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Spatial differentiation of airborne arboreal pollen in Lublin (Poland)

Krystyna Piotrowska-Weryszko[1]*, Elżbieta Weryszko-Chmielewska[2]

[1] Department of General Ecology, University of Life Sciences in Lublin, Leszczyńskiego 58, 20-950 Lublin, Poland

[2] Department of Botany, University of Life Sciences in Lublin, Akademicka 15, 20-950 Lublin, Poland

Abstract

The study compared the occurrence of airborne pollen of 7 arboreal taxa (*Corylus*, *Alnus*, Cupressaceae/Taxaceae, *Populus*, *Fraxinus*, *Betula* and *Carpinus*) during the period 2007–2009 from two sites in Lublin city, SE Poland. The sites differed in the character of building development and surrounding vegetation. Pollen monitoring was conducted by the volumetric method using two Hirst-type samplers. Daily and intradiurnal pollen counts were determined. For all the taxa, Spearman's test revealed statistically significant positive correlations between daily pollen fluctuations at two sites. Nevertheless, the Mann–Whitney *U*-test showed differences for Cupressaceae/Taxaceae, *Fraxinus*, *Populus* and *Corylus* between sites. The intradiurnal pattern of pollen concentration was characterized by high variation. Cupressaceae/Taxaceae and *Populus*, clearly differed in hourly pollen concentrations at both sites. Moreover, in the case of *Betula* and *Alnus* it was shown that a part of pollen recorded in Lublin can originate from long-distance transport. High pollen concentrations can be expected at different hours of the day. The lowest average pollen concentrations at both sites were found during morning hours at 5 and 6 a.m. Based on the obtained results, it can be concluded that data from a single pollen-sampling device are not representative of some taxa in the particular districts of the city. Average data obtained from at least two pollen samplers could provide optimum results.

Keywords: aerobiology; pollen counts; daily variations; intradiurnal patterns; two sites

Introduction

Trees positively affect the quality of life in urban areas. They are important producers of organic matter and oxygen. Tree crowns muffle noise, restrain the wind, and capture air pollutants [1]. Woody plants have a beneficial effect on human mental and physical health [2]. Nevertheless, some of them can pose a serious threat to public health due to the allergenic properties of their pollen grains [3,4]. No other plant part contains such strong allergens as pollen grains. Pollen allergens cause allergy symptoms in an ever increasing number of people [5]. Therefore, systematic estimation of airborne pollen concentrations is of essential importance. Pollen monitoring results are a reflection of the type of vegetation occurring near pollen sampling sites [6,7]. Meteorological conditions, topography, and the type of land development also affect variations in airborne pollen concentrations [8–10].

In an urban environment, trees are an important source of pollen emissions, since they release huge amounts of pollen grains into the atmosphere. In total, one *Alnus glutinosa* Gaertn. inflorescence can produce 19 548 000 pollen grains [11], while *Betula pendula* Roth 10 044 000 grains [12]. Urban areas with different land use and woody vegetation vary in terms of the quantity and quality of airborn pollen. There are differences observed of the internal and external pollen grains structure (e.g., deformations, shrinkage, cracking). Phenological stages can occur at different times in individuals belonging to the same species but found in different sites. Pollen release and dispersal depend on microclimatic conditions prevailing in a given area. According to Emberlin and Norris-Hill [13], pollen deposition patterns are different in the centre of cities than in their outskirts. The urban microclimate and increasing turbulence caused by urban development have a significant effect on pollen dispersal. High buildings, often found in the city centre, limit the dispersal of aeroplankton and for this reason high pollen concentrations can persist there longer than in open areas. Mean air temperature increases by 0.5–1°C in densely built-up areas of the city [14]. The urban heat island, which is created by, among others, the warming effect of urban development and numerous additional sources of heat emissions in the city, also affects significantly the dispersal of pollen grains. Higher temperatures in city centres can, among others, prolong the plant growth [15–17].

In individual plant species, diurnal fluctuations of pollen concentrations depend on the genetically determined pattern of pollen release from anthers, but this pattern is modified by

* Corresponding author. Email: krystyna.piotrowska@up.lublin.pl
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weather conditions [18]. Pollen from long-distance transport can have an effect on increasing daily pollen concentrations [8]. The diurnal distribution of pollen concentrations is clearly modified by rainfall. Rain, in particular persistent rain, effectively clears the air of particles suspended in it, including pollen grains, but at the beginning of a rainfall event there is a substantial increase in pollen concentration. The number of airborne pollen grains significantly decreases only after several hours when they are washed out of the air. The main factors that modify the diurnal patterns the most are rainfall and wind speed. Therefore, data from rainless days are used to analyze the intradiurnal patterns of pollen concentrations [8,19].

The present study defined the occurrence of airborne arboreal pollen, which may cause pollinosis. In Poland pollen grains of arboreal plants are present in the atmosphere during the spring period. Among them, *Betula* pollen, which contains strong allergens and occurs at very high concentrations, is of the greatest importance from the point of view of allergology [20,21]. The aim of this study was to verify whether differences between pollen monitoring data from two sampling sites with different types of urban development and local vegetation, located in different district of the city, are significant. Seasonal, daily and intradiurnal pollen concentrations of selected arboreal taxa, frequently found in the area of Lublin and in other regions of Poland, were compared.

Material and methods

The study of airborne pollen concentrations of 7 taxa (*Corylus*, *Alnus*, Cupressaceae/Taxaceae, *Populus*, *Fraxinus*, *Betula* and *Carpinus*) was conducted in two districts of Lublin, SE Poland, during the period 2007–2009. The distance between sampling sites was slightly more than 2 km. Pollen monitoring was carried out by the volumetric method according to the recommendations of the International Association for Aerobiology [22]. Two Hirst-type samplers were used (Lanzoni VPPS 2000).

Site 1 was located in the city centre in Akademicka Street (51°14′37″ N, 22°32′25″ E; 197 m above sea level). Its immediate vicinity is a quite densely built-up area with several storey buildings. The plants from the following genera: *Betula*, *Quercus*, *Salix*, *Aesculus*, *Populus*, and *Larix* grow nearby the sampling site. A bit further away, there is a cemetery with a predominance of Cupressaceae and Taxaceae as well as the University Park and the Saxon Garden (Ogród Saski), in which *Populus* dominates. Moreover, trees and shrubs of the following genera can be found there: *Quercus*, *Acer*, *Fagus*, *Carpinus*, *Picea*, Cupressaceae, Taxaceae and *Pinus*. Tree plantings along nearby streets include mainly *Populus*, *Tilia*, and *Fraxinus*.

Site 2 was located in a western district of Lublin, outside the city centre in Skromna Street (51°15′11″ N, 22°30′17″ E; 189 m above sea level). Low buildings are predominant in this neighborhood: single-family houses with gardens as well as service and retail facilities. Single individuals of *Carpinus*, *Betula*, *Thuja*, and *Populus* (female plants) are found in the immediate vicinity. Trees growing in home gardens, allotment gardens, the Botanical Garden, and the Open-Air Village Museum, located in the Czechówka River valley, are also a potential source of pollen (*Corylus*, *Alnus*, *Tilia*, *Populus*, and *Betula* predominate).

The pollen traps at site 1 and site 2 were installed at a height of 18 m and 15 m above ground level, respectively. Silicone fluid was used as the adhesive substance and glycerine jelly stained as the mounting number of pollen grains per cubic meter of air (P/m^3). The 95% method was used to determine the start and end dates of the pollen season [23]. The start of the season was defined as the date when 2.5% of the seasonal cumulative pollen count was trapped and the end of the season when the cumulative pollen count reached 97.5%. Rainless days on which the concentration was relatively high and exceeded 20 P/m^3 were chosen to analyze the hourly pattern of occurrence of airborne pollen [8]. Intradiurnal variation of pollen concentration are expressed as percentage of the total daily count.

The order of the studied taxa in the tables and figures follows the sequence of plant flowering phenology. The following pollen season parameters were analyzed: start, end, peak value (daily maximum pollen concentration), peak date (date of daily maximum pollen concentration), mean daily concentrations and SPI (seasonal pollen index – the sum of pollen grains during the given season).

The distribution of data was tested using the Shapiro–Wilk test. Because the data did not fit a normal distribution curve, Spearman's correlation test was used for testing the degree of similarity of fluctuations of pollen counts [24]. The Mann–Whitney *U*-test was used to compare average daily pollen concentrations at both sites [25]. Cluster analysis (the *k*-means method) was used for the classification of the diurnal pattern of variation in pollen concentration. This method is based on automatic grouping of similar objects. All statistical analyses were performed using STATISTICA ver. 8.

Results

The comparison of the average daily concentrations of airborne pollen of the studied taxa at both sites in Lublin for the three-year study period is shown in Fig. 1. The curves representing the occurrence of airborne pollen grains of *Corylus*, *Alnus*, *Betula* and *Carpinus* were very similar at both sites. The pollen concentrations had in many days similar values and showed a decreasing or increasing trend over the same period of time (Fig. 1). However, distinct differences in the values of daily pollen concentrations were recorded for Cupressaceae/Taxaceae, *Populus*, and *Fraxinus*. In spite of similar increasing or decreasing trends, much higher pollen concentrations of the above-mentioned last three taxa were observed at site 1, in particular in the second half of the pollen season (Fig. 1).

During pollen monitoring carried out at both sites, it was found that pollen season started earlier at site 2 than at site 1 for two taxa – Cupressaceae/Taxaceae by 1–5 days, and *Fraxinus* by 5–10 days (Tab. 1, Fig. 1). Generally, for these taxa slightly larger differences were observed for the end dates of the season than for its onset. The start and end dates of the *Alnus* and *Carpinus* pollen seasons were characterized by the lowest variation between both sites.

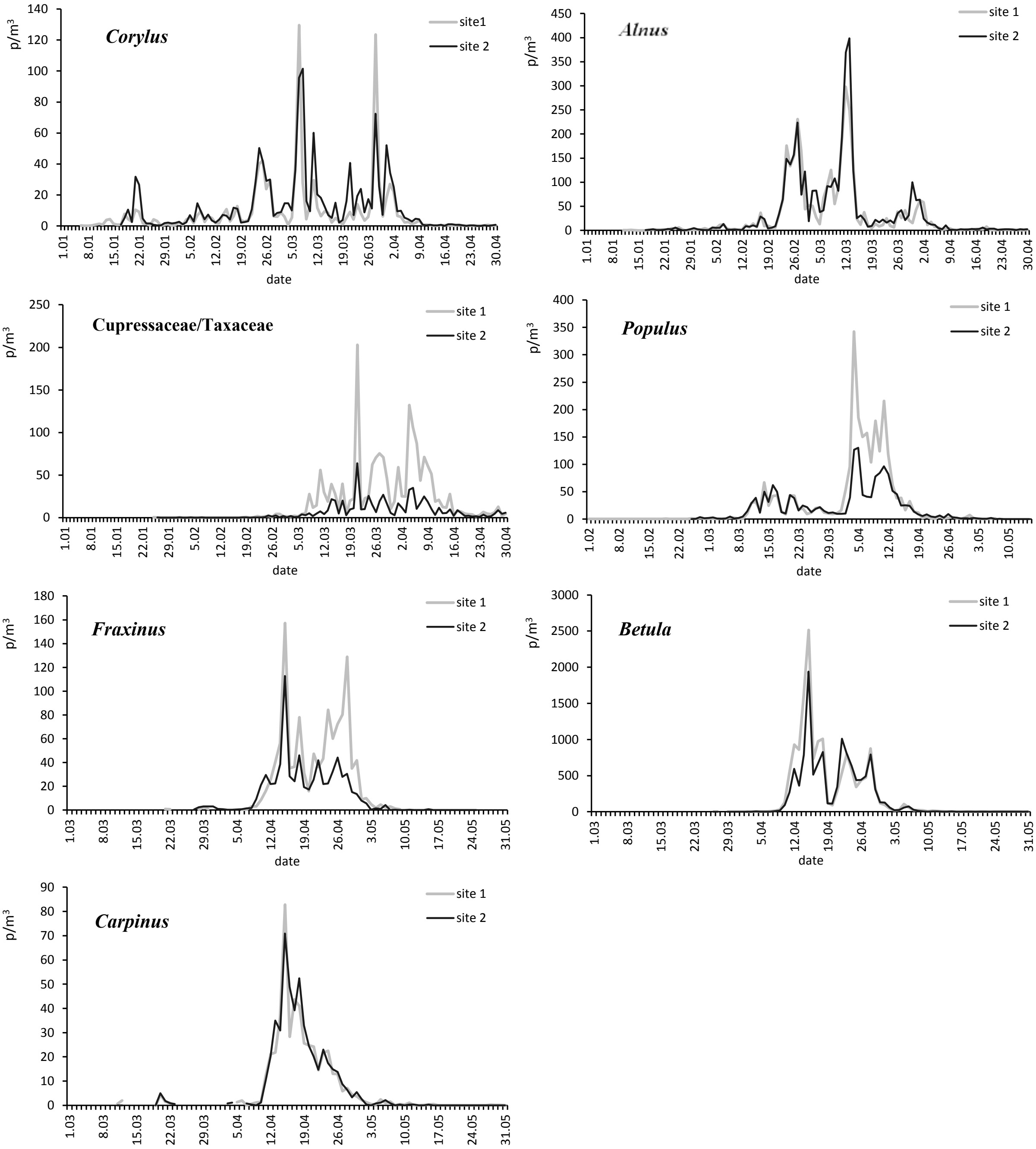

Fig. 1 Daily pollen concentrations of seven arboreal taxa at two sites in Lublin, SE Poland (average from 2007–2009).

The values of maximum pollen concentration varied the most for Cupressaceae/Taxaceae, *Populus*, and *Fraxinus*. Over the 3-year study period, higher peak values for these taxa were recorded at site 1 than at site 2. The maximum *Betula* pollen concentrations were higher in two years of the study (2007 and 2008) at site 1, whereas in 2009 the peak value was slightly higher at site 2 (Tab. 1). The lowest differences in the peak values and SPI between sites were observed for *Carpinus*. The maximum pollen concentrations of most of the taxa occurred at the same or similar time (Tab. 1). The average for the three-year study period showed higher values of SPI at site 1 for Cupressaceae/Taxaceae, *Fraxinus*, *Populus*, and *Betula*, while at site 2 for *Corylus*. The seasonal pollen index for *Alnus* was higher at site 2 in two years of the study (2007 and 2009), whereas in 2008 the value of SPI at both sites was similar. Also, the SPI for *Populus* was lower at site 2 in 2009 (Fig. 2).

For all the taxa, Spearman's test revealed statistically significant positive correlations between daily pollen fluctuations at two sites. (Tab. 2). The strongest correlation was found for *Betula*, while the weakest one for Cupressaceae/Taxaceae. Based on the Mann–Whitney *U*-test, it was found that the daily pollen concentrations of *Alnus*, *Betula* and *Carpinus* did not differ between sites over three years of the study (Tab. 3). At site 1, significantly higher pollen concentrations of Cupressaceae/Taxaceae and *Fraxinus* were

Tab. 1 Characteristics of the pollen season of the selected arboreal taxa at two sites in Lublin city, SE Poland.

		Dates of pollen season (start and end)		Maximum daily pollen concentration (P/m³)		Date of maximum daily pollen concentration	
Taxon	Year	site 1	site 2	site 1	site 2	site 1	site 2
Corylus	2007	14.01–20.03	17.01–22.03	388	304	7.03	8.03
	2008	4.02– 30.03	4.02–14.03	104	127	24.02	24.02
	2009	8.02– 9.04	8.02–9.04	368	217	28.03	28.03
Alnus	2007	1.03–27.03	28.02–27.03	829	1117	12.03	13.03
	2008	6.02–18.03	7.02–18.03	691	670	27.02	27.02
	2009	10.03–30.04	10.03–27.04	176	291	1.04	31.03
Cupressaceae/ Taxaceae	2007	12.03–11.05	8.03–20.05	605	191	21.03	21.03
	2008	27.02–12.05	25.02–8.05	142	23	11.03	10.04
	2009	29.03–10.05	28.03–10.05	326	105	4.04	5.04
Populus	2007	13.03–16.04	11.03–21.04	720	185	4.04	16.03
	2008	7.03–17.04	2.03–12.04	273	73	11.04	10.04
	2009	4.04–19.04	3.04–23.04	405	382	9.04	5.04
Fraxinus	2007	13.04–4.05	8.04–5.05	193	92	28.04	26.04
	2008	10.04–30.04	31.03–26.04	454	312	15.04	15.04
	2009	16.04–2.05	9.04–2.05	135	37	24.04	30.04
Betula	2007	12.04–4.05	12.04–5.05	2762	1916	15.04	18.04
	2008	11.04–5.05	11.04–29.04	4356	3797	15.04	15.04
	2009	10.04–7.05	13.04–3.05	521	585	17.04	17.04
Carpinus	2007	11.04–28.04	11.04–27.04	133	122	15.04	16.04
	2008	10.04–5.05	10.04–30.04	115	94	15.04	15.04
	2009	17.04–2.05	15.04–30.04	78	111	18.04	18.04

recorded in two years, while for *Populus* in one year of the study. At site 2, significantly higher pollen concentrations of *Corylus* were observed in one year of the study.

The analysis of the diurnal pollen concentration revealed different pollen patterns. In the case of *Corylus* and *Carpinus*, high counts were observed between 11 and 16 hours. At both sampling sites, higher concentrations of *Alnus* pollen were recorded in the afternoon and in the evening hours, and of *Fraxinus* in the afternoon hours (14–17). The number of Cupressaceae/Taxaceae pollen grains increased earlier at site 2 than at site 1, but it remained at a rather equal level, whereas at site 1 the highest concentrations were recorded between 14 and 15 hours. The intradiurnal concentrations of *Populus* pollen were characterized by an irregular pattern, while elevated concentrations were observed in different hours of a day. No one clear peak throughout 24 hours was observed for *Betula* (Fig. 3).

Based on *k*-means clustering analysis, we distinguished three types of curves showing the intradiurnal occurrence of pollen. The first type was characterized by several not very high peaks occurring at different times during the day, with small differences between the hours of maximum and minimum concentration, whereas the second and third types had one clear peak. The largest number of curves of diurnal variation in pollen concentration was classified as the first type and included the following data: from both sites for *Alnus*, *Fraxinus* and *Betula*, from site 1 for *Populus*, while from site 2 for Cupressaceae/Taxaceae. In the second type, the maximum hourly concentrations occurred between 11 and 16 hours. The data for *Corylus* and *Carpinus* from both sites as well as the data for *Populus* from site 2 were included in this type. Only the diurnal counts of Cupressaceae/Taxaceae pollen from site 1 were included in type three which was characterized by one clear peak in the early afternoon. The analysis of the data shows that the largest differences between sites were found in the hourly distribution of pollen for Cupressaceae/Taxaceae and *Populus*. Based on the average pollen concentrations of all taxa, it was found that the lowest concentrations were recorded at 5 and 6 a.m.

Discussion

Despite that the sampling sites clearly differed in the type of vegetation as well as in the type of buildings and land use, the shape of the curves representing the occurrence

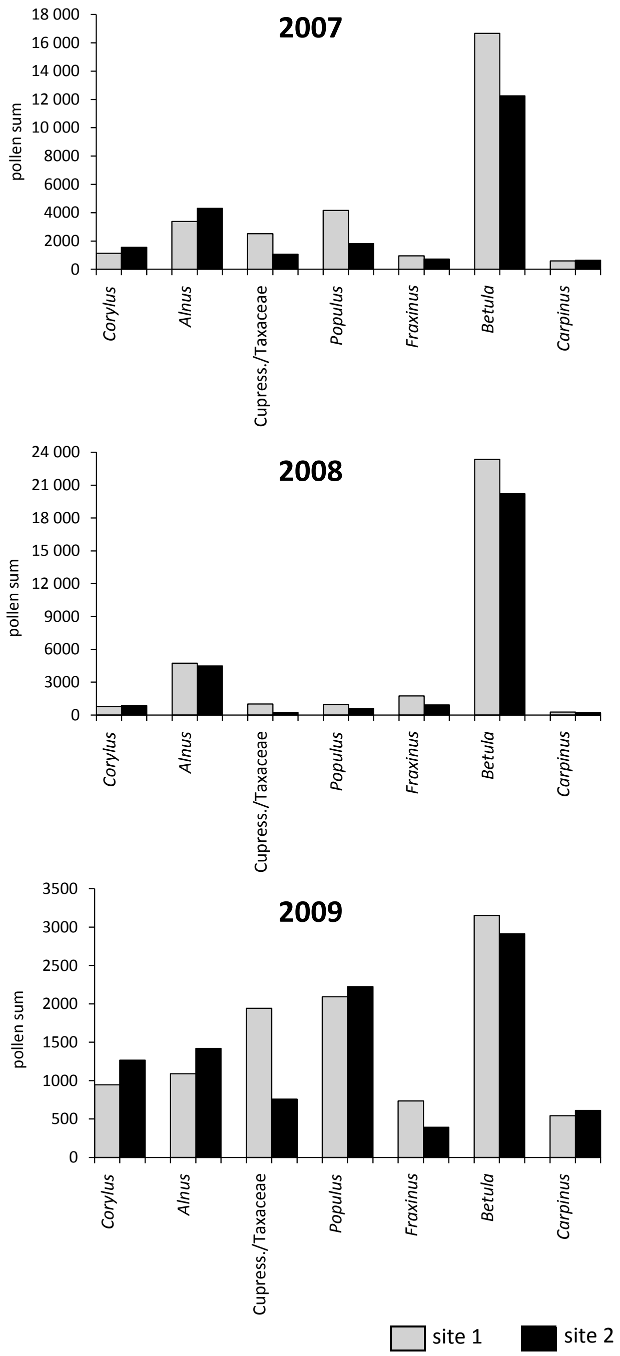

Fig. 2 Comparison seasonal pollen index of seven taxa at two sites in Lublin, SE Poland (2007–2009).

Tab. 2 Significant Spearman correlation coefficients between daily pollen concentrations at two sites in Lublin, SE Poland.

Taxon	2007	2008	2009
Corylus	0.812	0.773	0.729
Alnus	0.777	0.845	0.870
Cupress./Taxaceae	0.759	0.574	0.755
Populus	0.694	0.744	0.847
Fraxinus	0.763	0.656	0.857
Betula	0.934	0.907	0.930
Carpinus	0.696	0.742	0.866

$P < 0.01$.

Tab. 3 Comparision of daily pollen concentrations between two sites in Lublin, SE Poland. Results of Mann–Whitney *U*-test. The values of *z* statistic are given.

Taxon	2007	2008	2009
Corylus	−1.082 ns	−2.575**	−1.910 ns
Alnus	−0.564 ns	0.219 ns	−1.519 ns
Cupress./Taxaceae	2.237*	4.569**	1.774 ns
Populus	3.028**	0.219 ns	0.828 ns
Fraxinus	1.173 ns	3.440**	3.162**
Betula	0.128 ns	−0.983 ns	−1.566 ns
Carpinus	−0.610 ns	−0.514 ns	−0.509 ns

* $P < 0.05$; ** $P < 0.01$; ns – not significant.

of airborne pollen grains of most of the studied taxa which were recorded at both sites in Lublin was very similar. This results from a relatively close distance between these sampling sites at which similar weather conditions prevail. According to many authors, differences in the main pollen seasons are not significant in areas characterized by similar climatic conditions [26–28]. The results of measurements of daily pollen concentrations in Lublin at both sites were significantly correlated. Other authors have also found a high positive correlation for daily pollen concentrations at sites located in different districts of a city [7,27,29].

The research carried out in Lublin found that the start and end dates of pollen seasons of most of the plant taxa studied were similar at both sites. An exception was the *Fraxinus* pollen season which started earlier by 5–10 days at site 2, which may result from the location of the ash stands at very sunny sites with lower diurnal air temperature amplitudes, characteristic of areas distant from large urban centres [30].

The variations mostly related to the peak value and SPI. The higher pollen concentrations of Cupressaceae/Taxaceae, *Populus* and *Fraxinus* at site 1 result from the close vicinity of plants belonging to the above-mentioned taxa. In turn, the higher *Corylus* pollen counts at site 2 can be attributable to *Corylus* stands located near this sampling site. However, numerous authors stress that even in closely located areas, e.g., in different districts of the same city, spatial differences in pollen concentration are recorded [7,13,31,32]. These differences are irrelevant from the point of view of allergology, since after the threshold value for the allergic reaction has been reached even large quantitative differences cause minor consequences [7,31]. It can be therefore assumed that

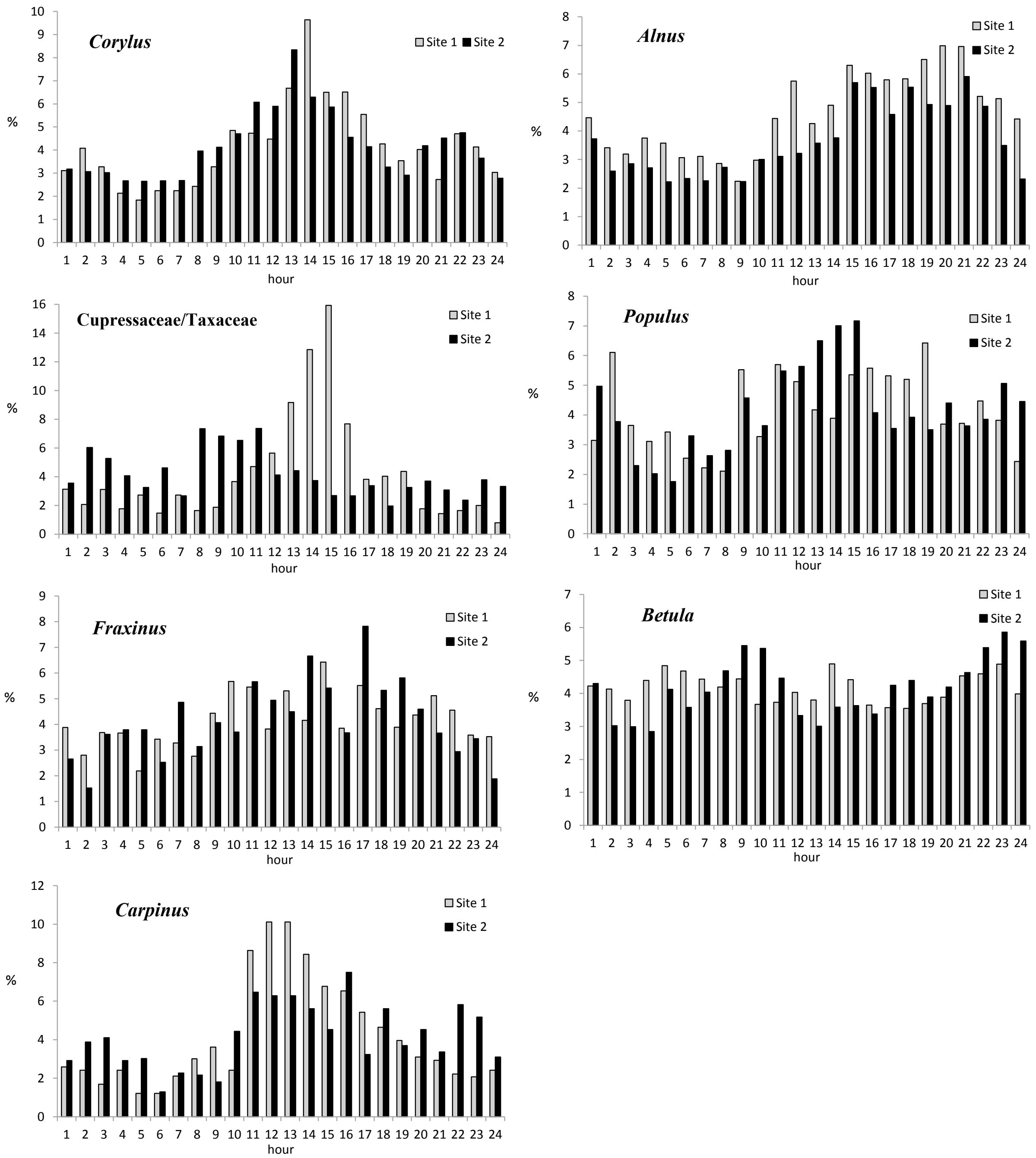

Fig. 3 Intradiurnal variation of pollen concentrations of seven arboreal taxa at two sites in Lublin, SE Poland.

data from one locality in a city are sufficient for providing pollen forecasts for allergy sufferers. Also according to Velasco-Jiménez et al. [7], data from a single volumetric sampler located in a city with a uniform topography and similar vegetation conditions are sufficient for monitoring major types of airborne pollen. According to Kasprzyk [15], the pollen spectrum and the seasonal cycle of occurrence of airborne pollen were similar in two sites differing in land development (an urban area and a rural area) and located about 10 km away from each other. Based on her research, the above-mentioned author found that pollen concentrations at one site could be predicted on the basis of data taken from another one.

The results for the diurnal variation of pollen concentration in Lublin for some pollen types were similar to the data found in the literature. For example, at both sites in Lublin hourly *Alnus* pollen concentrations in the first half of the day were much lower than during the second half. A similar pattern of the diurnal fluctuation of *Alnus* pollen concentrations has been found in Poznań, E Poland and Gdańsk, N Poland [19,33]. The curve of the diurnal variation of Cupressaceae/Taxaceae pollen in Lublin (site 1) had one clear maximum at 2–3 p.m. The diurnal maximum for Cupressaceae/Taxaceae was observed exactly at the same time in Spain [34]. At both sites in Lublin, the birch pollen concentration showed relatively small fluctuations at particular hours of the day.

Similar observations have been made by other authors in different cities of Poland [9,19].

In the study conducted in Lublin, the lowest pollen concentration throughout 24 hours for most of the taxa studied was found at both sites during morning hours at 5 and 6 a.m. In Denmark, the lowest pollen concentration of birch pollen was found between 5 and 7 a.m. [35]. According to Cariñanos et al. [36], the lowest values of pollen concentration occurring between 5 and 7 a.m. are a consequence of the negative effect of environmental humidity.

The similarities in the diurnal variation in pollen concentrations of some taxa in Lublin and at other sampling sites, sometimes located in other countries, may indicate the genetically determined pattern of pollen release in plants. The diurnal patterns show very similar general features, regardless of the study region [19]. On the other hand, there are marked differences in the intradiurnal distribution of pollen concentration at sites with a different topography, even located at a short distance [10]. The character of building development and various urban planning solutions are also of major importance [9]. The differences in the diurnal patterns for Cupressaceae/Taxaceae and *Populus* at the two sites in Lublin located at a close distance from each other are evidence of the great effect of local factors. The differences in hourly pollen concentrations at both sites in Lublin probably result from different land development that creates slightly different conditions for pollen release and dispersal. The spatial distribution of buildings in the district more distant from the city centre (site 2) may modify the microclimatic conditions prevailing there by decreasing the diurnal temperature amplitudes and increasing relative humidity relative to the districts located closer to the city centre, which was found in an earlier study [30].

As far as the diurnal pattern of high concentrations of *Betula* and *Alnus* pollen is concerned, it should be stressed that they also occurred during evening and night hours. Because pollen grains of *Betula* (19–22 μ) and *Alnus* (21–24 μ) are small and light, it can be presumed that they were carried by air currents at night from distant areas as a result of long-distance transport of aeroplankton (over 10 km). Many studies have shown that small pollen grains (18–19 μ) of *Ambrosia* are carried for large distances due to the movement of air masses [37,38].

In the study conducted in Lublin, three types of the hourly distribution of airborne pollen concentrations were distinguished based on *k*-means clustering. This method had been earlier used to classify pollen seasons based on daily pollen concentrations [39,40]. The type in which there was no well-expressed trend was represented by the largest number. High pollen concentrations occurred both during the day and at night. Galan et al. [41] distinguished two types of the diurnal pattern of airborne pollen. The first type was characterized by small differences between maximum and minimum hourly pollen concentrations, while in the case of the second type these differences were large. The maximum pollen concentrations were also recorded at different hours in particular years. This primarily related to the taxa whose pollen was present in the air in small amounts [41].

Conclusions

Seasonal occurrence of pollen of the taxa studied at both sampling sites was to a certain extent similar with highly convergent trends of decrease and increase in daily pollen concentrations. Significant correlations between average daily concentrations at both sites for all taxa studied was evidenced. The differences between sites are mostly related to maximum concentrations and the seasonal pollen index. The disparity was mainly due to the species composition of tree plants in the vicinity of the sampling sites.

The analysis of hourly pollen concentrations of the arboreal plants studied revealed three types of curves representing the intradiurnal pattern of occurrence of airborne pollen. The type that was characterized by the absence of one peak and frequently by a quite equal pollen concentration throughout 24 hours was represented by the greatest number. The second and third types of intradiurnal variation of pollen concentration had a clear peak, in the afternoon hours. Similar results for hourly pollen concentrations at both sites were obtained for *Corylus*, *Alnus*, *Fraxinus*, *Betula*, and *Carpinus*. On the other hand, the other types of pollen, Cupressaceae/Taxaceae and *Populus*, clearly differed in hourly pollen concentrations at both sites. Moreover, in the case of *Betula* and *Alnus* it was shown that a part of pollen recorded in Lublin can originate from long-distance transport. High pollen concentrations can be expected at different hours of the day. The lowest average pollen concentrations at both sites were found during morning hours at 5 and 6 a.m.

Data from a single pollen-sampling device are not representative for some taxa in the particular districts of the city. Average data obtained from at least two pollen samplers could provide optimum results.

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Authors' contributions

The following declarations about authors' contributions to the research have been made: microscope analysis: KPW, EWC; statistical analysis: KPW; writing the manuscript: KPW, EWC.

Competing interests

EWC is a honorary editor of the *Acta Agrobotanica*; KPW: no competing interests.

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Przestrzenne zróżnicowanie stężenia pyłku drzew w powietrzu Lublina (Polska)

Streszczenie

W pracy porównywano dane z monitoringu pyłkowego prowadzonego w Lublinie na dwóch stanowiskach, które różniły się charakterem zabudowy i lokalną roślinnością. Analizowano występowanie w powietrzu pyłku 7 taksonów roślin drzewiastych (*Corylus*, *Alnus*, Cupressaceae/Taxaceae, *Populus*, *Fraxinus*, *Betula* i *Carpinus*) w latach 2007–2009. Badania prowadzono metodą wolumetryczną z wykorzystaniem aparatów typu Hirsta. Określano dobowe i godzinowe stężenia pyłku w powietrzu. Analiza testu Spearmana dla wszystkich badanych taksonów wykazała istotną pozytywną korelację między dobowymi koncentracjami pyłku rejestrowanymi na dwóch stanowiskach. Na podstawie testu *U* Mann–Whitney'a stwierdzono istotne różnice między stanowiskami dla stężeń pyłku Cupressaceae/Taxaceae, *Fraxinus*, *Populus* i *Corylus*. Godzinowa rytmika stężenia pyłku charakteryzowała się dużą zmiennością. Cupressaceae/Taxaceae i *Populus*, wyraźnie różniły się pod względem godzinowych koncentracji pyłku na obu stanowiskach. Ponadto w przypadku *Betula* i *Alnus* wykazano, że część rejestrowanego w Lublinie pyłku może pochodzić z dalekiego transportu. Wysokich stężeń pyłku można spodziewać się w różnych godzinach doby. Najniższe średnie stężenia pyłku na obu stanowiskach stwierdzono w godzinach porannych o 5.00 i 6.00. Na podstawie uzyskanych wyników można przyjąć, że dane pochodzące z jednego punktu pomiarowego nie są reprezentatywne dla niektórych taksonów w poszczególnych częściach miasta. Optimum wyników mogłyby zapewnić średnie dane pochodzące z co najmniej dwóch aparatów pomiarowych umieszczonych w różnych dzielnicach.

