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The airborne pollen calendar for Lublin, central-eastern Poland

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Abstract

An aerobiological study was conducted to investigate the quantity and quality of pollen in the atmosphere of Lublin in central-eastern Poland. Pollen monitoring was carried out in the period 2001–2012 using a Hirst-type volumetric spore trap. The atmospheric pollen season in Lublin lasted, on average, from the end of January to the beginning of October. The mean air temperature during the study period was found to be higher by 1.1 °C than the mean temperature in the period 1951–2000. 56 types of pollen of plants belonging to 41 families were identified. 28 types represented woody plants and 28 represented herbaceous plants. The study distinguished 5 plant taxa the pollen of which was present most abundantly in the air of Lublin, which altogether accounted for 73.4%: ***Betula**, Urtica, Pinus*, **Poaceae**, and ***Alnus***. The mean annual pollen index was 68 706; the largest amount of pollen was recorded in April and accounted for 33.3% of the annual pollen index. The pollen calendar included 28 allergenic plant taxa. The pollen of woody plants had the highest percentage in the pollen spectrum, on average 58.4%. The parameters of the pollen calendar for Lublin were compared with the calendar for central-eastern Europe with regard to the start of the pollen season of particular taxa. The pollen calendar for Lublin was demonstrated to show greater similarity to the calendar for Münster (Germany) than to the calendar for Bratislava (Slovakia).

Key words

aerobiology, pollen spectrum, allergenic pollen, season diversity, Poland

INTRODUCTION

A significant increase in the incidence of pollen allergy has been observed over the last 20–30 years. Global warming induced changes in plant development have been also recorded. Higher temperatures contribute to the acceleration of plant phenological stages and increase the production of pollen and its allergenicity. Additionally, changes in the geographical distribution of plants can be observed (e.g. new localities of *Ambrosia artemisiifolia*) [1]. By affecting the development of plants, global warming becomes a potential threat to human health. Pollen calendars are an important tool that can be used in the diagnostics, prevention and treatment control of pollen allergy, since they allow possible dates of occurrence of allergenic pollen grains to be determined for a given region. The timing and severity of pollen seasons differ significantly in particular regions of Poland and these differences are associated with local climatic conditions and richness of local flora. Therefore, regional pollen calendars which inform about pollen seasons in a particular area, are of great importance for allergists and their patients. The increased incidence of pollinosis results in increasingly greater interest in local results of aerobiological surveys [2, 3, 4, 5, 6, 7]. Pollen calendars present seasonal changes in airborne pollen counts for different types of pollen in the order according to the phenology of pollen release. The presented diagrams also illustrate the abundance of pollen. The results accompanying pollen calendars also present comparisons of annual pollen sums for different taxa between years. This information is important for the population of a given region since it provides data on the phenology of pollen release and the level that airborne pollen concentrations reach which, to some extent, can prevent the incidence of allergic diseases.

In Lublin, pollen monitoring has been carried out continuously since 1995 [8, 9, 10]. The gravimetric method was initially used for the monitoring, but from 2001 the volumetric method, recommended by the International Association for Aerobiology, was introduced [11, 12, 13, 14]. Long-term aerobiological surveys conducted in accordance with the standard methods allow phenological pollen calendars to be created for a particular region. The determination of pollen content in the air is important from the point of view of evaluation of biological cleanliness of air. Detailed analysis of the data enables determination of the level of exposure of Lublin's residents to contact with allergenic pollen.

The aim of the presented study was to characterize the pattern of occurrence of airborne anemophilous pollen in Lublin, to determine the pollen spectrum and main types of pollen, as well as the preparation a pollen calendar based on a 12-year aeropalynological survey. The obtained results will be compared with the data for central and eastern Europe presented in other publications.

MATERIAL AND METHODS

The climate of the study area is temperate and is affected by continental air masses. It is characterized by high weather variability and significant variations in seasonal weather patterns in particular years [15]. The growing season in Lublin lasts 215 days. The long-term meteorological data for the period 1951–2007 show that the mean annual air temperature in the study area is 8.2°C. The coldest month is January, with an average temperature of -2.8°C, while

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the warmest month is July, with an average temperature of 18.9°C. The mean annual total rainfall in Lublin for the same period is 546 mm. The lowest monthly total rainfall is observed in January and February (28 mm in each), while the highest rainfall in July (80 mm) [15, 16].

The flora of Lublin is characterized by a diversity of tree and shrub species. Single individuals from the following genera: *Betula*, *Quercus, Salix, Aesculus, Populus, Larix, Tilia, Fraxinus, Taxus,* and *Juniperus,* are found close to the sampling site. There is a park nearby in which the following genera grow: *Quercus, Acer, Fagus, Carpinus, Picea, Pinus* as well as *Populus* which is the dominant genus.

Airborne pollen counts were recorded by the standard volumetric method using a Lanzoni VPPS 2000 trap manufactured based on a Hirst-type sampler [17]. The pollen trap was placed on the flat roof of the building of the University of Life Sciences, 18 m above ground level. The pollen sampling site was located near the city centre (51°14'37" N and 22°32'25" E). The research methodology followed the recommendations of the International Association for Aerobiology [18]. Daily average pollen counts were expressed as the number pollen of grains per cubic meter of air (P/m^3).

The meteorological data on temperature and rainfall for the period 2001–2010 were obtained from the Meteorological Observatory located at a distance of about 1.5 km from the pollen sampling site, of the Meteorology and Climatology Department of the Maria Curie-Sklodowska University in Lublin, while in the period 2011–2012 such data were obtained from automatic weather station Vantage Pro 2 located close to the pollen trap. The statistical dependence between pollen counts and meteorological data was calculated by Spearman's rank correlation coefficient. A standard deviation was calculated for pollen concentration in particular months of the year. The pollen calendar was prepared using Polpal Aero software. It included 28 plant taxa whose pollen occurred regularly in the air of Lublin and reached high or medium concentrations.

RESULTS

During the period 2001–2012, the mean annual temperature in Lublin was 9.2°C. An average temperature of -2.0°C was recorded in the coldest month (January) and 20.6°C in the warmest one (July) (Fig. 1). June and August, with a mean temperature of 18.0°C and 19.5°C, respectively, were also characterized by relatively high temperature. Over the 12-year study period, the mean total rainfall was 554 mm. The highest rainfall was observed in July (on average 82.6 mm), while the lowest amount of precipitation was recorded in November, December, January, and February (26.9 mm – 29.6 mm). Analysis of the mean daily air temperature and pollen concentration showed that there was a positive statistically significant correlation (r_s=0.61; p<0.01) between these variables. This dependence was particularly high in the first months of the year (Fig. 2). Spearman's correlation coefficient between temperature and pollen concentration during the pre-peak period was 0.86. The correlation between total rainfall and daily pollen concentration for all plant taxa was also positive, but much lower than the one for temperature (r_s=0.24; p<0.05).

During the period 2001–2012, 56 types of pollen of plants from 41 families were identified during the aerobiological

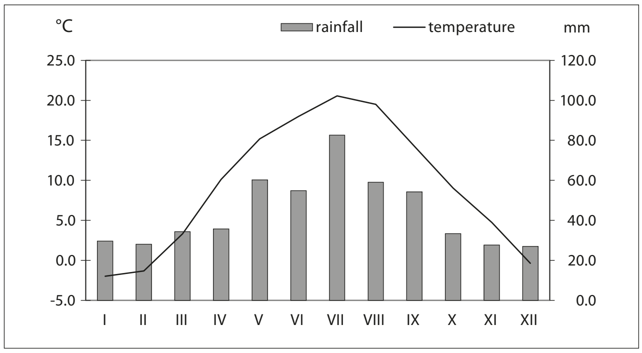

Figure 1. Mean temperature and rainfall in Lublin (average 2001–2012)

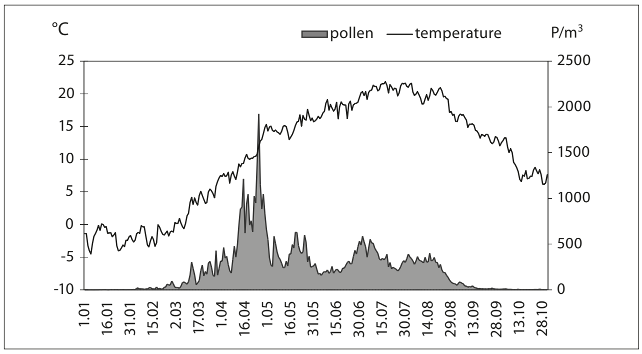

Figure 2. Pollen concentrations in the atmosphere of Lublin and the mean temperature pattern during the pollen season, means for 2001–2012

surveys carried out in Lublin. Among them, the pollen of 28 taxa belonged to woody plants, while 28 taxa represented herbaceous plants. The taxa with the highest allergenic potential include: *Corylus, Alnus, Betula*, Poaceae, *Artemisia* and *Ambrosia*.

In the pollen season patterns, many peaks can be noticed which resulted from the successive flowering of different anemophilous taxa (Fig. 2). The first small peaks that can be observed in the middle and the third decade of March were found during the time of pollen shed of *Alnus, Corylus*, and *Populus*. The two highest peaks recorded in the second half of April reflect primarily the concentrations of *Betula, Fraxinus*, and *Acer* pollen. A small peak in the first decade of May occured during maximum pollen shed of *Quercus*, while the peaks in the second half of May illustrate, in the first place, the intense release of Pinaceae pollen. The highest pollen concentrations recorded in the first half of July were associated with large amounts of Poaceae and *Urtica* pollen, whereas those found subsequently, during 4 weeks of August, were mainly attributable to large amounts of *Urtica, Artemisia* and *Ambrosia* pollen. The temperature curve shows that the highest pollen concentration peak was accompanied by a temperature of 12°C, while the highest temperature occured in the second half of July (Fig. 2).

5 plant taxa had the highest percentage in the pollen spectrum in Lublin: *Betula* (23.6%), *Urtica* (22.8%), Pinaceae (10.6%), Poaceae (9.3%), and *Alnus* (7.3%) (Fig. 3). The above-mentioned taxa, on average, accounted for 73.4% of the annual total. The following taxa had lower percentages in the pollen spectrum determined for the atmospheric air of Lublin: *Populus* (3.7%), *Quercus* (3.1%), *Artemisia* (2.6%), *Fraxinus* (2.5%), Cupressaceae/Taxaceae (2.4%), *Rumex* (2.1%), Corylus (1.5%), *Salix* (1.3%), *Acer* (1.2%), *Carpinus* (1.0%), *Plantago* (0.7%), and *Ambrosia* (0.65%). The following

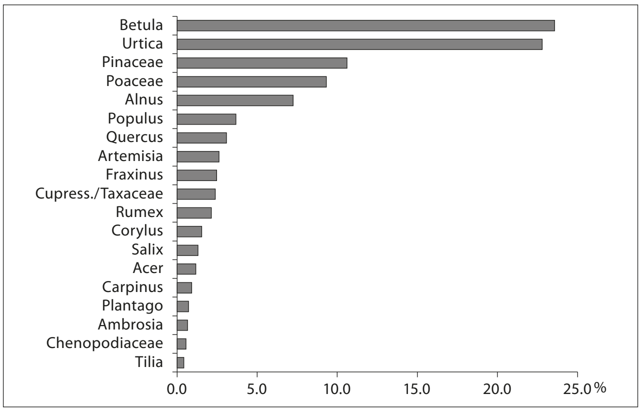

Figure 3. Percentages of pollen of some plant taxa in the pollen spectrum of Lublin, means for 2001–2012

taxa: Chenopodiaceae, *Tilia,* Asteraceae, *Juglans, Ulmus, Secale, Morus, Aesculus, Fagus*, showed the lowest percentages (0.6% – 0.1%) in the mean annual sum (Fig. 3).

The annual pollen index showed a large variation between years and its mean value was 68,706. The largest amount of pollen was recorded in 2010 (93,818) and in 2003 (89,966), whereas the lowest amount in the years 2009, 2005, and 2011 (50,377–54,976). Similar numbers of pollen grains were recorded in the years 2006, 2007, and 2008 (73,489–75,007) (Fig. 4).

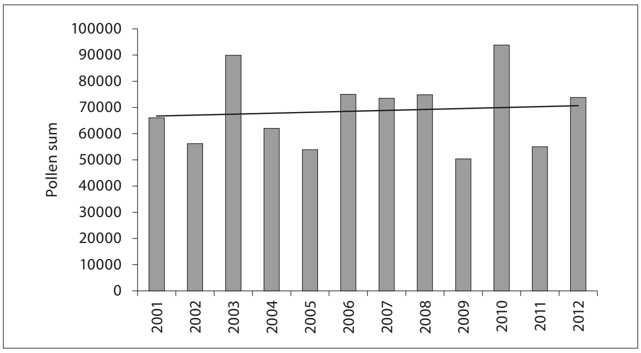

Figure 4. Annual pollen sums for all plant taxa in the air of Lublin and the trend line, 2001–2012

The monthly airborne pollen concentrations in Lublin for different plant taxa were very high in the period March – August, when 97.5% of the annual total pollen concentration was recorded. The mean value of pollen concentration in April much exceeded the counts for the other months. In April, the pollen content, on average, accounted for 33.3% of the annual total, in May – 17.6%, June – 11.6%, July – 16.5%, and in August – 11.5%. The highest pollen concentrations were observed in April in 10 out of the 12 years of the study, and only in the years 2002 and 2009 the highest concentrations were recorded in July. The largest standard deviation was observed for the April data, followed by those from March and May (Fig. 5).

The average percentage of the pollen of woody plants (arboreal pollen – AP) in the annual sums was 58.4% and that of herbaceous plants (non-arboreal pollen – NAP) – 41.6%. In 2003, the largest amount of AP (74.7%) and the lowest amount of NAP (25.3%) were recorded, whereas in 2009 the lowest percentage of AP (42.0%) and the highest percentage of NAP (58.0%) were observed. The percentage of

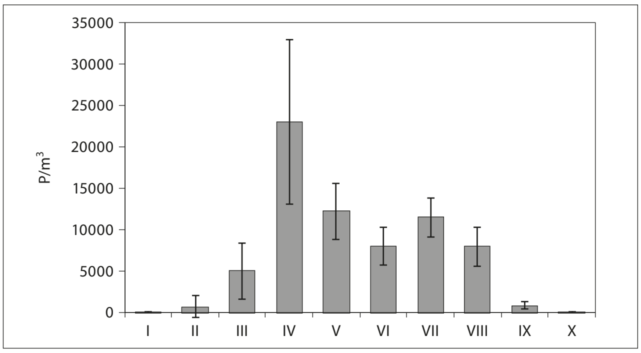

Figure 5. Frequency of pollen of all plant taxa in the air of Lublin in particular months of the year, means for 2001–2012, and the standard deviation

non-arboreal pollen in the annual sums of all pollen grains was higher than the percentage of arboreal pollen only in 2 years of the study (2002 and 2009). These were years when the highest pollen concentrations were recorded in July (Fig. 6). Analysis of meteorological conditions during the study period demonstrated that in 2002 and 2009 the highest rainfall occurred in June; this probably had a beneficial influence on the development of herbaceous plants and, in effect, on the severity of pollen seasons of these plants.

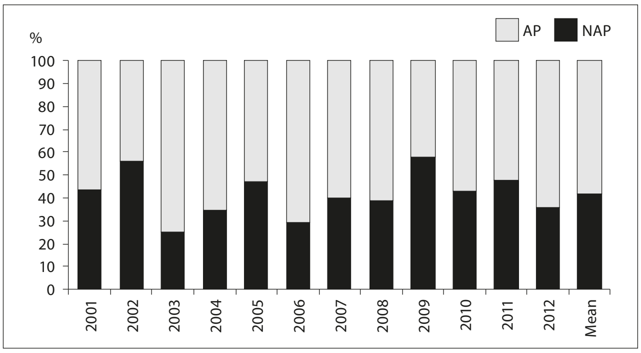

Figure 6. Comparison of percentage distribution of arboreal (AP) and non-arboreal (NAP) airborne pollen in Lublin, 2001–2012

4 basic groups of plants, the pollen of which was recorded in the air Lublin are distinguished. Deciduous trees make up 46.2% of the total annual pollen count, conifers – 13.0%, Poaceae – 9.3%, and herbs, except for Poaceae, on average, have a percentage of 30.7% in the annual sum. Unidentified pollen grains account for 0.6% (Fig. 7).

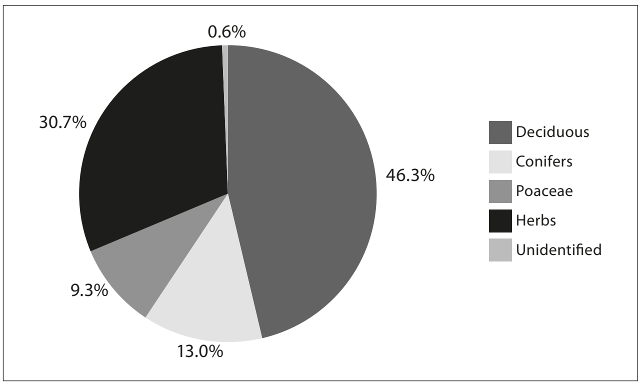

Figure 7. Percentages of pollen of some plant taxa in the pollen spectrum of Lublin in 2001–2012

The pollen calendar for Lublin shows that *Corylus* and *Alnus* start the pollen season earliest, already in January (Fig. 8). The first pollen of Cupressaceae/Taxaceae was recorded in February. In March, the beginning of the pollen season of *Populus, Salix, Ulmus, Acer,* and *Fraxinus,* was observed. The pollen of 8 taxa floated in the air during the above-mentioned month. In April, the pollen season of *Betula, Carpinus, Quercus, Fagus, Morus, Carex* and Poaceae started; the pollen of 14 plant taxa were recorded in the last decade of this month. The onset of the pollen season of Pinaceae, *Juglans, Aesculus* and *Rumex* occurred at the beginning of May, while the pollen of *Sambucus, Secale, Plantago* and *Urtica* appeared in the next decades of May. In May, pollen of the largest number of taxa (21) drifted in the air during the pollen season in Lublin. The beginning of the pollen season of *Tilia*, Chenopodiaceae, and Asteraceae was in June, with the pollen of 16 taxa present in the air. The start of the *Artemisia* pollen season was recorded in July, while in August that of *Ambrosia*. The number of anemophilous taxa, the pollen of which was present in the air of Lublin in July, August, and September is 11, 9, and 8, respectively. A few pollen grains of Poaceae, *Urtica, Artemisia, Ambrosia* and of other Asteraceae, as well as single pollen grains of *Rumex* and Chenopodiaceae floated in the aeroplankton in September (Fig. 8).

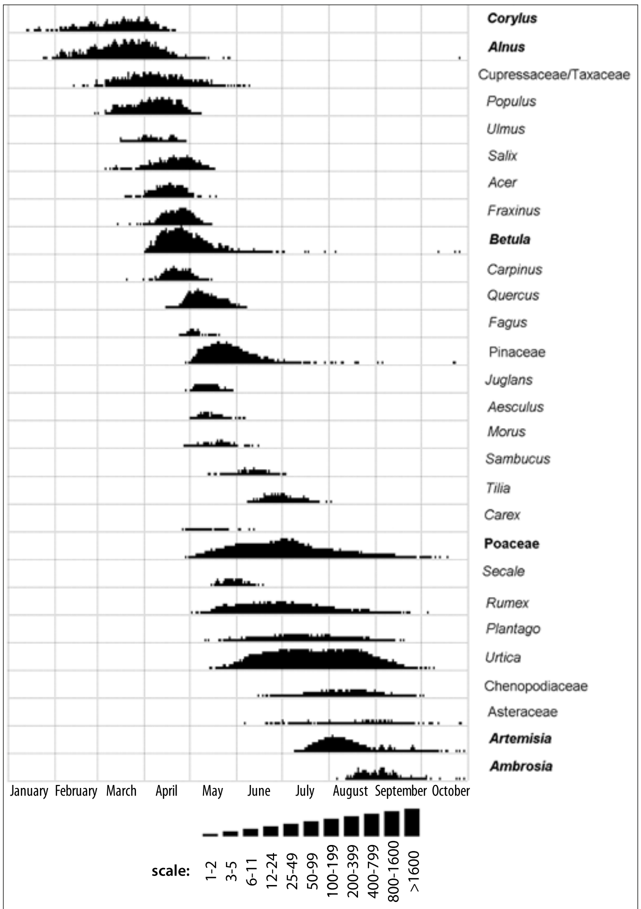

Figure 8. Pollen calendar for Lublin, 2001–2012. The taxa with the highest allergenic potential are written in bold font

DISCUSSION

Studies of many authors show that the global warming observed in the last decades has caused an increase in the amount of pollen produced by plants, which has been demonstrated in relation to various plant species. Spieksma et al. [19] found a statistically significant increase in annual totals of *Quercus, Urtica,* and *Artemisia* pollen in several cities of Western Europe, among others in Leiden (The Netherlands). The authors of the above-mentioned paper also showed that there was no increasing trend in the amount of pollen produced by some plant taxa in several pollen monitoring stations, among others, in Germany. The study conducted in Lublin in the period 2001–2012 also did not find any increasing trend in annual pollen counts.

In aerobiological pollen surveys conducted in Salamanca (Spain) during the period 2000–2007, Rodriguez-de la Cruz et al. [6] showed a strongly rising trend line for the total annual sums for all plant taxa. In recent years, an increasing trend in the amount of pollen produced by *Pinus* and *Quercus* in Catalonia (Spain) has also been found by Fernandez-Llamazares et al. [20]. On the other hand, in a study carried out in the south and north of Finland, Rantio-Lehtimäki [21] showed that the trend lines for the annual sums of *Betula* pollen differed significantly. There were increasing trends in the south of the country and decreasing trends in the north. This situation can be attributable to special climatic conditions in the north where, due to higher precipitation, a thicker snow cover forms which persists longer and the presence of which delays the beginning of the growing season.

A comparison of meteorological data for Lublin shows that in recent years there has been an increase in air temperature. During the period 1951–2000 the mean air temperature was 8.1°C [15]; it was therefore lower by 1.1°C than the mean temperature in 2001–2012. Our earlier study shows that the highest increase in temperature was in April (by 1.4°C) [22]. Mainly pollen grains of woody plants were recorded in the air in this month, but our analysis of annual pollen counts of these plants over the 12-year period did not show a significant increasing trend.

Similarly, as reported for Finland by Rantio-Lehtimäki [21], the mean rainfall recorded in Lublin in the period 2001–2010 was higher by 22 mm, compared to the data for the period 1951–2000 [22]. Such an increase in rainfall, even with higher temperature, did not cause an effect stimulating flowering and pollen production in the conditions of Lublin.

We compared the pollen calendar created for Lublin with similar data for the neighbouring countries of Poland. The geographical characteristics of the selected cities and their distance from Lublin are as follows: Münster, Germany (51°57'N, 7°37'E) is about 1,000 km distant from Lublin (51°14'N, 22°32'E), while Bratislava, Slovakia (48°10'N, 17°10'E) about 520 km. The above-mentioned cities are characterized by a warm temperate climate. The lowest annual temperature is recorded in Lublin. Münster is predominantly affected by maritime air masses, whereas Lublin and Bratislava are influenced by continental air masses. It can be concluded that in Lublin the pollen spectrum included much more plant taxa (56) than those shown in the conditions in Münster [24] nd Bratislava [23] (34 in each of these cities). Woody plants are dominant in the pollen calendar for Lublin, as well as in those for Münster and Bratislava, and account for 58%, 72% and 65%, respectively.

The annual pollen index showed a large variation between years, but the average amount of pollen recorded in Lublin (68,706) exceeded almost twice the annual total sum given for Münster (34,737) [24] and for Bratislava (36,608) [23].

The main pollen types identified in the spectrum for Lublin accounted for 73.4 % of the annual total sum and belonged to the following taxa: ***Betula***, *Urtica*, Pinaceae, **Poaceae,** and ***Alnus***. The taxa in bold font have the highest allergenic potential. On the other hand, the 5 taxa, the pollen for which was represented in largest numbers in the aeroplankton of Bratislava, were as follows: ***Betula***, Urticaceae, *Populus*, Pinaceae, and **Poaceae** [23]. In the case of Münster, the first 2 positions are occupied by the same taxa (***Betula***, Urticaceae) and, in terms of the amount of pollen produced, they are followed by Cupressaceae, *Quercus,* and ***Alnus*** [24]. The highest pollen content of most of the above-mentioned taxa was recorded in the air of Lublin, and was two or three times more than in Münster or Bratislava. Only the pollen of *Betula* and *Quercus* had comparable values in Lublin and Münster.

Comparing the start date of pollen seasons of particular taxa shown in the pollen calendar for Lublin with the pollen calendars prepared for central-eastern Europe [25], both differences and similarities were found. In Lublin, the beginning of pollen seasons for most of the major taxa occurred about 10–14 days later. This applies to *Betula, Quercus*, Poaceae, *Plantago*, Urtica, and *Ambrosia*. But the *Artemisia* pollen season started at the same time, while that of Chenopodiaceae 2 weeks earlier than those demonstrated by the data for central-eastern Europe. The comparison of the pollen calendars for Münster [24], Bratislava [23], and Lublin shows that the start date of pollen seasons of many taxa in Lublin is similar to that recorded in Münster, but differs significantly from the data for Bratislava. The occurrence and dispersal of airborne pollen are modified by environmental factors, primarily by weather conditions. They determine, to the greatest extent, seasonal and daily fluctuations in pollen concentrations in a given area and shape the pollen season pattern. The literature shows that the extent of the effect of meteorological conditions on the same taxa in various geographic regions is different. Differences in pollen calendars for areas located even relatively close arise from this fact.

CONCLUSIONS

1. 56 types of pollen were identified in the air of Lublin, among which the major ones were as follows: *Betula, Urtica, Pinus*, Poaceae, and *Alnus*.
2. Woody plants were the dominant group; their pollen on average accounted for 58% in the aeroplankton.
3. The mean annual pollen index for airborne pollen of all taxa in Lublin was 68,706, with the highest percentage of pollen in April (33%).
4. In spite of an increase in mean annual temperature by 1.1°C in Lublin during the last 12 years, the trend line in annual pollen sums did not show any clear increasing trends.

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