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EFFECT OF METEOROLOGICAL FACTORS ON *BETULA, FRAXINUS* AND *QUERCUS* POLLEN CONCENTRATIONS IN THE ATMOSPHERE OF LUBLIN AND SZCZECIN, POLAND

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Abstract: The aim of the study was to compare the concentration of 3 allergenic taxa pollen (ash, birch and oak) in the cities of Lublin (eastern Poland) and Szczecin (western Poland) during the years 2004 and 2005 and examine correlations between weather factors and pollen concentration. The meteorological parameters analysed were maximum and mean air temperature, relative humidity, amount of precipitation and wind speed. Measurements were performed by the volumetric method (Lanzoni 2000 pollen sampler). Pollen seasons were defined as the period in which 95% of the total catch occurred. The pollen seasons of the studied taxa started earlier in Szczecin than in Lublin. In both cities much higher *Betula* pollen concentration and slightly higher *Fraxinus* pollen concentration were recorded in 2004 compared to 2005. But for *Quercus*, higher concentrations were recorded in Lublin and in Szczecin in 2005. Annual totals and maximum daily pollen grain concentrations of the tree taxa in question were higher in Lublin than in Szczecin. In 2005, maximum *Betula* and *Fraxinus* pollen concentrations occurred in each of the cities at the same time: in Lublin on 18 April, in Szczecin on 16 April. Among the meteorological parameters analysed, maximum temperature and relative humidity belong to the most important factors which affect ash, birch and oak pollen concentrations in the air.

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INTRODUCTION

Birch (*Betula* spp.), ash (*Fraxinus* spp.) and oak (*Quercus* spp.) are found in Poland in mixed forests and used in urban plantings. Birch is planted particularly frequently on account of its fast growth and small habitat requirements, which create possibilities for restoration of degraded soils [1, 36].

Pollen grains of the above-mentioned tree genera are a frequent cause of pollinosis [21, 24]. Among the 3 above-listed taxa, the strongest allergenic properties are shown by birch pollen which causes most allergies in northern and central Europe [5, 42]. *Fraxinus excelsior* pollen is also numbered among the very allergenic pollen by some authors [34, 35].

The flowering periods of the tree taxa in question fall in Poland in April and May [33, 40]. Therefore, the pollen seasons of these trees to a large extent overlap, with conditions found in Kraków [41] and Lublin [44]. The first allergy symptoms caused by birch pollen occur in

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Poland's conditions already with the concentration of 20 pollen grains × m^{-3} [29].

The above-mentioned tree genera were selected for study due to the concurrence of their pollen seasons, significant allergenicity, and the occurrence of cross-reactivity between birch and ash pollen [43], as well as birch and oak pollen [20, 23, 28].

The aim of the study was to compare the course of the birch, ash and oak pollen seasons in 2 distant cities of Poland over a period of 2 years and to determine the effect of selected meteorological factors on pollen concentration in the air.

MATERIALS AND METHODS

The analysis of pollen grain concentrations of the studied trees was conducted in Lublin and in Szczecin based on data from the years 2004-2005. In Lublin the trap site was located in the Śródmieście (City Centre) district 18 m above ground level, in Szczecin also in the City Centre 21 m above ground level. The measurements of pollen concentrations were carried out by the volumetric method using the VPPS Lanzoni 2000 sampler [19]. The pollen concentration was expressed as the number of pollen grains × m^{-3} per 24 h. The start and end of the pollen season was determined by the 95% method [4].

The pollen calendar was created in the Polpal – Aero programme based on 2-year mean values. (The authors of the programme are A. Walanus and D. Nalepka of the W. Szafer Institute of Botany of the Polish Academy of Sciences in Kraków.) Diagrams drawn by means of this programme are compliant with recommendation of the International Association for Aerobiology.

On the basis of literature data, the number of days at which the pollen concentrations of the studied taxa exceeded the threshold values at which allergy symptoms develop, was determined. Rapiejko *et al.* [29] reported a threshold value for birch pollen of 20 grains × m^{-3} in Poland, while Hofman and Michalik [10] reported 50 grains × m^{-3} for ash also in Poland, and Rodriguez-Rajo *et al.* [32] reported 50 grains × m^{-3} for oak pollen in Spain.

For analysis of the pollen concentration in 2004 in relation to meteorological parameters, maximum temperature, maximum wind speed, mean daily precipitation and mean daily relative humidity were used. The meteorological data for Lublin were provided by the Department of Meteorology and Climatology at the Maria Curie-Skłodowska University in Lublin, whereas for Szczecin - from a meteorological station situated in the Dąbie district and from a Vaisala automatic weather station installed in the Śródmieście (City Centre) trap site.

The degree of correlation between particular meteorological parameters and the concentrations of trees pollen was described by the Pearson's correlation coefficient r (statistical error risk was estimated at the significance level of 95%, $\alpha = 0.05$) [39].

Table 1. Results of aerobiological study.

City		Lublin		Szczecin	
		2004	2005	2004	2005
Fraxinus spp.	ps	16.04-2.05 (17)	8.04-6.05 (29)	4.04-30.04(27)	5.04-11.05 (37)
	tn	1,771	1,357	638	564
	max	200	149	119	85
	max day	26.04	18.04	15.04	16.04
	dn	15	11	5	3
Betula spp.	ps	15.04-5.05 (21)	15.04-19.05 (35)	14.04-10.05 (27)	8.04-11.05 (34)
	tn	12,647	6,944	9,018	3,084
	max	1,367	1,815	1,373	455
	max day	22.04	18.04	22.04	16.04
	dn	22	20	18	19
Quercus spp.	ps	2.05-1.06 (31)	3.05-30.05 (28)	30.04-27.05 (28)	15.04-28.05 (44)
	tn	1,386	2,245	654	1,547
	max	347	351	69	330
	max day	5.05	6.05	6.05	2.05
	dn	5	18	2	8

ps – pollen season established by the 95% method (with number of days), tn – total number of pollen grains collected in the season, max – maximum number of pollen grains m-3/24 h, max day – date of pollen max number, dn – number of days with threshold of pollen concentration at which allergy symptoms develop.

RESULTS

There were many differences in the course of the *Fraxinus*, *Betula* and *Quercus* pollen seasons studied in Lublin and Szczecin, but a similarity of certain characteristics was also found.

***Fraxinus* (Ash).** In both years, the ash pollen seasons started earlier in Szczecin than in Lublin (Tab. 1, Fig. 1). In Szczecin in the years 2004-2005, the onset of the *Fraxinus* pollen season occurred at the same time; however, the season was much longer in 2005. In Lublin, the onset of the pollen season occurred earlier in 2005 than in 2004, and was marked by a greater length in 2005 (Tab. 1).

Maximum daily pollen grain concentrations in Lublin were much higher than in Szczecin. The dates of occurrence of the highest concentrations also differed; in Szczecin they were recorded in the years in question by 2 and 11 days earlier, respectively (Tab. 1, Fig. 1).

The comparison of annual totals of *Fraxinus* grain pollen demonstrates that in Lublin they were twice as high (Tab. 1). The number of days with high pollen concentration in Lublin was higher (15 and 11) than in Szczecin (5 and 3).

***Betula* (Birch).** In 2004, the birch pollen season started in Lublin and Szczecin at the same time, whereas in 2005 the start of the season was recorded a week earlier in Szczecin (Tab. 1, Fig. 2). The length of the pollen seasons differed between the cities only in 2004 (by 6 days).

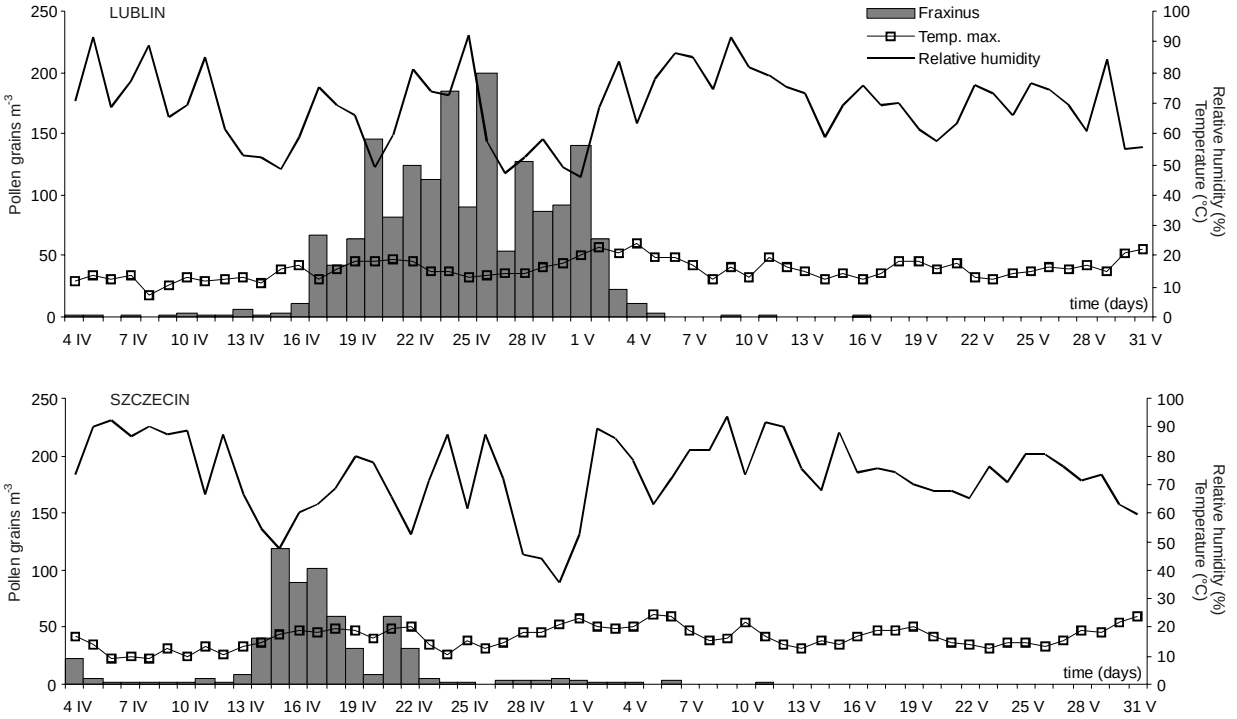

Figure 1. Influence of selected meteorological factors on ash pollen counts in Lublin and Szczecin in 2004.

Maximum concentration levels were similar in both cities in 2004, and in spite of the large distance between the cities, peak days occurred at the same time (22 April). In 2005, maximum daily *Betula* pollen concentrations also occurred at close dates in both cities, but in Lublin the concentration was 4-fold higher than in Szczecin (Tab. 1).

Annual totals of birch pollen grains in both years were much higher in Lublin. The number of days with high and very high pollen concentration was also higher in the case of Lublin (22 and 20 days) than Szczecin (18 and 19 days).

***Quercus* (Oak).** In Szczecin, the oak pollen seasons started earlier than in Lublin, in particular in 2005, when the difference was as much as 18 days (Tab. 1). In 2004, the length of the pollen seasons in both cities was similar (28-31 days), while in 2005 in Szczecin a season lasting 44 days was recorded.

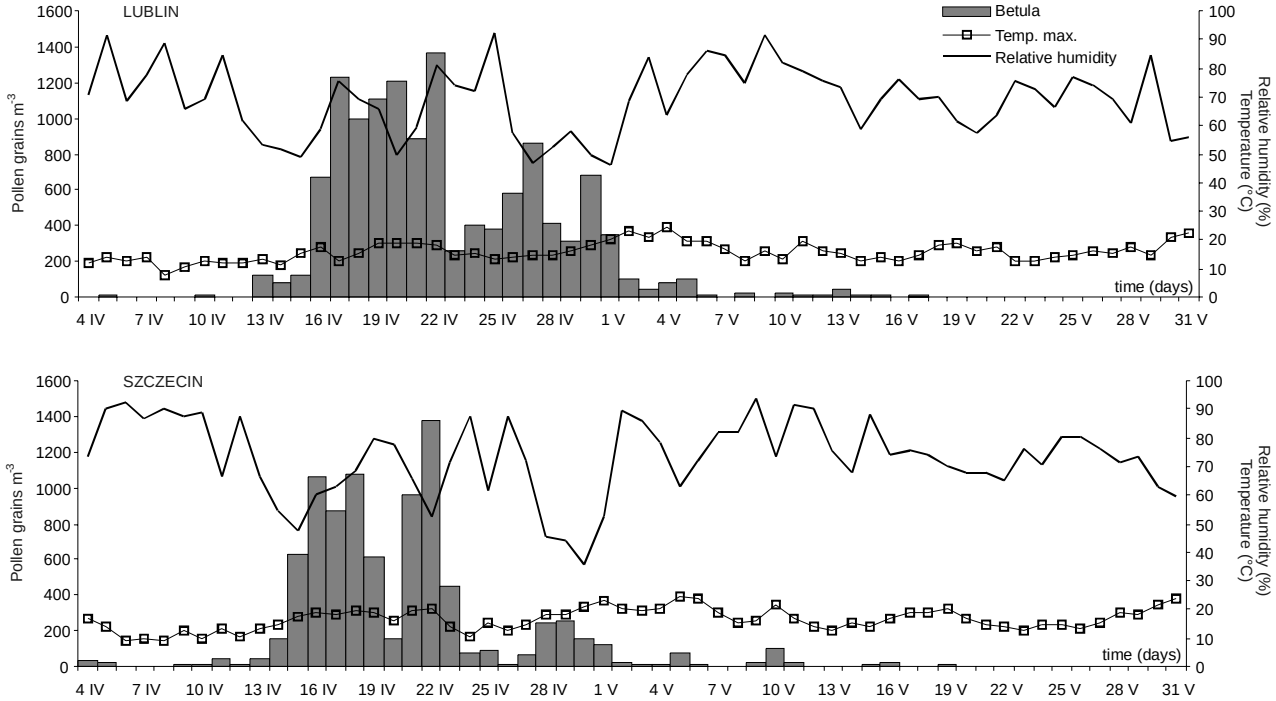

Figure 2. Influence of selected meteorological factors on birch pollen counts in Lublin and Szczecin in 2004.

Table 2. Correlation coefficients between trees pollen counts and meteorological factors in 2004.

Taxon	City	Temperature max. (°C)	Rainfall (mm)	Wind speed max. (m/s)	Relative humidity (%)
Fraxinus spp.	Lublin	0.1268	-0.2096	-0.2714	-0.2366
	Szczecin	0.3389	-0.2844	0.3467	-0.3835*
Betula spp.	Lublin	0.1988	-0.1870	-0.1161	-0.2714
	Szczecin	0.3481*	-0.2655	0.2261	-0.4561*
Quercus spp.	Lublin	0.4288*	-0.077	0.3791*	-0.3517*
	Szczecin	0.4695*	0.0287	0.283	-0.1937

*Correlation statistically significant ($p<0.05$).

Maximum *Quercus* pollen grain concentrations in particular years were higher in Lublin than in Szczecin, and they occurred almost at the same time (5-6 May), except for the 2005 season in Szczecin (2 May) (Tab. 1, Fig. 3).

Annual totals of *Quercus* pollen grains reached much higher values in Lublin (1.5-2 ×) than in Szczecin. The number of days with high pollen concentration was also higher in Lublin, and in successive years it was 5 and 18 days, whereas in Szczecin - 2 and 8 days, respectively.

Comparison of *Betula, Fraxinus* and *Quercus* pollen seasons. The *Betula* and *Fraxinus* pollen seasons, both in Lublin and in Szczecin, overlapped to a large extent (Fig. 4). Periods of high and very high concentrations also occurred at the same time. But the start of pollen release by *Quercus* coincided with the end of the *Betula* and *Fraxinus* season. Comparing 2-year means, it can be stated that longer pollen seasons of the studied taxa occurred in Szczecin than in Lublin, in particular for *Fraxinus* (by 9 days) and *Quercus* (by 6 days) (Tab. 1).

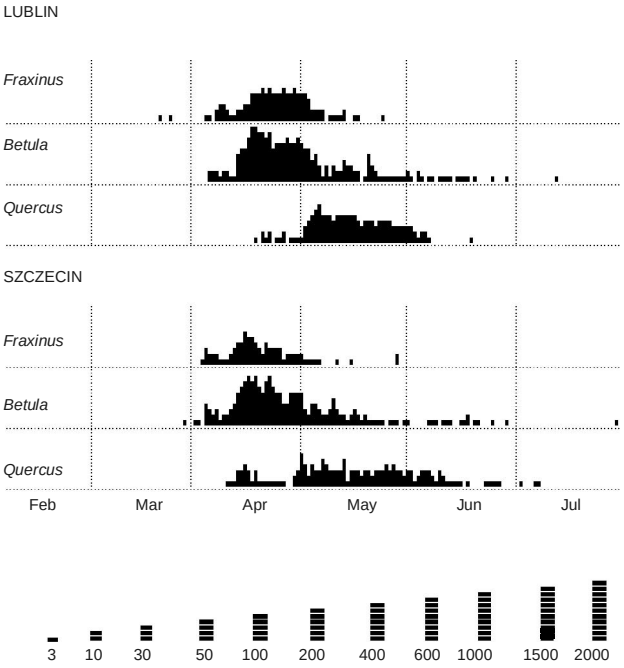

Figure 4. Pollen seasons of *Fraxinus*, *Betula* and *Quercus* in Lublin and Szczecin (average concentrations of 2004-2005 years).

The longest pollen season (2-year means) was recorded in the case of *Quercus*: in Lublin it covered 30 days, in Szczecin 36 days, while the shortest season was calculated for *Fraxinus*: in Lublin - 23 days, in Szczecin - 32 days.

To sum up, it can be stated that the pollen seasons of the studied taxa started earlier in Szczecin than in Lublin:

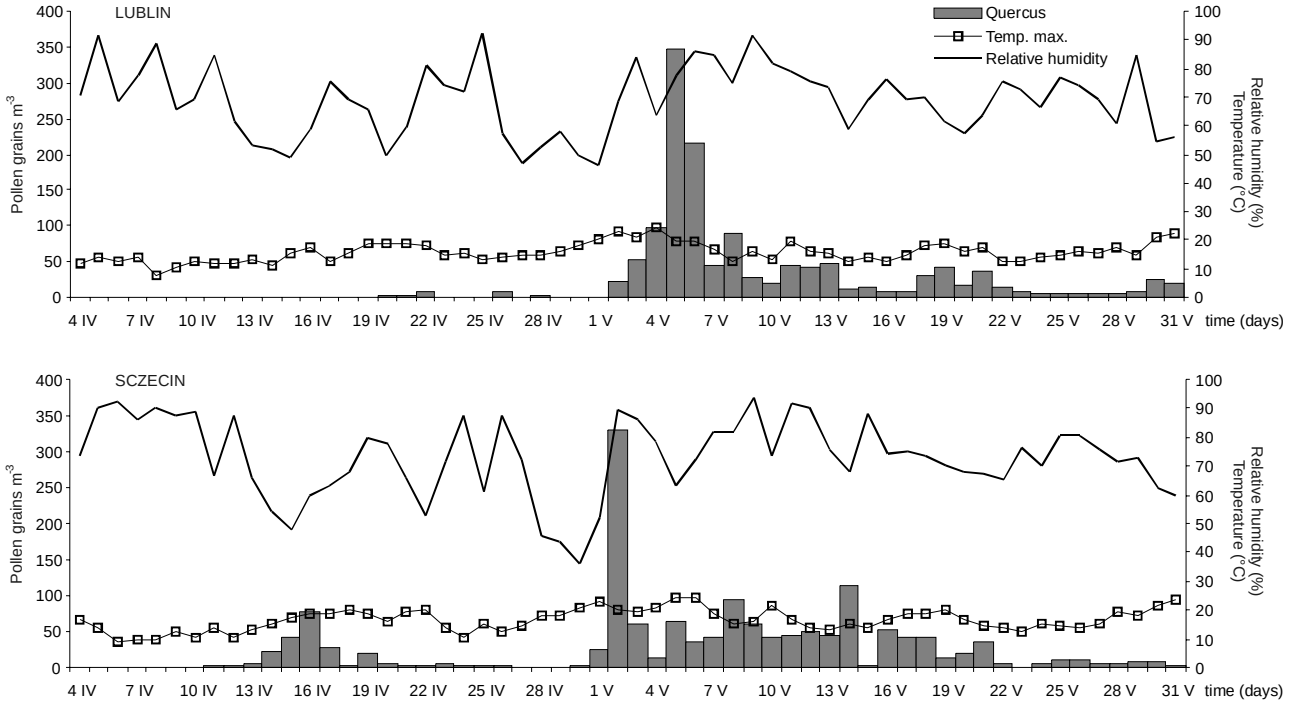

Figure 3. Influence of selected meteorological factors on oak pollen counts in Lublin and Szczecin in 2004.

Fraxinus by 3-14 days, *Betula* by 1-7 days, *Quercus* by 2-18 days. In 2004, a much higher concentration of *Betula* pollen was found in both cities, and a slightly higher *Fraxinus* pollen concentration than in 2005. But for *Quercus*, higher concentrations occurred in Lublin and in Szczecin in 2005. Annual totals and maximum daily concentrations of pollen grains of the studied tree taxa were higher in Lublin than in Szczecin. Maximum concentrations of *Betula* and *Fraxinus* pollen occurred in each of the cities at the same time in 2005: in Lublin on 18 April, whereas in Szczecin on 16 April (Tab. 1).

The effect of weather factors on ash, birch and oak pollen concentrations. Statistical analysis demonstrated for Szczecin a negative, statistically significant correlation between the ash pollen concentration and relative humidity of the air. The other meteorological factors were not significantly correlated with the pollen concentration of this taxon (Fig. 1, Tab. 2).

With respect to the birch pollen concentration in Szczecin, statistically significant correlations with maximum air temperature (positive) and relative humidity (negative) were found (Fig. 2, Tab. 2).

In Lublin statistically significant dependencies between the oak pollen concentration and 3 out of the 4 weather parameters in question, i.e., temperature (positive), wind speed (positive) and relative humidity of the air (negative), were found. In Szczecin, this correlation occurred (positive) only in relation to maximum air temperature (Fig. 3, Tab. 2).

No statistically significant correlation between the ash, birch and oak pollen concentrations and precipitation was reported in any of the analysed seasons. Among the analysed weather parameters, maximum air temperature and relative humidity were most frequently correlated with pollen concentrations of the trees in question (Tab. 2).

DISCUSSION

Results obtained in the study demonstrated differences in the course of the pollen seasons of the studied taxa in both cities. These differences related to the start dates of the seasons, the seasonal growth rate, and values of maximum concentrations and annual pollen totals for the studied trees. Similarities included the durations of certain seasons and the dates of occurrence of high pollen concentrations, chiefly recorded for ash and birch. Analysing the seasonal growth rate presented in pollination calendars, Szczepanek [41] and Kasprzyk [15] included *Fraxinus*, *Betula* and *Quercus* in taxa groups with compact pollen seasons, the pollen of which is found abundantly in the air, and seasonal maxima are recorded over a short period of time after the appearance of first grains in the aeroplankton. A similar picture of the pollen seasons of the studied trees was observed in Lublin and Szczecin.

The start dates of the ash, birch and oak pollen seasons are primarily dependent on air temperature recorded in early spring. The potential number of pollen grains of this plant group also depends on thermal conditions occurring in summer and autumn in the year preceding pollination when the development of anthers starts [7]. The study conducted by Kasprzyk *et al.* [16] in seven cities in Poland (Zakopane, Rabka, Kraków, Ostrowiec Świętokrzyski, Warsaw, Poznań, Gdańsk) shows that the start of the *Fraxinus* season occurs in the first 10 days of April. Comparable results were obtained in Lublin and in Szczecin in 2005. But in 2004, ash pollen was observed in the atmosphere of Lublin as late as in the second half of April.

Studies of the effect of air temperature on the start of the birch pollen season were conducted over a 20-year period (1982-1999) in many cities of Europe, among others, in London, Turku, Kevo, Vienna, Brussels, Zurich [6]. A trend of an earlier start of the birch pollen season in successive years was found. The authors attribute this phenomenon to climatic changes which are manifested by, among others, an increase in air temperature in spring. Similar tendencies were reported in multi-year studies in Copenhagen (Denmark) [30], Neuchâtel (Switzerland) [2] and in Gdańsk (Poland) [17]. The comparison of the start dates of the pollen seasons in Lublin and in Szczecin showed that the birch pollen season started by 1-7 days earlier in Szczecin than in Lublin. This was attributable to higher air temperature in Szczecin in the period directly preceding pollination.

Garcia-Mozo *et al.* [7] analysed in Cordoba (Spain) the effect of air temperature on the start of the *Quercus* pollen season over 16 years, and determined that the start of the season fell in the period between 26 February-7 April. The effect of air temperature on the start of oak flowering in Southern Europe was also confirmed by Corden and Millington [3], Rodriguez-Rajo *et al.* [31] and Clot [2]. Differences in air temperature were also the cause of the earlier start of the oak season in Szczecin compared to Lublin.

The ash, birch and oak flowering seasons fall in Poland in April and May. Some oak species flower even in June [33, 40]. In this period, pollinosis symptoms are found in persons sensitive to pollen allergens. Studies conducted in Hungary showed that among patients with pollen allergies 17% react positively to birch pollen allergens, and 10.5% - to oak pollen allergens [14]. But in Vienna, hypersensitivity to ash pollen allergens was observed among 17.6% of patients [8]. However in Poland, in spite of locally high concentrations, ash pollen rarely causes allergy symptoms [10].

The highest *Betula* pollen risk in Lublin and in Szczecin occurs in April. High concentration values, exceeding the threshold values at which allergy symptoms are observed [29], were also recorded in both cities in May. Similar observations were made in Poznań [38], Kraków [41] and earlier in Lublin [26]. Hjelmroos [9] in Sweden, Johansen [13] in Norway, Porsbjerg *et al.* [27] in Greenland recorded an additional peak of birch pollination in May, outside the pollen season, most probably attributable to long-distance transportation.

The study conducted by Corden and Millington [3] in Derby (UK) showed an increase in risk of oak pollen allergens. This results from increasingly earlier flowering, as well as from more abundant and longer *Quercus* pollen seasons. In 2005, an exceptionally prolonged (44 days) oak pollen season was recorded in Szczecin.

Long-term aeropalynological studies conducted all over the world allow tendencies relating to changes in pollen concentrations in the macroregional scale to be determined. Jäger *et al.* [11], when analysing results from many seasons, observed in Brussels (Belgium) and Leiden (The Netherlands) weak growth trends in the *Betula* concentration. Similar results were obtained in London [4]. Growth trends in annual totals of *Betula* and *Quercus* pollen were also found in Delmenhorst (Germany), Helmond and Leiden (The Netherlands), Brussels (Belgium) and Derby (UK) [37]. Latorre [18], carrying out phenological observations of tree pollination in an urban agglomeration, observed the occurrence of endogenous pollination rhythm in *Betula* pendula and *Quercus* ilex. This rhythm is characterised by 2-year cyclic recurrence and does not depend on weather conditions. The 2-year rhythm of increased pollination in *Betula* was also recorded by other authors: Jäger *et al.* [11], Jato *et al.* [12], Latałowa *et al.* [17]. Results obtained for *Betula* in Lublin in the previous years of studies (1995-2003) do not show such dependencies [unpublished data].

A statistically significant correlation between the birch pollen concentration and air temperature and relative humidity was recorded in 2004 only in Szczecin. Similar correlations with regard to the pollen of this taxon were observed by Rasmussen [30], Latałowa *et al.* [17], Rodriguez-Rajo *et al.* [32], Porsbjerg *et al.* [27], Peternel *et al.* [25], Méndez *et al.* [22]. However, the oak pollen concentration was positively correlated with maximum air temperature in Lublin and Szczecin. A similar effect of temperature on the start and the course of the *Quercus* pollen season was also demonstrated by Corden and Millington [3], Rodriguez-Rajo *et al.* [32]. In addition, in Lublin the oak pollen concentration was positively correlated with wind speed and negatively with relative humidity of the air, which was also observed in Lugo (Spain) [32]. In Zagreb (Croatia), likewise in Szczecin, a statistically significant dependence between relative humidity of the air and the ash pollen concentration was recorded [25].

CONCLUSIONS

Differences in pictures of pollination of the taxa studied in Lublin and Szczecin in 2004-2005 relate to the start dates of the pollen seasons, and maximum concentrations and annual totals of pollen. Similarities included the durations of certain seasons and the dates of occurrence of high pollen concentrations.

The pollen seasons of the taxa in question started earlier and were longer in Szczecin than in Lublin.

Annual totals and maximum daily concentrations of pollen grains of the studied tree taxa were higher in Lublin than in Szczecin. In 2004-2005, maximum concentrations of *Betula* and *Fraxinus* pollen in both cities were recorded between 15-26 April, and of *Quercus* pollen between 2-6 May.

The number of days in which allergy symptoms are observed in sensitive persons was higher in Lublin than in Szczecin for all the taxa in question. With regard to birch pollen allergens, this difference was small - 1-4 days.

Among all the analysed weather parameters, maximum air temperature and relative humidity most frequently showed a significant correlation with pollen concentrations of the studied trees.

No statistically significant correlation between ash, birch and oak pollen concentrations and precipitation was recorded in any of the analysed seasons.

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