapped, and the end of the season was set as the date when 95% of the seasonal cumulative spore count was reached.

The meteorological data for the 3 years of the study period were provided by the meteorological station in the Dąbie district of Szczecin and by the automatic weather station at Vaisala. The meteorological parameters taken into account in the assessment of the effect of meteorological conditions on the airborne fungal spores were: daily level of precipitation, relative humidity and air temperature.

The statistical relationship between spore concentration and meteorological factors was established using the STATISTICA program ver. 6.1 (StatSoft, Tulsa, OK).

3 Results

The cumulative annual and monthly totals concentrations of the five selected spore types are shown in Table 1.

Spores were present in large numbers throughout the summer, with the highest levels occurring from May to October. For *Ganoderma* and *Alternaria*, peak spore concentrations were recorded in August (in 2006 for *Ganoderma* in October), while *Cladosporium*, *Leptosphaeria* and *Didymella* spores reached their highest concentrations mainly in July (Table 1).

During the 3 years of this study the *Alternaria* spore count exceeded the threshold value in Szczecin for 70 and 73 days in 2004 and 2005, respectively; in 2006, however, the period during which the threshold value was exceeded was shorter and lasted only for 42 days (Table 2). Similar results were obtained for *Cladosporium*: in 2004 and 2005, the threshold value was exceeded for 79 and 78 days, respectively, and in 2006 only for 43 days (Table 2). For the other spore

Table 1 Monthly and annual totals of selected spore types in 2004, 2005 and 2006

Month	<i>Cladosporium</i>	<i>Ganoderma</i>	<i>Alternaria</i>	<i>Leptosphaeria</i>	<i>Didymella</i>
Selected spore types in 2004					
January	0	0	0	0	0
February	1,446	27	111	10	9
March	4,218	6	177	10	24
April	11,589	9	942	200	327
May	23,067	120	1,416	1,500	3,624
June	89,538	1,113	2,052	10,100	21,765
July	236,862	8,550	5,802	67,000	88,227
August	192,660	8,614	8,961	11,000	27,028
September	49,122	5,703	2,208	2,900	4,773
October	56,379	5,877	1,080	1,200	2,547
November	20,895	1,053	246	200	627
December	1,680	24	12	56	153
Annual totals	687,456	31,096	23,007	94,176	149,104
Selected spore types in 2005					
January	243	0	6	0	0
February	324	3	66	1	3
March	933	6	57	2	6
April	903	3	27	2	3
May	20,391	306	180	1,550	1,719
June	44,747	2,898	942	2,333	5,770
July	264,453	6,759	10,125	35,000	42,123
August	202,178	9,009	11,542	11,050	32,817
September	106,635	8,489	4,494	2,400	5,331
October	47,319	4,095	1,389	1,200	4,599
November	10,092	423	210	2,100	3,714
December	0	0	0	2	0
Annual totals	698,218	31,991	29,038	55,639	96,079
Selected spore types in 2006					
January	0	0	0	0	0
February	348	0	3	0	0
March	1,839	3	27	1	0
April	10,578	18	90	570	1,243
May	14,193	1,011	201	1,765	8,892
June	75,384	3,915	847	7,890	10,941
July	96,015	4,467	4,257	3,500	4,185
August	143,265	3,798	4,329	12,067	29,208
September	34,182	5,424	1,218	3,420	7,075
October	38,727	5,433	564	3,450	6,762
November	19,608	2,913	39	4,568	6,516
December	5,088	573	9	1,780	3,058
Annual totals	439,227	27,555	11,584	39,011	77,880

Measurements in bold indicate the month during which the peak concentration of airborne spores for that taxon was reached

types, the peak period occurred from July until August [*Ganoderma* (2004), *Didymella*, *Leptosphaeria*] and, in some cases, until September [*Ganoderma*

(2005)] and October [*Ganoderma* (2006)], when they exceeded the threshold values causing a risk of provoking allergy symptoms (Table 2).

Table 2 Descriptive statistics of selected spore types in 2004, 2005 and 2006

Taxon	Seasonal data			
	Start data 5% ^a	End data 5% ^a	Duration days	Tsc ^b
Selected spore types in 2004				
<i>Cladosporium</i>	19 May	23 October	258	79
<i>Ganoderma</i>	02 July	05 November	127	62
<i>Alternaria</i>	29 April	12 October	167	70
<i>Leptosphaeria</i>	04 May	15 October	164	62
<i>Didymella</i>	17 June	01 September	77	62
Selected spore types in 2005				
<i>Cladosporium</i>	14 June	07 October	116	78
<i>Ganoderma</i>	19 June	14 October	118	61
<i>Alternaria</i>	04 July	04 October	93	73
<i>Leptosphaeria</i>	25 May	02 November	161	62
<i>Didymella</i>	12 June	25 October	136	62
Selected spore types in 2006				
<i>Cladosporium</i>	24 May	06 November	167	43
<i>Ganoderma</i>	03 June	21 November	172	61
<i>Alternaria</i>	21 June	01 October	103	42
<i>Leptosphaeria</i>	17 May	10 December	207	62
<i>Didymella</i>	19 May	21 November	187	31

^a The start of the season was defined as the date when 5% of the seasonal cumulative spore count was trapped; the end of the season was set as the date when 95% of the seasonal cumulative spore count was reached

^b Tsc, The number of days with a spore count that will elicit allergy symptoms

In 2005, the season started in May (*Leptosphaeria*), June and July and finished in October and November (*Leptosphaeria*). For the majority of spore types (except *Didymella* and *Leptosphaeria*), the shortest airborne spore season during the 3-year study period occurred in 2005, and the annual totals of the daily concentrations in this year were the highest for these three spore types (except *Didymella* and *Leptosphaeria*) (Tables 1, 2). For most spore types, the day of the highest concentration occurred approximately in the middle of the season (Table 1).

The dynamics of the spore season was very similar in each of the 3 years of the study period for both *Cladosporium* and *Alternaria*. The differences in the length during each single stage (0–5%, 5–25%, 25–50%, 50–75%, 75–100%) were not longer than few days. Contrary to 2004 and 2005, the third stage (25–50%) was longer and the fourth stage (50–75%) was shorter for *Cladosporium* in 2006. For *Ganoderma*, *Leptosphaeria* and *Didymella* spore types, the dynamics of the 2006 spore season was different than that observed in 2004 and 2005: the second (5–25%), the third and the fourth season stage was markedly longer for *Ganoderma* in 2006 than in 2004 and 2005. Also in 2006, the second and the third stage were longer for *Didymella*, with the third stage being the

longest, whereas for *Leptosphaeria*, the fourth was the shortest out of the three seasons analyzed (Fig. 1).

The multiple regression analysis was performed to determine which meteorological variables were associated with spore concentrations. Meteorological data used in the multiple regression analysis included minimum temperature, relative humidity and rainfall.

During 2004, 2005, 2006, the analyzed season of spore concentration was positively correlated with minimum temperature for all spore types (Table 3). The concentration of *Alternaria* was significantly and negatively correlated with relative humidity in 2004 and 2006 (Table 3).

A significant correlation between spore concentration and rain occurred only for three spore types: a positive correlation was obtained for *Didymella* and *Leptosphaeria* in 2004 and 2006, and a negative was obtained for *Ganoderma* in 2005 and 2006. For the other spore types, the correlation with rainfall was not statistically significant in any of the study periods (Table 3).

4 Discussion

Based on these results, we can conclude that the airborne fungal spores occur in Szczecin nearly

Fig. 1 Dynamics of fungal seasons in Szczecin, 2004–2006. Diagrams of consecutive stages of the fungal season: 1%, 5%, 25%, 50% (vertical line), 75%, 95%, 99%

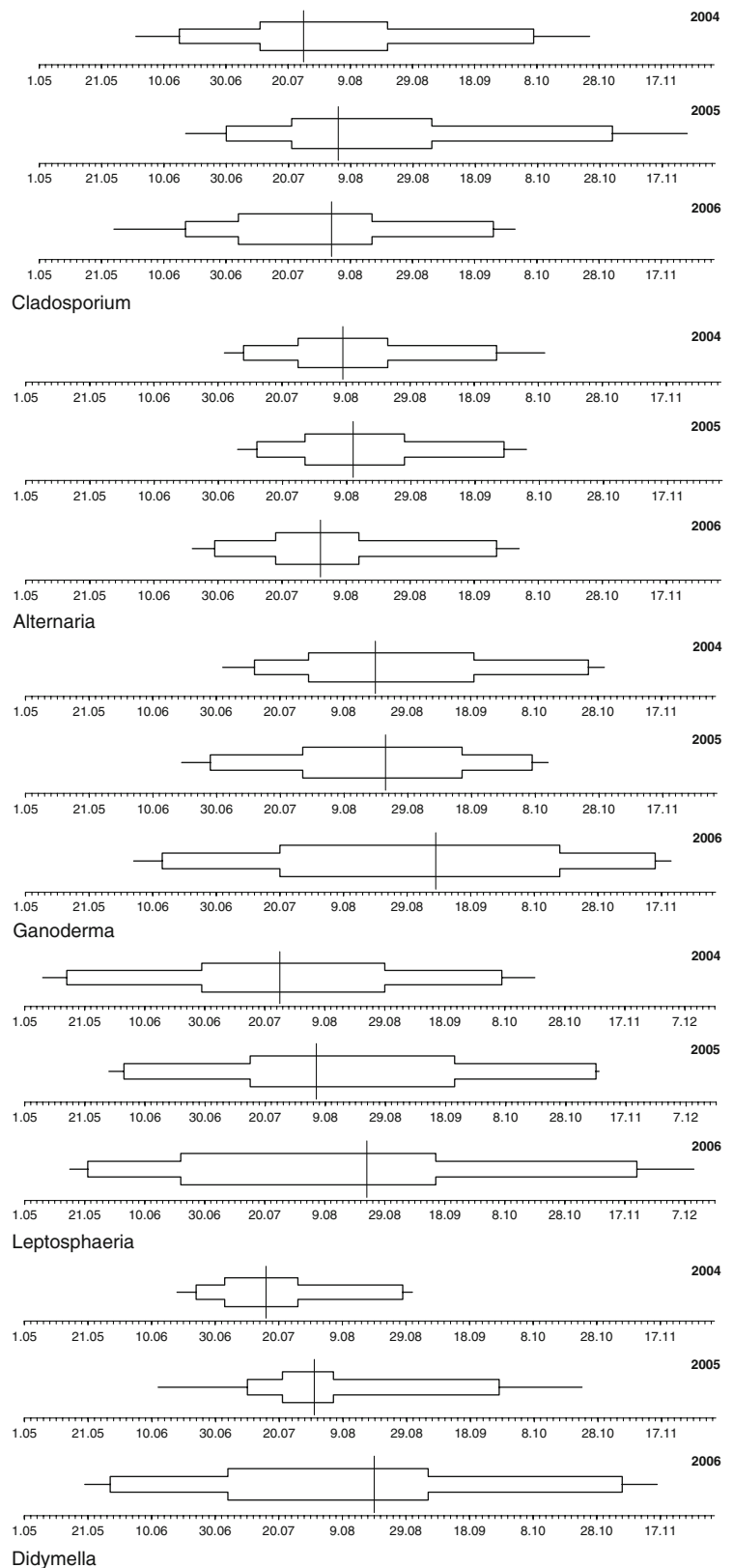


Table 3 Concentration vs. meteorological factors in 2004, 2005 and 2006

Taxon	Period ^a	<i>n</i> ^b	Variance analysis at $\alpha = 0.05$	Adjusted R^{2c}	Explanatory variables ^d	Explained variation (R^2)	Partial correlation
Factors in 2004							
<i>Cladosporium</i>	6.02 to −14.12	129	$F = 14.30998$ $P = 0.000000$	0.5619	Rain	−0.06	−
					Humid	−0.03	−
					$T_{\min}$	0.601	+
<i>Ganoderma</i>	21.02 to −13.12	80	$F = 5.496236$ $P = 0.000618$	0.4761	Rain	−0.01	−
					Humid	0.001	−
					$T_{\min}$	0.530	+
<i>Alternaria</i>	6.02 to −14.12	109	$F = 13.15563$ $P = 0.000000$	0.5796	Rain	−0.11	−
					Humid	−0.19	+
					$T_{\min}$	0.567	+
<i>Leptosphaeria</i>	22.02 to −15.12	93	$F = 6.198812$ $P = 0.000099$	0.4601	Rain	0.306	+
					Humid	0.087	−
					$T_{\min}$	0.382	+
<i>Didymella</i>	21.02 to −13.12	92	$F = 6.188923$ $P = 0.000198$	0.4706	Rain	0.302	+
					Humid	0.089	−
					$T_{\min}$	0.263	+
Factors in 2005							
<i>Cladosporium</i>	18.01 to −24.11	276	$F = 30.29561$ $P = 0.000000$	0.5558	Rain	−0.05	−
					Humid	−0.07	−
					$T_{\min}$	0.528	+
<i>Ganoderma</i>	06.02 to −22.11	172	$F = 12.62049$ $P = 0.000000$	0.4817	Rain	−0.14	+
					Humid	−0.09	−
					$T_{\min}$	0.452	+
<i>Alternaria</i>	19.01 to −16.11	185	$F = 15.33603$ $P = 0.000000$	0.5041	Rain	−0.05	−
					Humid	−0.06	−
					$T_{\min}$	0.466	+
<i>Leptosphaeria</i>	10. 02 to −22.11	143	$F = 6.067804$ $P = 0.000126$	0.3843	Rain	−0.09	−
					Humid	−0.10	−
					$T_{\min}$	0.294	+
<i>Didymella</i>	10.02 to −20.11	152	$F = 6.309904$ $P = 0.000103$	0.3828	Rain	0.118	−
					Humid	0.066	−
					$T_{\min}$	0.250	+
Factors in 2006							
<i>Cladosporium</i>	13.02 to −26.12	305	$F = 28.53843$ $P = 0.000000$	0.5250	Rain	0.098	−
					Humid	−0.04	−
					$T_{\min}$	0.473	+
<i>Ganoderma</i>	10.03 to −20.12	206	$F = 5.569271$ $P = 0.000285$	0.3158	Rain	−0.20	+
					Humid	0.128	−
					$T_{\min}$	0.303	+
<i>Alternaria</i>	25.02 to −04.12	185	$F = 12.46077$ $P = 0.000000$	0.4656	Rain	−0.02	−
					Humid	−0.17	+
					$T_{\min}$	0.375	+

Table 3 continued

Taxon	Period ^a	<i>n</i> ^b	Variance analysis at $\alpha = 0.05$	Adjusted R^{2c}	Explanatory variables ^d	Explained variation (R^2)	Partial correlation
<i>Leptosphaeria</i>	29.03 to –25.12	237	$F = 16.54041$ $P = 0.000006$	0.4614	Rain	0.252	+
					Humid	–0.13	–
					$T_{\min}$	0.213	+
<i>Didymella</i>	02.04 to –24.12	238	$F = 17.97318$ $P = 0.000000$	0.4855	Rain	0.237	+
					Humid	0.111	–
					$T_{\min}$	0.280	+

^a Period, Season (day/month) when the spore samples were collected

^b *n*, Number of days with occurrence of selected spore types in the air

^c Adjusted R^2 , Percentage of explained variation

^d Rain, Rainfall; Humid, relative humidity; $T_{\min}$, minimum temperature

throughout the whole year, although their concentrations in the spring, late autumn and winter are usually low. The maximum spore concentrations of most taxa were observed in July and August, which is similar to results reported for other cities in Poland (Kasprzyk et al. 2004; Konopińska 2004; Myszkowska et al. 2002; Stępańska et al. 1999; Stępańska and Wołek 2005) and Europe (Nikkels et al. 1996). Our values, however, their daily concentrations varied considerably.

Cladosporium spores had the highest concentration in the seasonal spore count. The dominance of this genus in comparison with the other spores analyzed has been observed in many locations, including Denmark (Larsen and Gravesen 1991), Spain (Infante-Garcia-Pantaleon et al. 1992), Italy (Cosentino et al. 1990; Fillipello Marchisio et al. 1997), Austria (Ebner et al. 1992), Sweden (Hjelmroos 1993), Finland (Kurkela 1997), Jordan (Shaneen 1992), India (Chakraborty et al. 2003; Singh et al. 1994), Canada (Li and Kendrick 1994) and Australia (Mitakakis and Guest 2001).

The level of the spore count for *Alternaria* was the highest during summer season (July and August) and was very high in terms of number of spores. Previous monitoring studies on fungal spores in Poland revealed that summer is the most favourable season for *Alternaria* occurrence (Gaweł et al. 1996; Kasprzyk et al. 2004; Konopińska 2004; Stępańska and Wołek 2005). Similar results were also noted in Denmark (Larsen and Gravesen 1991) and Sweden (Hjelmroos 1993). In contrast, in Amman (Jordan), maximum *Alternaria* spore counts were recorded in

October due to the wet and warm conditions found there (Shaneen 1992).

The most important meteorological factor associated with most of analyzed spore types was the minimum temperature. In each season, a statistically significant correlation between the concentration of spores and minimum temperature was noted for all spore types. The strongest correlation was noted for *Cladosporium*, *Alternaria*, *Ganoderma* in 2004 and 2005 and for *Cladosporium* and *Alternaria* in 2006. The positive, significant correlation between spore count and minimum temperature for *Cladosporium* was noted in Cracow by Stępańska and Wołek (2005). Fernandez et al. (1998) also observed an increase in *Cladosporium* spore level at a minimum temperature above 13°C during the summer.

Only *Alternaria* showed a negative and significant correlation with relative humidity in 2004 and 2006. Hjelmroos (1993) and Stępańska and Wołek (2005) recorded increasing spore counts in the air with increasing relative humidity. Hjelmroos (1993) studied (10-year period) the presence of *Cladosporium* and *Alternaria* in relation to weather factors using a statistical model and found that, for *Alternaria*, none of the meteorological parameters had significant canonical coefficients. Therefore, no statistical model was proposed.

Didymella was the second spore type for which the highest number of spores was noted. The release of spores by this taxon may be triggered by local weather conditions, i.e., rainy period preceded by a temperature above 20°C (Corden and Millington 1994). Such conditions occurred in July and August

when the high maximum temperature were followed by heavy rainfall. the results of the multiple regression analysis suggest that during the study period precipitations were the most influential factor only for *Didymella* spore types. The positive, significant correlation between precipitation and *Didymella* spore count occurred in two from three analyzed seasons (2004 and 2006). Corden and Millington (1994) linked *Didymella* to increased asthma admissions in Derby after an unexpected increase in its spore count in the air during the summer season.

Very similar results were noted for *Leptosphaeria*. Both spore types occurred more or less during the same weather periods and depended on similar factors.

Ganoderma spores occurred very often together with those of *Cladosporium* and *Alternaria* in Szczecin. Seasonally, spore levels of *Ganoderma* peaked towards the summer and autumn. Tarlo et al. (1979) found *Ganoderma* basidiospores to be the most prevalent fungal air spores in Canada, and Hasnain et al. (1985); Hasnain (1993) in their studies from New Zealand reported that *Ganoderma* basidiospores constituted a major component of the airspora. *Ganoderma* spores have been reported to constitute an important and prevalent group of fungal airspora worldwide (Halawag 1994; Hasnain 1993; Lehrer et al. 1994; Levetin 1990; Li and Kendrick 1995; Mitakakis and Guest 2001; Stępańska and Wołek 2005). Gregory and Hirst (1952) were the first to suggest that basidiospores may be associated with allergy.

Of all the spores types analyzed in our study, only *Ganoderma*—in two seasons (2005, 2006)—had a negative, statistically significant correlation with rainfall. The same results were noted by Hasnain (1993) in Auckland (New Zealand).

The summer peak in spore concentrations may be the consequence of favourable temperature and humidity conditions. The low spore frequency in the winter months is probably due to the snow cover, but the spore frequencies start decreasing as early as November, before any snowfall, when the temperature falls below zero, thereby preventing sporulation.

It is not certain that all variation in spore concentrations can be explained by meteorological variables only. Spore concentrations may also depend on the state of the host and the weatherings on the host plants. The increase in fungal spore concentrations may also be related to the maturing of tree foliage, grasses and local crops.

Our study examined only part of microfungal flora in a selected area. Further, more extensive studies are necessary in order to evaluate the effects of local vegetation and climate on the fungal flora.

4.1 Conclusions

- The high concentrations of analyzed spore types found in the air of Szczecin during the summer months could trigger asthma attacks in sensitive patients.
- Based of our results, clinicians should consider the spore types described herein as a possible cause of severe asthma attacks during periods of warm, dry summer weather, especially from July to September and, most particularly, from mid-July to mid-August.
- Spores of the studied fungal taxa occurred in the air nearly throughout the whole year; however, their daily concentrations varied considerably.
- During the 3-year study period, the minimum temperature was the most important factor affecting spore concentration, being significantly and positively correlated with the concentration of the majority of spores.

Acknowledgements This research was financed by KBN Grant No. 2, P04G 099 29 in the years 2005 and 2006.

References

- Bush, R. K. (1989). Aerobiology of pollen and fungal allergens. *The Journal of Allergy and Clinical Immunology*, 84, 1120–1124.
- Bush, R. K., & Prochnau, J. J. (2004). *Alternaria*-induced asthma. *The Journal of Allergy and Clinical Immunology*, 113, 227–234.
- Calderon, C., Lacey, J., McCartney, H. A., & Rosas, I. (1995). Seasonal and diurnal variation of airborne basidiomycete spore concentrations in Mexico City. *Grana*, 34, 260–268.
- Chakraborty, P., Gupta-Bhattacharya, S., & Chanda, S. (2003). Aeromycoflora of an agricultural farm in West Bengal, India: A five-year study (1994–1999). *Grana*, 42, 248–254.
- Corden, J. M. (2005). The Midlands Asthma and Allergy Research Association—MAARA. Aerobiology the way forward. AEROTOP, Fungal workshop. Poznań, 2005
- Corden, J. M., & Millington, W. M. (1994). *Didymella* ascospores in Derby. *Grana*, 33, 104–107.
- Cosentino, S., Pisano, P. L., Fadda, M. F., & Palmas, F. (1990). Pollen and mould allergy: Aerobiological survey in the

- atmosphere of Cagliari, Italy (1986–1988). *Annals of Allergy*, 65, 393–399.
- Cutten, A. E. C., Hasnain, S. M., Bai, T. R., & McKay, E. J. (1988). The basidiomycete *Ganoderma* and asthma; collection, quantitation and immunogenicity of the spores. *The New Zealand Medical Journal*, 101, 361–363.
- D'Amato, G., Chatzigeorgiou, G., Corsico, R., Gioulekas, D., Jäger, L., & Jäger, S. (1997). Evaluation of the prevalence of skin prick test positivity to *Alternaria* and *Cladosporium* in patients with suspected respiratory allergy. A European multicenter study promoted by the subcommittee on aerobiology and environmental aspects of inhalant allergens of the European Academy of Allergology and Clinical Immunology. *Allergy*, 52, 711–716.
- Diaz, M. R., Iglesias, I., & Jato, V. (1998). Seasonal variation of airborne fungal spore concentrations in a vineyard of North-West Spain. *Aerobiologia*, 14, 221–227.
- Ebner, M. R., Haselwandter, K., & Frank, A. (1992). Indoor and outdoor incidence of airborne fungal allergens at low- and high-altitude alpine environments. *Mycological Research*, 96, 117–124.
- Fernandez, D., Valencia, R. M., Molnar, T., Vega, A., & Sagüés, E. (1998). Daily and seasonal variations of *Alternaria* and *Cladosporium* airborne spores in León (North-West, Spain). *Aerobiologia*, 14, 215–220.
- Fillipello Marchisio, V., Airaudi, D., & Barchi, C. (1997). One-year monitoring of the airborne fungal community in a suburb of Turin (Italy) and assessment of its functional relations with the environment. *Mycological Research*, 101, 821–828.
- Gawel, J., Halota, A., Pisiewicz, K., Kurzawa, R., Radliński, J., & Doniec, Z. (1996). Allergenic airborne sporomorphs calendar for Rabka (southern Poland), 1991–1995. *Annals of Agricultural and Environmental Medicine*, 3, 87–98.
- Gregory, P. H., & Hirst, J. M. (1952). Possible role of basidiospores as airborne allergens. *Nature*, 170, 414.
- Halawagy, M. H. (1994). Fungal airspora of Kuwait city, Kuwait. *Grana*, 33, 340–345.
- Hasnain, S. M. (1993). Influence of meteorological factors on the airspora. *Grana*, 32, 184–188.
- Hasnain, S. M., Wilson, J. D., & Newhook, F. J. (1985). Allergy to basidiospores: Immunologic studies. *The New Zealand Medical Journal*, 98, 393–396.
- Hjelmroos, M. (1993). Relationship between airborne fungal spore presence and weather variables. *Grana*, 32, 40–47.
- Infante-Garcia-Pantaleon, F., Galan-Soldevilla, C., Dominguez-Vilches, E., Angulo-Romero, J., & Mediavilla-Molina, A. (1992). Air spore microfungi in dwellings of south of Spain. *Aerobiologia*, 8, 245–253.
- Kasprzyk, I., Rzepowska, B., & Wasylów, M. (2004). Fungal spores in the atmosphere of Rzeszów (South-East Poland). *Annals of Agricultural and Environmental Medicine*, 11, 285–289.
- Konopińska, A. (2004). Monitoring of *Alternaria* and *Cladosporium* Link airborne spores in Lublin (Poland) in 2002. *Annals of Agricultural and Environmental Medicine*, 11, 347–349.
- Kurkela, T. (1997). The number of *Cladosporium* conidia in the air in different weather conditions. *Grana*, 36, 54–61.
- Larsen, L., & Gravesen, S. (1991). Seasonal variation of outdoor airborne viable microfungi in Copenhagen, Denmark. *Grana*, 30, 467–471.
- Lehrer, S. B., Hughes, J. M., Altman, L. C., Bousquet, J., Davies, R. J., Gell, L., et al. (1994). Prevalence of basidiomycete allergy in the USA and Europe and its relationship to allergic respiratory symptoms. *Allergy*, 49, 460–465.
- Levetin, E. (1990). Studies on airborne basidiospores. *Aerobiologia*, 6, 177–180.
- Levetin, E. (1991). Identification and concentration of airborne basidiospores. *Grana*, 30, 123–128.
- Li, D., & Kendrick, B. (1994). Functional relationships between airborne fungal spores and environmental factors in Kitchener-Waterloo, Ontario, as detected by canonical correspondence analysis. *Grana*, 33, 166–176.
- Li, D., & Kendrick, B. (1995). A year-round outdoor aeromycological study in Waterloo, Ontario, Canada. *Grana*, 34, 199–207.
- Mitakakis, T. Z., & Guest, D. I. (2001). A fungal spore calendar for the atmosphere of Melbourne, Australia, for the year 1993. *Aerobiologia*, 17, 171–176.
- Myszkowska, D., Stępańska, D., Obtułowicz, K., & Porebski, 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.
- Nikkels, A. H., Terstegge, P., & Spieksma, F. Th. M. (1996). Ten types of microscopically identifiable airborne fungal spores at Leiden, The Netherlands. *Aerobiologia*, 12, 107–112.
- Rapiejko, P., Lipiec, A., Wojdas, A., & Jurkiewicz, D. (2004). Threshold pollen concentration necessary to evoke allergic symptoms. *International Review of Allergology & Clinical Immunology*, 10, 91–94.
- Resano, A., Sanz, M. L., & Oehling, A. (1998). Sensitization to *Alternaria* and *Cladosporium* in asthmatic patients and its in vitro diagnostic confirmation. *Journal of Investigational Allergology & Clinical Immunology*, 8, 353–358.
- Richardson, M. J. (1996). The occurrence of airborne *Didymella* spores in Edinburgh. *Mycological Research*, 100, 213–216.
- Shaneen, I. (1992). Aeromycology of Amman area, Jordan. *Grana*, 31, 223–228.
- Singh, A., Gangal, S. V., & Singh, A. B. (1994). Airborne fungi in the hospitals of metropolitan Delhi. *Aerobiologia*, 10, 11–21.
- Stępańska, D., Harmata, K., Kasprzyk, I., Myszkowska, D., & Stach, A. (1999). Occurrence of airborne *Cladosporium* and *Alternaria* spores in Southern and Central Poland in 1995–1996. *Aerobiologia*, 15, 39–47.
- Stępańska, D., & Wołek, J. (2005). Variation in fungal spore concentration of selected taxa associated to weather condition in Cracow, Poland, in 1997. *Aerobiologia*, 21, 43–52.
- Tarlo, S. M., Bell, B., Srinivasan, J., Dolovich, J., & Hargreave, F. E. (1979). Human sensitization to *Ganoderma* antigen. *The Journal of Allergy and Clinical Immunology*, 64, 43–49.