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The effect of the meteorological factors on the *Alnus* pollen season in Lublin (Poland)

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Abstract

Alder pollen seasons and the effect of meteorological conditions on daily average pollen counts in the air of Lublin (Poland) were analysed. *Alnus* pollen grains reach very high concentrations in the atmosphere of this city during the early spring period and the parameters of pollen seasons were very different in the particular years studied. The pollen season lasted on average one month. The highest variation was observed for the peak value and the Seasonal Pollen Index (SPI). The pollen seasons, which started later, had shorter duration. Peak daily average pollen counts and SPI value were higher during the shorter seasons. Similarities in the stages of pollen seasons designated by the percentage method depended on the start date of the pollen season. Season parameters were mainly correlated with thermal conditions at the beginning of the year. Regression analysis was used to predict certain characteristics of the alder pollen season. The highest level of explanation of the variation in *Alnus* pollen season start and peak dates was obtained in the model using mean temperature in February. The obtained regression models may predict 82% of the variation in the pollen season start date, 73% of the variation in the duration, and 62% in the peak date.

Keywords: *aerobiology, alder pollen season, weather conditions, regression models*

In recent years, an earlier occurrence of particular phenological stages in plants has been observed, which is associated with a marked increase in temperature (Emberlin et al., 2007). This phenomenon can particularly be observed at the beginning of the year when the growing season of plants starts. Pollen seasons have become longer and more severe in recent years. Global warming is responsible not only for the earlier timing of the pollen seasons, but also for increased concentrations of airborne pollen and thus, for increased incidence of pollen allergies (Emberlin et al., 1997, 2007; Frei, 1998). Aerobiological research providing information on the occurrence of airborne pollen can be a good indicator of climate change.

Alnus (alder) and *Corylus* (hazel) are the earliest allergenic trees to flower in Poland. Their pollen appears in the air almost simultaneously, from end of January until end of March (Weryszko-Chmielewska, 2006). Regional variation in the start

of the alder pollen season in Poland depends on the longitude. The season begins in the west of the country and moves in an eastern direction (Weryszko-Chmielewska et al., 2001; Piotrowska, 2006; Myszkowska et al., 2010).

During the spring period, alder pollen is the most frequent cause of pollinosis after birch pollen (Rapiejko et al., 2004; d'Amato et al., 2007; Jantunen et al., 2012). Alder pollen allergens are of great clinical importance due to their high aerial concentrations and cross reactions with birch pollen allergens (Matthiesen et al., 1991). Epidemiological studies have shown that 95% of patients allergic to alder pollen allergens are also sensitised to birch pollen allergens. It has been proven that as birch pollen shed more severe clinical symptoms occur after exposure to alder pollen (Rapiejko et al., 2004).

In the present study, *Alnus* was selected for analysis because pollen grains of this taxon reach very high concentrations in the atmosphere of Lublin

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and they are potentially responsible for allergic reactions during the early spring period. Monitoring of alder pollen content in the air is of essential importance in the diagnosis and treatment of pollen allergy. The occurrence of airborne pollen depends primarily on meteorological conditions in a given area. In aerobiological research, a lot of attention is devoted to studying the effect of weather on the occurrence of airborne pollen and to forecasting the main parameters of the pollen season. It is particularly difficult to develop pollen forecast models for trees, since their pollen season does not depend only on meteorological conditions in the current year, but also on those prevailing in the year preceding pollen release. Alder male flowers begin forming in the summer of the previous year and the weather at that time may have a significant effect on pollen production and, in consequence, on the pollen season (Krawiarz & Chałupka, 1980).

The aim of the present study was to analyse the alder pollen seasons in Lublin and to determine, which meteorological factors have the greatest effect on the occurrence of pollen grains of this taxon in the air. The regression analysis was used to predict onset, duration and peak date of pollen season.

Material and methods

Pollen monitoring was carried out in the years 2001–2012 by the volumetric method according to the recommendations of the International Association for Aerobiology (Mandrioli et al., 1998). *Alnus* pollen data were recorded using a Hirst type volumetric spore trap (Hirst, 1952). The pollen trap (Lanzoni VPPS 2000) was placed on the roof of a building of the Lublin University of Life Sciences at a height of 18 m above ground level (51° 14' 37" N, 22° 32' 25" E; 197 m above sea level). Mean daily *Alnus* pollen concentrations were expressed as the number of pollen grains per cubic metre of air (P/m^3).

The 95% method was used to determine the start and end dates of the pollen season (Andersen, 1991). 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%. Meteorological data 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-Skłodowska University in Lublin. The following daily meteorological data were used for the analysis: mean, minimum and maximum air temperature, relative air humidity, rainfall, cloud cover, and wind speed.

Statistical dependence between season parameters as well as between season parameters and meteorological data was calculated by Spearman's rank correlation coefficient. The relationship between the pollen season and meteorological conditions in different periods was analysed. The study took into account: ten-day periods from January to March, the periods of 10, 20, 30 and 40 days before the season, the months from January to April in the year of pollen release as well as the months from August to December in the year preceding pollen release.

The rate of increase in airborne pollen concentration was determined on the basis of the stages defined as 1, 2.5, 5, 25, 50, 75, 97.5 and 99% of the annual pollen count (Latałowa et al., 2002). The phases in particular seasons were compared by cluster analysis in the form of hierarchical tree with Euclidean distance and Ward's joining method (Gozdowski et al., 2008). Regression analysis was performed to produce forecast models. Before its application, the scatterplots of independent and dependent variables as well as their correlation were analysed. If Spearman correlation was high and linear relationship was observed, then a linear regression function was obtained. The regression models were constructed based on the results from the period 2001–2011 and tested with the 2012 data. All statistical calculations were performed using the software package STATISTICA 8.

Results

The alder pollen seasons in Lublin were characterised by very large variations. The difference between the earliest and latest season start date was 52 days (Table I). The seasons in the years 2002 and 2008 started earliest – on 4 and 6 February, respectively (Figure 1). They were preceded by days with relatively high air temperature. Mean air temperature in the third ten-day period of January was the highest during these two years of the study (Figure 2). In 2002 and 2008, February was also exceptionally warm, with average temperatures higher by, respectively, four and three times than the mean February temperature over the 11-year study period. High temperature was recorded most frequently at the beginning of this month.

The latest start date of the alder pollen season was observed in the years 2003, 2005 and 2006 (Figure 1). These were the years with some of the lowest temperature in February and March compared to the other study years (Figure 2).

The *Alnus* pollen season ended earliest in 2008, on 18 March, and latest in 2009, on 30 April. The end of the alder pollen season in 2008 occurred earlier than the onset of the season in the years 2003 (by

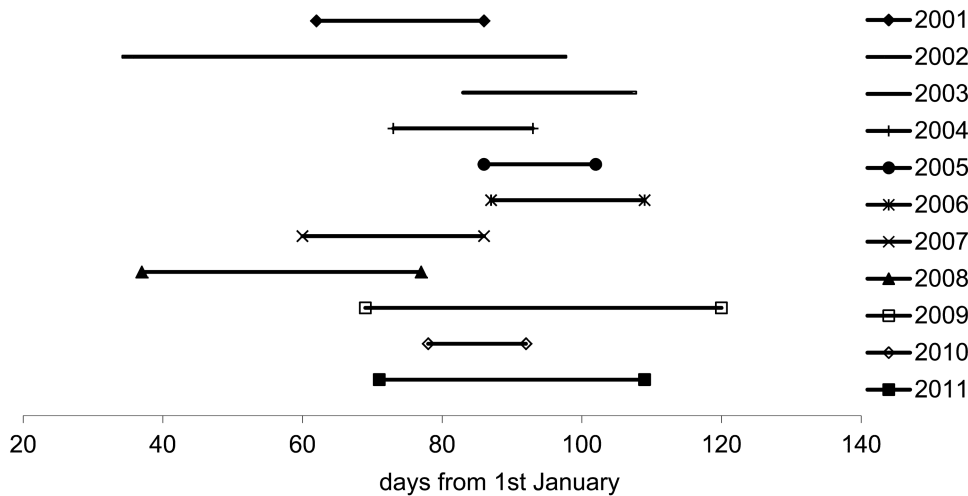


Figure 1. Start and end dates of the *Alnus* pollen season (95% method) in Lublin, Poland, 2001–2011.

six days), 2005 (by nine days), 2006 (by ten days) and 2010 (by one day). On average, the alder pollen season lasted one month (Table I). The difference between the shortest and longest season was 48 days.

The highest maximum air temperature was recorded during the shortest season (2010). The highest variation was observed for the peak value. The seasonal peak in 2003 was almost 14 times higher than in 2009. The maximum pollen concentration was recorded earliest in 2008 (at the end of February), while in 2005 and 2006, it was recorded latest (at the beginning of April). The Seasonal Pollen Index (SPI) was also characterised by very large variations; the difference between the highest and lowest values of the SPI was 7330 grains (Table I).

The analysis of the relationships between the season parameters shows that the highest correlation was between the season start date and peak date (a positive correlation). The seasonal peak occurred earlier when the season started earlier. A high positive correlation was also found between the peak value and SPI as well as between the peak date and the season end date. Besides, it was found that the

season that started later had shorter duration and that the peak value and SPI were higher in a shorter season (Table II).

Irrespective of the number of pollen grains, pollen phases are used to compare pollen seasons; these phases are determined on the basis of specific percentage values of the annual pollen count. The study determined the dates when the pollen sum reached, respectively, 1, 2.5, 5, 25, 50, 75, 97.5 and 99% of the annual pollen count (Latałowa et al., 2002). On the base of this data set, the cluster analysis was performed to compare the rate of increase in the pollen concentration in particular years.

Two groups of seasons were distinguished (Figure 3). The first group comprised the years, in which a late season start date was recorded (the years 2003, 2005, 2008, 2009, 2010, 2011), while the other group included the years characterised by an early season start date (2001, 2002, 2004, 2007, 2008). One can conclude on this basis that the rate of increase in the pollen concentration is similar in seasons with a similar season start date.

The season started earlier when higher temperature was recorded in February and 30 and 40 days before the season. The season end was negatively correlated with air temperature in March and rainfall in January. The season duration depended mainly on temperature in the third ten-day period of January, in February and at the beginning of March. The peak date was recorded earlier when January and February were warm as well as when air humidity was low in February. The SPI and peak value depended mainly on meteorological conditions in the previous year – temperature in October and humidity in September (Table III).

The regression models were constructed by means of linear function. The best-fitting regression models were chosen based on the value of R^2 . The highest

Table I. Statistics of the parameters of the *Alnus* pollen season in Lublin, Poland, 2001–2011 and 2012.

Statistics	Pollen season			Peak		SPI
	Start	End	Duration (days)	Value (P/m ³)	Date	
Mean	67	98	32	1207	79	4841
Minimum	35	77	15	176	58	1090
Maximum	87	120	63	2433	92	8420
Standard deviation	17.9	12.7	15.3	786.4	11.7	2310.9
V (%)	26.5	13.0	48.2	65.1	14.8	47.7
2012	74	88	15	1246	77	4292

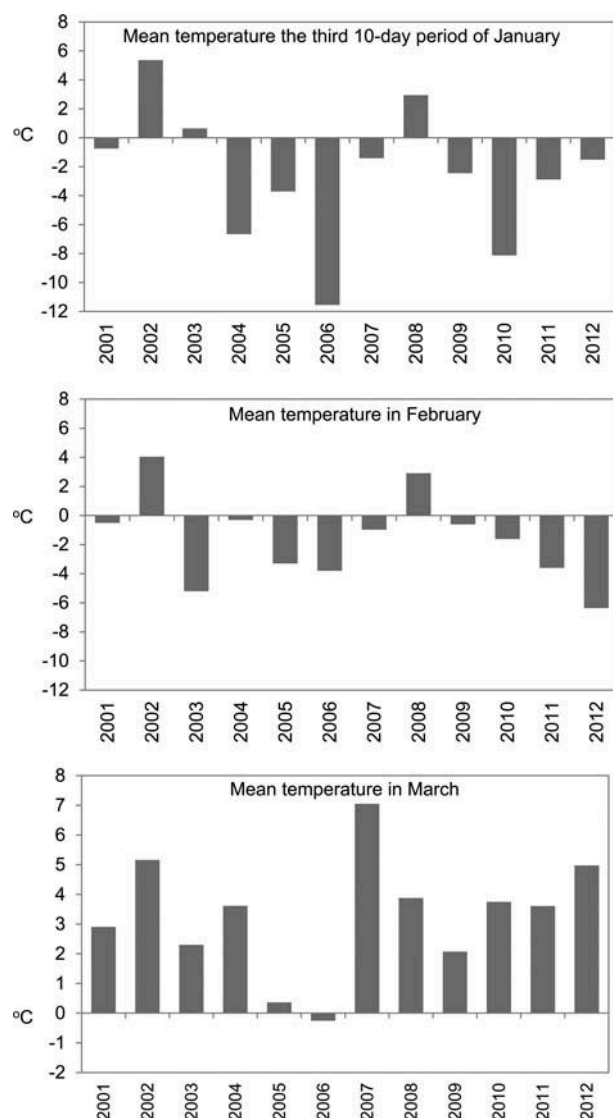


Figure 2. Mean temperature in the third ten-day period of January, in February and in March, Lublin 2001–2012.

level of explanation of the variation in *Alnus* pollen season start and peak dates was obtained in the model using the mean temperature in February (Figure 4). For the start date, however, the determination coefficient value ($\text{Adj}R^2 = 0.819$) was higher than for the peak date ($\text{Adj}R^2 = 0.616$). The best results for duration were shown by the model with rainfall in September from the previous year. The adjusted determination coefficient value was high enough ($\text{Adj}R^2 = 0.729$). On the basis of the calculated regression models, a useful forecast for the duration of 2012 was gained. The predicted and observed values differed by three days. However, the prediction for start and peak date was not satisfactory. The start date forecast differed the most from the expected one probably because of an extremely

low temperature in February 2012 (-6.5°C), when average from 2001 to 2011 amounted to -1.6°C .

Discussion

In northern and central Europe, *Alnus* pollen is one of the main causes of pollen allergy (Rapiejko et al., 2004; d'Amato et al., 2007; Jantunen et al., 2012). The onset of the alder pollen season falls in the period between December and April (d'Amato et al., 2007). This is mainly determined by the geographic location, altitude above sea level and the distance from large water bodies, which make the climate milder. Analysis of *Alnus* pollen counts in Lublin (Poland) and Skien (Norway) showed that in the year 2000, the seasonal peaks were characterised by higher values and occurred earlier in Norway than in Poland. It was probably attributable to the effect of the warm Gulf Stream from the subtropical zone at that time (Piotrowska, 2004).

In the same location, large year-to-year differences in start dates of the alder pollen season can be observed in particular years. They can reach up to two months (Kasprzyk et al., 2004; Smith et al., 2007; Myszkowska et al., 2010). The beginning of the alder pollen season primarily depends on thermal conditions preceding pollen release (Frenguelli et al., 1991; Kasprzyk et al., 2004; Emberlin et al., 2007). The study carried out in Lublin demonstrates that there was a correlation between the season start and the minimum and mean temperatures during the period of 30 and 40 days before the season. In the Netherlands and Italy, a significant correlation was found between the start of the alder pollen season and the mean and maximum temperatures 30, 40 and 50 days before the season (Frenguelli et al., 1991). In Spain, where the alder pollen season usually begins in the first half of January, the average temperature in December had the greatest effect on the season start date (Gonzalez-Minero et al., 1999). However, in Worcester (UK), a significant positive correlation was found between the onset of the alder season, temperature in October and rainfall at the beginning of November, but results of hierarchical multiple regression analysis showed that rainfall does not significantly affect the start of alder pollen season (Emberlin et al., 2007).

A comparison of alder pollen seasons in six cities of Poland (Kraków, Poznań, Szczecin, Sosnowiec, Rzeszów and Lublin) during the years 2001–2005 shows that there was a similar trend in start and peak dates as well as in the peak value (Węryszo-Chmielewska, 2006). In all these cities, the earliest start and peak dates were recorded in 2002, while the latest were in 2003. The lowest value of the seasonal peak was observed in all these cities

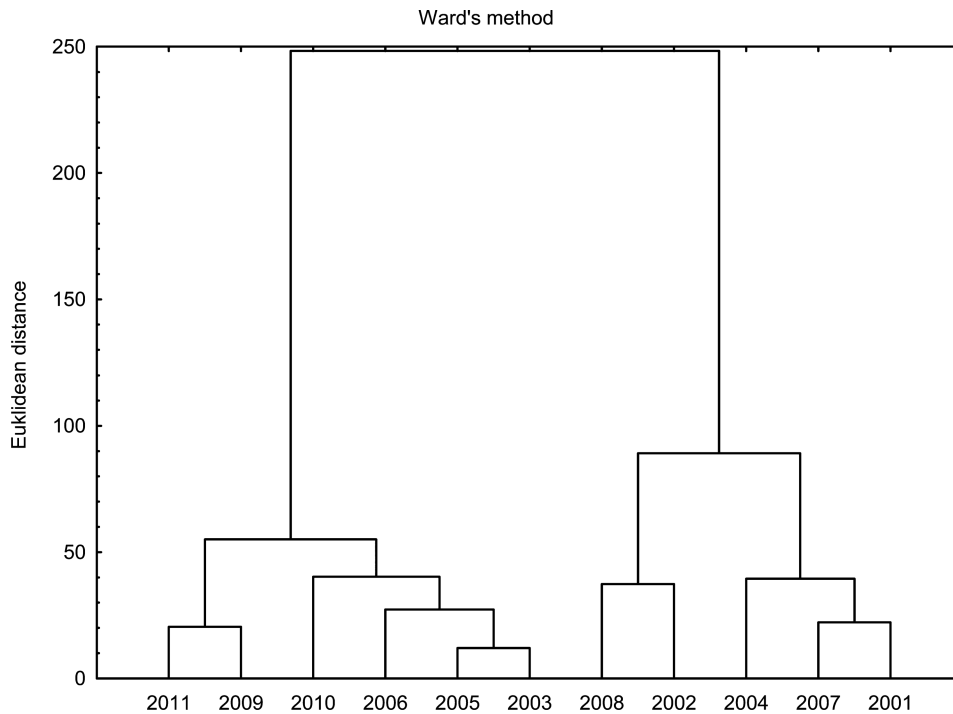


Figure 3. Similarities in the increase rate of *Alnus* pollen concentration in the air of Lublin, Poland, 2001–2011.

in the year, in which the season started earliest and lasted longest (2002). The agreement in the trend of the particular parameters of the alder pollen season in these different cities of Poland is evidence of the influence of a climatic factor operating on a wider regional scale.

Pidek et al. (2006) made similar observations on annual *Alnus* pollen counts in eastern Poland at sites located at a distance of 120 km from each other. However, the pollen season pattern is clearly modified by local meteorological factors. For example, in 2002, the date of the seasonal peak in the cities compared differed by more than a month; and it was observed between 4 February (Poznań) and 9 March (Kraków). In 2003, in which the peak value was recorded latest, the peak date occurred at a similar time (27–29 March) in all six cities (Weryszko-Chmielewska, 2006).

Table II. List of significant Spearman's correlations between the parameters of the *Alnus* pollen season in Lublin, Poland, 2001–2011.

Parameters of the pollen season	Spearman coefficient
Start and duration	−0.7608
Start and peak date	0.8859
End and peak date	0.7408
Duration and peak value	−0.7790
Duration and SPI	−0.7517
Peak value and SPI	0.8545

Note: Level of significance 0.01.

According to Kasprzyk et al. (2004), low temperature in February and March has an effect on shortening the alder pollen season. This relationship was statistically confirmed by the study carried out in Lublin during the period 2001–2011 (Table III). With a lower temperature in the third 10-day period of January, in February and at the beginning of March, shorter alder pollen seasons were observed.

A warmer early spring promotes longer duration of the season (Emberlin et al., 2007). The research conducted in ten centres in Poland demonstrates that longitude and latitude have a significant effect on annual pollen counts and the duration of the alder pollen season (Myszkowska et al., 2010). Compared to other cities in Poland, Lublin was the city with highest seasonal peaks and annual alder pollen counts (Weryszko-Chmielewska, 2006).

The present study found a statistically significant negative correlation between the peak value and duration of the alder pollen season; a higher peak value is observed during a shorter season. Ranta and Satri (2007) also observed a similar phenomenon in several cities of Finland. The highest peak value was observed in Lublin in 2003. In that year, the temperature in February was the lowest compared to the other study years. As a result of the analysis of Spearman's correlation, the highest coefficient was obtained ($r_s = 0.555$) between the minimum temperature in February and the peak value, but it

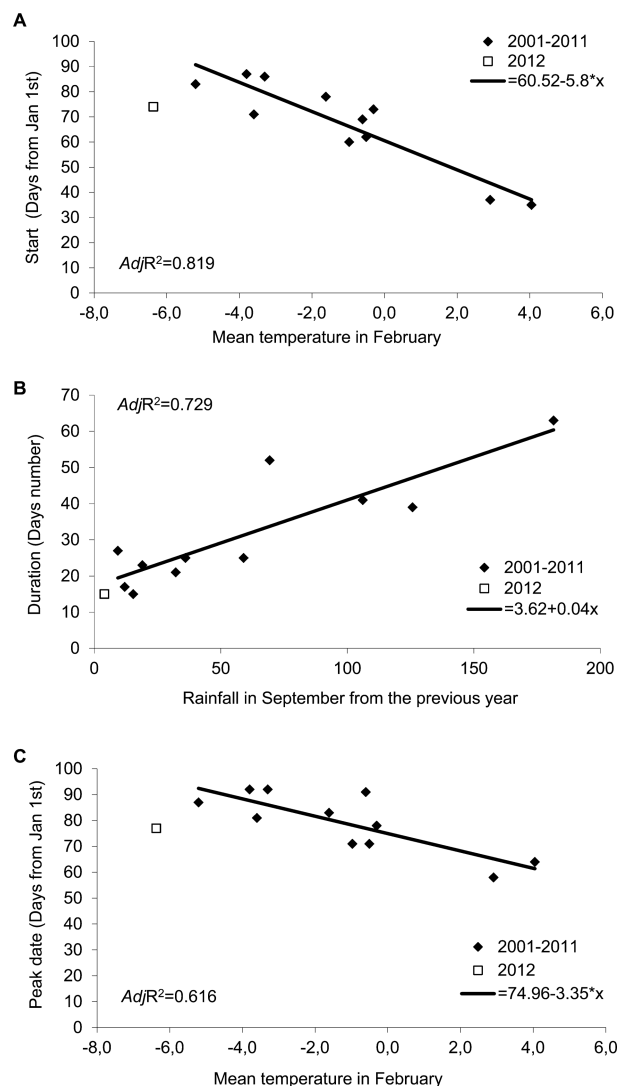


Figure 4. Scatterplots showing the relationships between season parameters and selected meteorological factors. Lublin, Poland, 2001–2011.

was not statistically significant. Such correlation was found in the case of birch. With frosty February, one may expect very high birch pollen concentrations (Piotrowska & Kubik-Komar, 2012). In Lublin a significant negative correlation was observed between the SPI value and minimum temperature in January. According to other authors, the airborne pollen sum was correlated with the mean temperature in spring and summer of the year preceding pollen release (e.g. Ranta & Satri, 2007). According to Kaszewski et al. (2008), the annual *Alnus* pollen count was significantly higher when lower precipitation was recorded in February and August of the previous year.

Cluster analysis was used to compare the pattern of pollen seasons in Lublin. The season start date was found to affect the further course of the season. The rate of an increase in pollen concentration

is similar in seasons with a similar season start date. In the studies conducted in different cities of Poland, it was observed that a delay in the onset of the alder pollen season affected season duration as well as the value of skewness and kurtosis of the pollen curve (Myszkowska et al., 2010). Weather also has a significant effect on the start of particular phases of the pollen season defined on the basis of specific percentage values of annual pollen counts (Kasprzyk et al., 2004). Dąbrowska-Zapart (2010) used cluster analysis (k-means method) to compare the pattern of alder pollen seasons in Sosnowiec. The author distinguished five types of seasons, with one dominant season that was characterised by a very long duration and low pollen concentrations.

In Poland, very high variability in weather conditions is observed at the beginning of the year. This poses great difficulties in forecasting pollen seasons of plants flowering in early spring. On the basis of the results of regression analysis, a good fit of the models was obtained in Lublin for three parameters of the alder pollen season: start and peak dates and season duration. The obtained regression models may predict 82% of the variation in pollen season start date, 73% of the variation in season duration and 62% of the peak date. But the results for the peak and SPI values were not satisfactory. Regression models for annual *Alnus* pollen sums were presented by Ranta and Satri (2007), but they obtained a very low determination coefficient. Based on multiple regression analysis, Puc (2007) found that minimum temperature and wind speed were the variables that affected the occurrence of airborne pollen most. The forecast models presented in this study will be tested and improved during the next years of research.

Conclusion

The alder pollen seasons in Lublin were characterised by very high variability. Over the 11-year study period, alder pollen grains were recorded from the beginning of February until the end of April. The start dates differed by almost two months. The variation recorded for the peak date was much smaller, since the difference was about a month. The seasonal peaks were observed earliest at the end of February and latest at the beginning of April. The pollen seasons, which started later, had shorter duration. During the shorter seasons, higher peak and SPI values were recorded. Similarities in the rate of increase in pollen concentration depended on the start date of the pollen season. The season start date can be a good indicator for the rate of increase in pollen concentration. Start, end, duration, peak value, peak date and SPI were primarily correlated with thermal conditions at the beginning of the year. The derived

regression models explain to a large extent the variation in start and peak dates as well as in season duration. Start and peak dates of the alder pollen season in Lublin can be predicted on the basis of mean

temperature in February and season duration on the basis of rainfall in September of the previous year. The forecast models need to be confirmed in the next years of research.

Table III. Significant Spearman's correlations between *Alnus* pollen season parameters and meteorological factors in Lublin, Poland, 2001–2011.

Season parameter vs. meteorological factor	Spearman coefficient
<i>Dependent variable: season start</i>	
Mean temperature in the first ten-day period of February	−0.745**
Minimum temperature in the first ten-day period of February	−0.727**
Maximum temperature in the first ten-day period of February	−0.818**
Mean temperature in February	−0.800**
Minimum temperature in February	−0.864**
Maximum temperature in February	−0.755**
Mean temperature 30 days before start of the season	−0.661*
Minimum temperature 30 days before start of the season	−0.758**
Humidity 30 days before start of the season	−0.784**
Mean temperature 40 days before start of the season	−0.648*
Minimum temperature 40 days before start of the season	−0.770**
<i>Dependent variable: end</i>	
Mean temperature in March	−0.680*
Maximum temperature in March	−0.717*
Rainfall in January	−0.662*
<i>Dependent variable: duration</i>	
Mean temperature in the third ten-day period of January	0.733**
Minimum temperature in the third ten-day period of January	0.724*
Mean temperature in the first ten-day period of February	0.624*
Minimum temperature in the first ten-day period of February	0.629*
Minimum temperature in February	0.665*
Mean temperature in the first ten-day period of March	0.770**
Minimum temperature in the first ten-day period of March	0.752**
Maximum temperature in September from previous year	−0.685*
Rainfall in September from previous year	0.752**
Humidity in September from previous year	0.842**
Minimum temperature in October from previous year	0.673*
<i>Dependent variable: peak value</i>	
Rainfall in the first ten-day period of January	−0.709*
Minimum temperature in October from previous year	−0.867**
Humidity in September from previous year	−0.745**
<i>Dependent variable: peak date</i>	
Mean temperature in the third ten-day period of January	−0.676*
Minimum temperature in the third ten-day period of January	−0.680*
Mean temperature in the first ten-day period of February	−0.785**
Minimum temperature in the first ten-day period of February	−0.763**
Maximum temperature in the first ten-day period of February	−0.822**
Humidity in the second ten-day period of February	0.804**
Mean temperature in February	−0.758**
Minimum temperature in February	−0.721*
Maximum temperature in February	−0.712*
Humidity in February	0.635*
<i>Dependent variable: SPI</i>	
Minimum temperature in January	−0.618*
Maximum temperature in September from previous year	0.685*
Minimum temperature in October from previous year	−0.806**
Humidity in September from previous year	−0.782**

Note: Level of significance: *0.05, **0.01.

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References

- Andersen, T. B. (1991). A model to predict the beginning of the pollen season. *Grana*, 30, 269–275.
- d'Amato, G., Cecchi, L., Bonini, S., Nunes, C., Annesi-Maesano, I. & Behrendt, H. (2007). Allergenic pollen and pollen allergy in Europe. *Allergy*, 62, 976–990.
- Dąbrowska-Zapart, K. (2010). Types of hazel (*Corylus* spp.) and alder (*Alnus* spp.) pollen seasons in Sosnowiec 1997–2007 (Poland). *Acta Agrobotanica*, 63, 75–83.
- Emberlin, J., Mullins, J., Cordon, J., Millington, W., Brooke, M., Savage, M. & Jones, S. (1997). The trend to earlier birch pollen season in the UK, a biotic response to change in weather conditions? *Grana*, 36, 29–33.
- Emberlin, J., Smith, M., Close, R. & Adams Groom, B. (2007). Changes in the pollen seasons of the early flowering trees *Alnus* spp. and *Corylus* spp. in Worcester, United Kingdom, 1996–2005. *International Journal of Biometeorology*, 51, 181–191.
- Frei, T. (1998). The effects of climate change in Switzerland 1969–1996 on airborne pollen quantities from hazel, birch and grass. *Grana*, 37, 172–179.
- Frenguelli, G., Spieksma, F. T. M., Bricchi, E., Romano, B., Mincigrucci, G., Nikkels, A. H., Dankaart, W. & Ferranti, F. (1991). The influence of air temperature on the starting dates of the pollen season of *Alnus* and *Populus*. *Grana*, 30, 196–200.
- Gonzalez-Minero, F. J., Morales, J., Tomas, C. & Candau, P. (1999). Relationship between air temperature and the start of pollen emission in some arboreal taxa in south-western Spain. *Grana*, 38, 306–310.
- Gozdowski, D., Roszkowska-Mądra, B. & Mądry, W. (2008). Spatial diversity of Podlasie rural communes for environmental conditions and agricultural land use. *Colloquium Biometricum*, 38, 125–134.
- Hirst, J. M. (1952). An automatic volumetric spore trap. *The Annals of Applied Biology*, 39, 257–265.
- Jantunen, J., Saarinen, K. & Rantio-Lehtimäki, A. (2012). Allergy symptoms in relation to alder and birch pollen concentrations in Finland. *Aerobiologia*, 28, 169–176.
- Kasprzyk, I., Uruska, A., Szczepanek, K., Latałowa, M., Gawęł, J., Harmata, K., Myszkowska, D., Stach, A. & Stępalska, D. (2004). Regional differentiation in the dynamics of the pollen seasons of *Alnus*, *Corylus* and *Fraxinus* in Poland (preliminary results). *Aerobiologia*, 20, 141–151.
- Kaszeński, B. M., Pidek, I. A., Piotrowska, K. & Węryszo-Chmielewska, E. (2008). Annual pollen sums of *Alnus* in Lublin and Roztocze in the years 2001–2007 against selected meteorological parameters. *Acta Agrobotanica*, 61, 57–64.
- Krawiarz, K. & Chałupka, W. (1980). Fizjologia wzrostu i rozwoju [Physiology of growth and development]. In S. Białobok (Ed.), *Olse – Alnus Mill. Nasze drzewa leśne* [Our forest trees] (pp. 165–200). Poznań: Państwowe Wydawnictwo Naukowe (in Polish).
- Latałowa, M., Miętus, M., & Uruska, A. (2002). Seasonal variations in atmospheric *Betula* pollen count in Gdańsk (southern Baltic coast) in relation to meteorological parameters. *Aerobiologia*, 18, 33–43.
- Mandrioli, P., Comtois, P., Dominguez, V. E., Galan, C., Syzdek, L. & Isard, S., 1998. Sampling: Principles and techniques. In P. Mandrioli, P. Comtois & V. Levizzani (Eds), *Methods in aerobiology* (pp. 47–112). Bologna: Pitagora Editrice.
- Matthiesen, F., Ipsen, H. & Löwenstein H. (1991). Pollen allergens. In G. d'Amato, F. T. M. Spieksma & S. Bonini (Eds), *Allergenic pollen and pollinosis in Europe* (pp. 36–44). Oxford: Blackwell.
- Myszkowska, D., Jenner, B., Puc, M., Stach, A., Nowak, M., Malkiewicz, M., Chłopek, K., Uruska, A., Rapiejko, P., Majkowska-Wojciechowska, B., Węryszo-Chmielewska, E., Piotrowska, K. & Kasprzyk, I. (2010). Spatial variations in dynamics of *Alnus* and *Corylus* pollen seasons in Poland. *Aerobiologia*, 26, 209–221.
- Pidek, I. A., Węryszo-Chmielewska, E. & Piotrowska, K. (2006). Comparison of pollen concentration of selected tree taxa in Lublin and in the Roztocze region (SE Poland) – the results of three monitoring methods. *Acta Agrobotanica*, 59, 355–364.
- Piotrowska, K. (2004). Comparison of *Alnus*, *Corylus* and *Betula* pollen counts in Lublin (Poland) and Skien (Norway). *Annals of Agricultural and Environmental Medicine*, 11, 205–208.
- Piotrowska, K. (2006). Kalendarz pyłkowy dla Lublina, 1995–2000 [Pollen calendar for Lublin, 1995–2000]. *Acta Agrobotanica*, 59, 529–538 (in Polish).
- Piotrowska, K. & Kubik-Komar, A. (2012). The effect of meteorological factors on airborne *Betula* pollen concentrations in Lublin (Poland). *Aerobiologia*, 28, 467–479.
- Puc, M. (2007). The effect of meteorological conditions on hazel (*Corylus* spp.) and alder (*Alnus* spp.) pollen concentration in the air of Szczecin. *Acta Agrobotanica*, 60, 65–70.
- Ranta, H. & Satri, P. (2007). Synchronized inter-annual fluctuation of flowering intensity affects the exposure to allergenic tree pollen in North Europe. *Grana*, 46, 274–284.
- Rapiejko, P., Lipiec, A., Wojdas, A. & Jurkiewicz, D. (2004). Threshold pollen concentration necessary to evoke allergic symptoms. *International Review of Allergology and Clinical Immunology*, 10, 91–94.
- Smith, M., Emberlin, J., Stach, A., Czarnecka-Operacz, M., Jenerowicz, D. & Silny, W. (2007). Regional importance of *Alnus* pollen as an aeroallergen: A comparative study of *Alnus* pollen counts from Worcester (UK) and Poznań (Poland). *Annals of Agricultural and Environmental Medicine*, 14, 123–128.
- Węryszo-Chmielewska, E. (Ed.) (2006). *Pyłek roślin w aeroplanktonie różnych regionów Polski* [Plant pollen in aeroplankton of different regions of Poland]. Lublin: Wydawnictwo Akademii Medycznej w Lublinie (in Polish).
- Węryszo-Chmielewska, E., Puc, M. & Rapiejko, P. (2001). Comparative analysis of pollen counts of *Corylus*, *Alnus* and *Betula* in Szczecin, Warsaw and Lublin (2000–2001). *Annals of Agricultural and Environmental Medicine*, 8, 235–240.