ORIGINAL ARTICLES AAEM

Ann Agric Environ Med 2004, 11, 237–244

ALLERGENIC AIRBORNE GRASS POLLEN IN SZCZECIN, POLAND

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Puc M, Puc MI: Allergenic airborne grass pollen in Szczecin, Poland. *Ann Agric Environ Med* 2004, **11**, 237–244.

Abstract: Grass pollens are known as very potent aeroallergens. The aim of the study was to analyse the grass pollen season in Szczecin (western Poland) in the years 2000–2003 and to establish a relationship between the meteorological conditions and the pollen counts of Poaceae. The meteorological parameters analysed were the maximum and mean air temperature, relative humidity, amount of precipitation and wind speed. Measurements were performed mainly by the volumetric method. In parallel, gravimetric monitoring was conducted in 4 Szczecin city districts in order to establish the spatial distribution of pollen in aeroplankton. Pollen seasons were defined as the periods in which 95% of the total catch occurred. In the 4 years studied, the lowest concentration of grass pollen was observed in 2000 with the maximum value of 123 pollen grains in 1 m^3 per 24 h. In subsequent seasons, the concentration of Poaceae pollen increased and the highest concentration of grass pollen, equal to 809 pollen grains in 1 m^3 per 24 h was noted in 2003. The majority of Poaceae species have constant periods of pollen release and the high number of their species means that the pollen season is long and lasts from the beginning of May until the middle of September. The longest pollen season was observed in the year 2000 when the lowest pollen count was found. In sensitive persons the symptoms of pollinosis occur after some threshold pollen count value, which for grass is 30 grains in 1 m^3 per 24 h. Therefore, the greatest threat from Poaceae pollen allergens is noted from the middle of May and until the end of July, and at the beginning of September. Analysis of the pollen distribution in different Szczecin city districts determined by the gravimetric method, has shown that the highest exposure to grass pollen allergens occurs in the districts Żelechowa and Śródmieście, in the area with parks, villas and gardens or garden allotments. However, in the pollen season the threshold Poaceae pollen count value is usually exceeded in the entire city. Statistically significant correlations have been found between the grass pollen count in the air and the maximum wind speed, air temperature, amount of precipitation and relative air humidity. The pollen count of grass is determined by the diversity of local flora and weather conditions, especially by the air temperature and relative humidity.

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Key words: Poaceae, pollen, meteorological conditions, correlations, Szczecin, Poland.

INTRODUCTION

In the temperate zone, allergens of grass pollen are the most frequent cause of allergic inflammation of nasal mucosa and conjunctivitis. In The Netherlands and France as many as 80% of pollinosis sufferers are allergic to antigens of Poaceae pollen [40]. Particular grass species show intense cross-reactivity between allergens on pollen structures [33, 40].

The threshold concentrations at which symptoms of allergy to grass pollen are observed are influenced by the degree of air pollution. In areas of high air pollution the

Received: 7 April 2004
Accepted: 20 November 2004

allergy threshold pollen value is 30 pollen grains in 1 m^3 per 24 h, while in the areas of low air pollution it is 71 pollen grains in 1 m^3 per 24 h [28, 29]. The difference can be attributed to the chemical properties of allergens and the presence of substances facilitating allergy-inducing properties in the air, such as ozone, sulphur oxides, nitrogen oxides, dusts. The study of Vieths [42] has shown that the allergic properties of profilin, being one of the allergens occurring in grass pollen, are related to the degree of air pollution. In industrialised areas and in big cities profilins act as the main allergens, whereas in the relatively clean air areas they as a weak allergen. Moreover, profilins can be responsible for the cross-reactions between the allergens of grass pollen and the allergens of edible vegetables [30]. Masuch *et al.* [24], studying the allergy-inducing properties of *Lolium perenne*, have shown that the presence of ozone increases the concentration of the allergen Lol p 5 in the pollen grains of ray grass. Ozone has also been shown to have an irritating effect on the mucous membrane of the airways. This compound forms as a result of complex photochemical reactions and its concentration is particularly high in big cities in summer in the few hours after the morning rush hour [19]. For the above reasons it is important to monitor the pollen count in city agglomerations.

The majority of Poaceae species have stable pollen release periods, but because of the high number of grass species the pollen season is relatively long. In Central Europe it usually starts from the middle of May, and is particularly intense in June and the fist half of July. The pollen count can reach very high values of 4,000-5,000 grains in 1 m^3 per 24 h [40]. The florescence of a spike usually lasts a few days, while pollen release of a single flower lasts only a few minutes. On sunny days, the majority of grasses open anthers in the morning to make use of the uplifting effect of convection currents. The anthers open again in the afternoon [39]. That is why the allergy symptoms are enhanced on sunny and windy days [15]. The pollen grains are monoporate, with operculum, ball- or egg-shaped, usually of thick intine [16]. The diameter of the pollen grains of the most allergenic species varies from 20–30 mm. This size of the sporomorphs facilitates their dispersal [39].

Analysis of the Poaceae pollen content in the air of Szczecin has been undertaken to:

- assess the level of exposure of Szczecin inhabitants to the allergenic grass pollen;
- compare the pollen seasons in 2000–2003;
- estimate the effect of meteorological conditions on the pollen count in the air;
- characterise the spatial distribution of pollen grains in aeroplankton in four Szczecin city districts;
- determine the length of the pollen seasons by different methods.

MATERIALS AND METHODS

Analysis of the pollen count and pollen fall distribution was performed on the basis of the data collected in Szczecin in the seasons of 2000–2003.

The volumetric measurement point was located in the Szczecin city district Śródmieście, at an elevation of 21 m above ground level. The pollen count was measured by the volumetric method with the use of a VST trap (Hirst-type), and expressed as the number of pollen grains in 1 m^3 per 24 h [4, 23, 29]. The gravimetric measurement points were located in 4 districts of Szczecin city (Śródmieście,

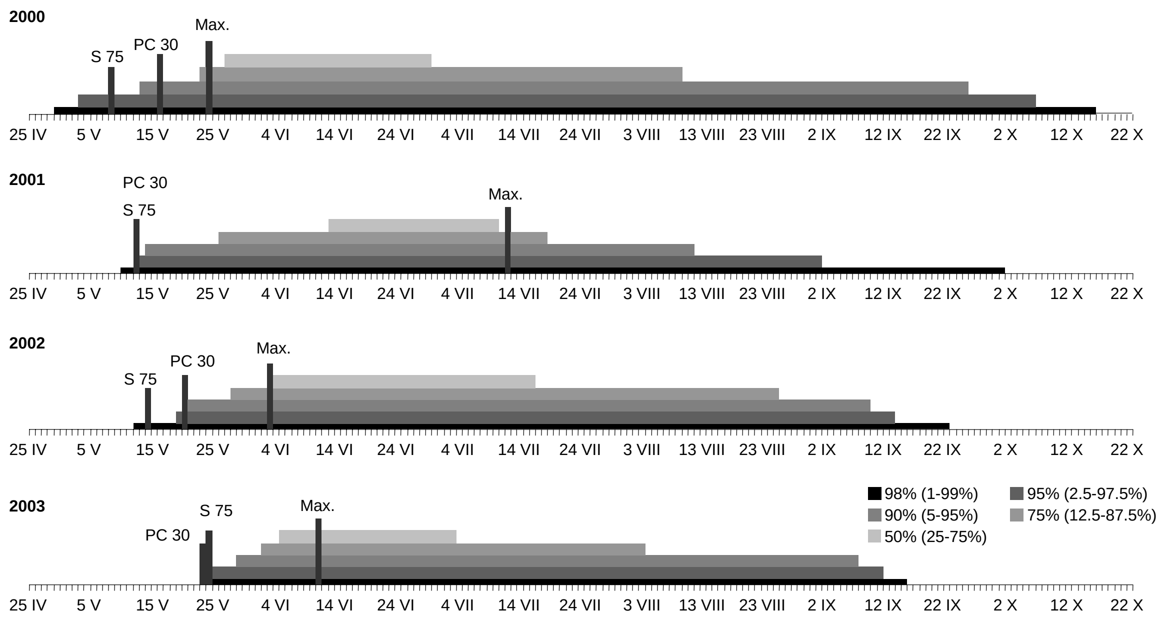

Figure 1. The starting and ending dates of the Poaceae pollen seasons 2000-2003; the following stages of the pollen season: 98% (1-99%), 95% (2.5-97.5%), 90% (5-95%), 75% (12.5-87.5%), 50% (25-75%) of the total annual pollen grains; Max. – maximum of pollen counts per 24 h, PC 30 – the method of 30 grains, S 75 – the method of 75 grains sum.

Pomorzany, Żelechowa, Majowe). Gravimetric monitoring was performed using a modified Durham trap [7, 23]. Pollen fall was expressed as the number of pollen grains at 1 cm^2 per 24 h [3].

The beginning and end of the seasons were established by the 95% method, i. e. the pollen season was defined as the period in which 95% of the annual total catch occurred [1]. Additionally, analysis of the annual sums of pollen in particular years permitted a characterisation of pollen seasons. In order to do this, the pollen seasons were determined by the method of 98% and 90%; these pollen seasons were defined as the period in which 98% and 90% of the annual total catch occurred [10, 13, 34]. The main pollen season was determined by the method proposed by Stach [36], assuming as the values limiting the beginning and end of the main season as 25% and 75% of the annual pollen sums. When this method was applied the seasonal maxima and days with high pollen count (above 30 grains) were noted outside the main pollen season, therefore, this method was modified. The beginning and end of the main pollen season were the days on which the airborne pollen count was 12.5% and 87.5% of the annual pollen sum. The prediction of the beginning of the pollen season was based on the method of 30 grains [2, 25] and the method of the sum of 75 grains [5, 34]. The beginning of the season determined by the method of 30 grains occurs on the day on which the mean daily pollen count reaches 30 grains in 1 m^3. In the method of the sum of 75 grains, the beginning of the season happens on the day when the accumulated day pollen count reaches or exceeds 75 grains.

The meteorological data for 2000–2003 were provided by the meteorological station in the Dąbie district of Szczecin. The meteorological parameters taken into regard in assessment of the effect of meteorological conditions on the airborne pollen count were: daily level of precipitation, wind speed, relative humidity and air temperature, as these factors have been known to influence pollen season [1, 21, 41].

Statistical analysis of the results was made on the basis of the percent contributions and accumulated sums. The degree of correlation between particular meteorological parameters and the concentrations of grass was described by the Pearson's correlation coefficient r (statistical error risk was estimated at the significance level of 95%, $\alpha = 0.05$) [26].

RESULTS

In subsequent seasons in 2000–2003, a considerable increase in the pollen count of Poaceae in Szczecin was observed. However, this tendency was not reflected by the annual pollen count sums. The lowest annual sum of sporomorphs of 2,094 grains was noted in 2000, while in the other seasons its values were close and equal to about 6,000 grains (Tab. 1). From among the 4 Poaceae pollen periods analysed, the lowest day pollen count of 123 grains in 1 m^3 per 24 h was noted in 2000. The highest pollen count was noted in 2003 and equal to 809 grains in 1 m^3 per 24 h (Tab. 1, Fig. 2, 3).

Table 1. Results of aerobiological study of grass pollen counts.

Taxon		2000	2001	2002	2003
Poaceae	ps	3 V–6 X (157)	13 V–1 IX (112)	19 V–13 IX (117)	25 V–11 IX (109)
	tn	2094	5620	6156	5861
	max	123	312	502	809
	tpc	24	47	55	48

ps – pollen season established by the 95% method (with number of days), tn – total number of pollen grains collected in the pollen season established by the 95% method, max – maximum number of pollen grains per 24 h, tpc – the number of days with pollen count above 30 pollen in 1 m^3 threshold of pollen counts at which allergy symptoms develop [28].

As the family Poaceae is represented by many taxa, the pollen seasons were long and the diagrams in subsequent years had many peaks. The pollen seasons determined by the method of 95% lasted in Szczecin from 109 days in 2003 to 157 days in 2000 (Tab. 1). Analysis of the duration of the pollen seasons against the intensity of pollen release of Poaceae leads to the conclusion that shorter pollen seasons are characterised by higher annual sums of sporomorphs, and vice versa in longer pollen seasons when the annual pollen sums are lower.

Starting from the third decade of May to the first decade of August and then in the first days of September, in the air over Szczecin the pollen count was very high. During this time, allergic persons develop symptoms of pollinosis. In the years studied the period in which the grass pollen count exceeded the threshold value of 30 grains in 1 m^3 per 24 h in Szczecin lasted from 47–55 days 2000 it was shorter and lasted only 24 days (Tab. 1).

The dates of the beginning of the pollen season and the dynamics of the seasons vary considerably, which is illustrated by the 5 subsequent periods with the pollen counts equal to 98%, 95%, 90%, 75% and 50% of the annual pollen sum (Fig. 1). The duration of particular periods depends on the weather conditions, mainly temperature of the air and precipitations in spring and directly before pollen season.

In the 3 years analysed, the maximum grass pollen count was noted in the first phase of the pollen season, until 11 June at the latest. In 2001, the maximum pollen count was noted as late as 12 July (Fig. 1). The delay was due to adverse weather conditions in this year, the vegetation season started late and was preceded by cold and wet early spring.

An important problem in the prophylactic of pollinosis is a correct prognosis of the beginning of the pollen season. In our study, we used for this purpose the method of 30 grains and the method of 75 grains sum. Results of the prognoses are presented in Figure 1. In 2001 and 2003, the dates of the beginning of the pollen season predicted by the 2 methods coincided. In 2000 and 2002, the beginning of the pollen season predicted by the method of the 75 grain sum was a week earlier than the

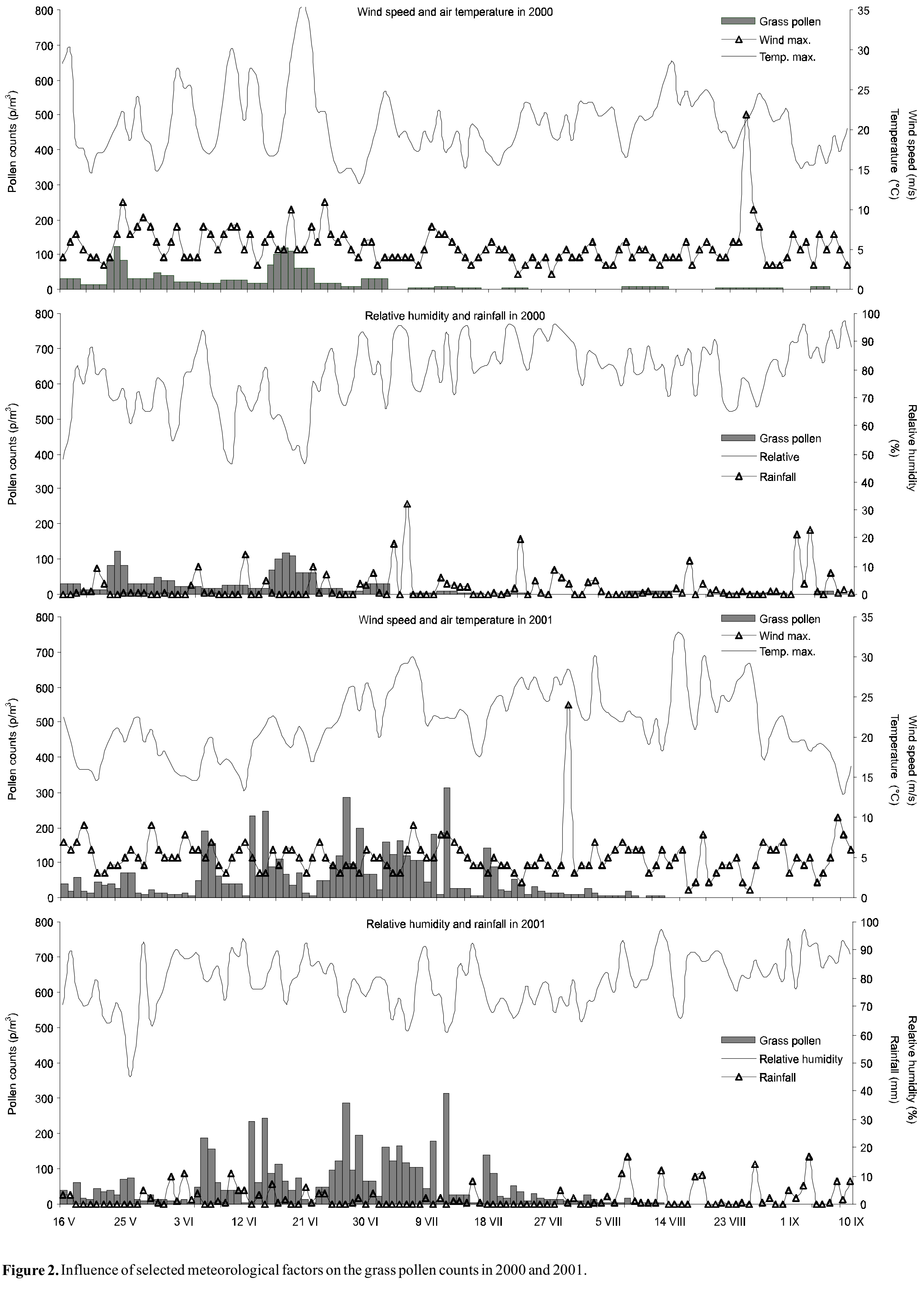

Figure 2. Influence of selected meteorological factors on the grass pollen counts in 2000 and 2001.

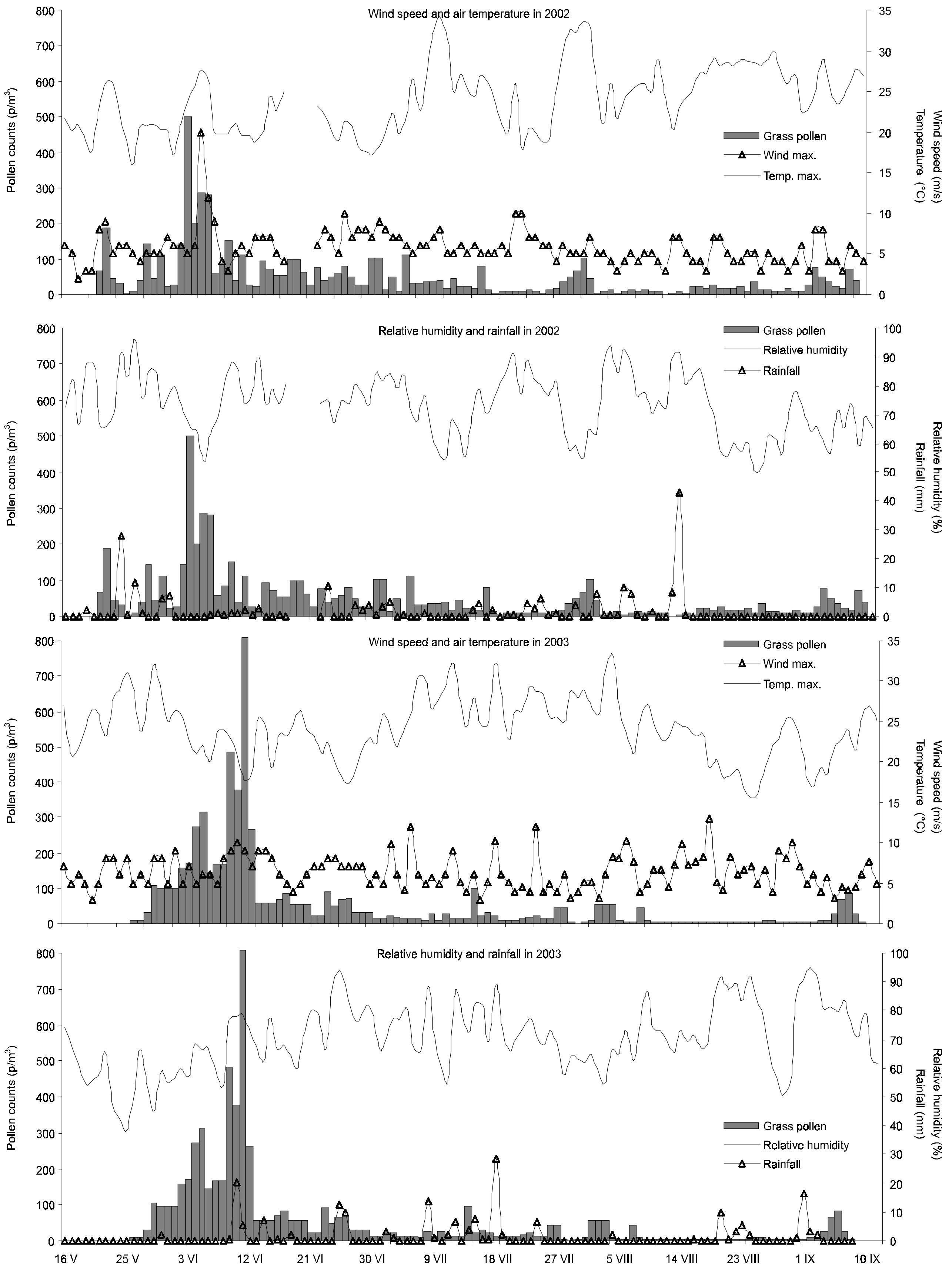

Figure 3. Influence of selected meteorological factors on the grass pollen counts in 2002 and 2003.

Table 2. Correlation coefficients between grass pollen counts and meteorological parameters.

Taxon	Years	Meteorological factors			
		Temperature max. (ºC)	Rainfall (mm)	Wind speed max. (m/s)	Relative humidity (%)
Poaceae	2000	0.2904*	-0.2273*	0.2410*	-0.5541*
	2001	0.2875*	-0.2529*	-0.1093	-0.2273*
	2002	-0.0253	-0.1307	0.3636*	-0.2161*
	2003	0.2170*	-0.1101	0.0816	-0.4313*

*Correlation statistically significant (p<0.05).

date obtained by the method of 30 grains. The method of 30 grains is based on the threshold value of the pollen count at which allergic persons develop pollinosis. The results obtained by the method of 30 grains are consistent with those determined by the method of 95%.

Apart from the individual rhythm of plant pollen season, weather conditions belong to the most important factors determining the dispersion and content of pollen in the air. In most of the seasons studied, the pollen count of Poaceae was statistically significantly correlated with the weather factors analysed (Tab. 2). The beginning of the pollen season of grasses was usually noted at the time when the maximum day temperature exceeded 17ºC (Fig. 2, 3). In 3 of the 4 seasons studied, a positive and statistically significant correlation was observed between the grass pollen count and the maximum air temperature.

In all the seasons the pollen count was negatively and statistically significantly correlated with the relative air humidity (Tab. 2). An increase in the relative air humidity is usually related to a decrease in the pollen count in the aeroplankton; however, in these conditions, grass sporomorphs often break and the cytoplasmatic mass with the allergenic proteins is released. This phenomenon explains the aggravation of allergy symptoms in the conditions of high air humidity during the pollen season of Poaceae.

Analysis of the pollen distribution in different Szczecin city districts determined by the gravimetric method, has shown that higher exposure to grass pollen allergens occurs in the Żelechowa and Śródmieście districts, in the area with parks, villas and gardens or garden allotments, rather than in the Majowe district which is characterised by closely built blocks (Fig. 4).

Exposure to grass pollen allergens was very high in the whole city during the pollen season, and the threshold values of pollen concentration were usually exceeded.

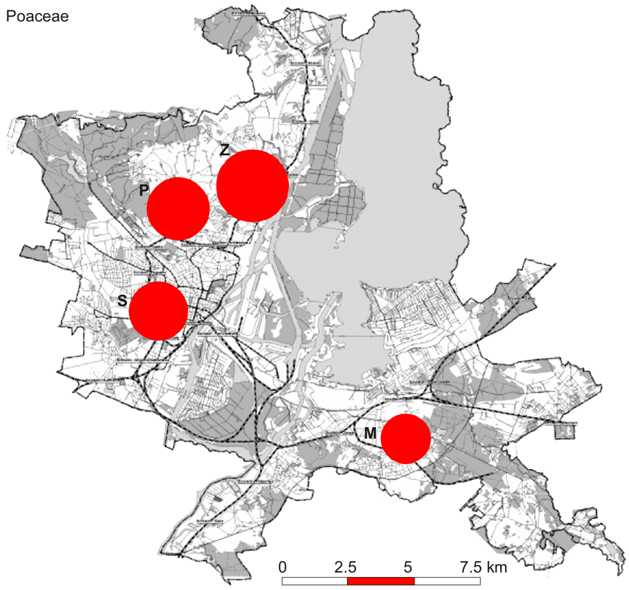

Figure 4. Differences in the grass pollen concentration in the 4 districts of Szczecin city, on the basis of the mean results collected in 2000–2002 (districts: Z – Żelechowa, P – Pomorzany, S – Śródmieście, M – Majowe).

DISCUSSION

In summer, pollinosis is most often evoked by grass pollen allergens. The Poaceae sporomorphs occur abundantly over the majority of the area of Poland from the second half of May until the second decade of August [17, 27, 36]; this situation is also met in Szczecin. In Greece, the grass pollen are noted from March until June [37], while in Spain, all the year round [32]. In the pollen calendar of Cracow, Szczepanek [38] indicated the presence of grass pollen in aeroplankton for many months. However, the pollen count in the air beyond the pollen season was low and the grains probably came from redeposition.

On the basis of results of the aeropalinological studies carried out all over the world, attempts have been undertaken to establish tendencies of pollen count changes on the macro-region scale. The increasing tendency of grass pollen count in the air has been noted in Genoa [43] and in Stockholm [8], while a tendency towards decreasing pollen count of Poaceae has been observed in Brussels [6]. In the long-term observations conducted in Denmark, The Netherlands, Belgium and Great Britain, no distinct trends have been established [35]. In Szczecin, a tendency towards increasing grass pollen count was observed during the years 2000–2003. Such differences are most probably caused by phenology of florescence of many grass species.

On the basis of analysis of the seasonal dynamics in the pollen calendars, Szczepanek [38] and Kasprzyk [17] distinguished 2 groups of taxa of different courses of pollen seasons. The first group includes the taxa whose pollen season is characterised by compact single-peak seasons. The second group, comprising also grasses, includes the taxa whose pollen seasons are long and show many peaks in subsequent years. Analogous character of the pollen seasons of Poaceae was been observed in Szczecin, and also in Poznań [36] and Lublin [27].

The dates of the beginning of the pollen seasons of grasses noted in subsequent years were very different. The differences were accounted for by the weather conditions, especially the air temperature in spring and the amount of precipitations in the period before pollen season [10, 18, 25]. The study performed by Rodriguez-Rajo *et al.* [31] in Spain has shown that the dates of the beginning of the grass pollen seasons in the years 1999–2001 differed by 16 days. In Szczecin, the pollen season usually started in the middle of May, but the differences between the dates in subsequent years differed by 3 weeks.

One of the methods for prediction of the beginning of the pollen season is that of the 75 grains sum. The beginning of the pollen season determined by this method occurs on the day on which the accumulated day pollen sum is 75 grains [5, 34]. Kupias *et al.* [20] and Mesa *et al.* [25] proposed that the beginning of the main pollen season of Poaceae should be the day on which the day pollen count reaches or exceeds 30 grains in 1 m^3 per 24 h, because this is the threshold value at which the symptoms of pollinosis are observed. In our study conducted in Szczecin, both methods were applied. The results obtained by the method of 30 grains coincided with the beginning of the pollen season determined by the method of 95%. The period over which the grass pollen count exceeded the threshold value of 30 grain in 1 m^3 per 24 h in Szczecin varied from 24–55 days, while in Lugo, Spain, the period in which the pollen count exceeded 25 grains in 1 m^3 per 24 h varied from 42–45 days [31].

The weather conditions belong to important factors affecting the airborne pollen count. In Szczecin, correlations between the pollen content in the air and the maximum day temperature, maximum wind speed, amount of precipitation and relative humidity have been analysed. Increasing pollen count in the air with decreasing relative humidity has been noted e.g. by Emberlin *et al.* [10], Stach [36] and Vega-Maray *et al.* [41]. The same tendency was observed in Szczecin in all the seasons studied, while a statistically significant decrease in the airborne pollen count after rainfalls was noted only in 2000 and 2001. In the other 2 seasons, no such correlation was observed. Moreover, during scant rainfalls, the water particles suspended in the air cause swelling of sporomorphs and cytoplasmic mass escapes out of the grains [14], which can enhance exposure to the pollen allergens. In Szczecin, in the majority of the seasons analysed, a positive and statistically significant correlation was found between the grass pollen count and the day maximum air temperature. Similar results in other cities have been obtained by e.g. Stach [36], Mesa *et al.* [25], Piotrowska and Weryszko-Chmielewska [27], Rodriguez-Rajo *et al.* [31]. Norris-Hill [22] has observed that the highest pollen count of Poaceae occurred on the days with a maximum air temperature of 21.1÷25ºC. In Szczecin, the maximum pollen counts in the seasons were recorded at the maximum temperature of 20÷22ºC. The significance of the wind for the process of pollen release and dispersal has been discussed by Emberlin *et al.* [11], Gassmann *et al.* [12], and Stach [36]. In Szczecin, a positive correlation between the pollen count and the wind speed was noted in 2000 and 2002.

Emberlin and Norris-Hill [9] studied spatial distribution of the Poaceae pollen fall at 14 measuring sites in London. Their results indicated that the differences in the grass pollen fall intensity depend on variable wind directions, and on the distance between the measuring point and the source of emission. In Szczecin, the high pollen fall was noted over the whole city and the reasons for the observed variation were, similar to London, the weather factors. The study by Stach [36] in Poznań has shown that the differences in the spatial distribution of the pollen fall depend also on the mode of the space use. Higher values of the annual sums of pollen of herbal plants were measured in areas with detached houses and gardens. A similar situation was observed in Szczecin. The relation of the spatial differences in the pollen fall and the mode of the space use may be of importance for people with allergy living in a given area.

CONCLUSIONS

- The grass pollen count in the air of Szczecin showed a tendency to increase; however, this observation needs to be confirmed by long-term studies.
- As follows from analysis of the duration and dynamics of the grass pollen seasons, in shorter pollen seasons the annual sums of sporomorphs are higher, while in longer pollen seasons these sums are lower.
- The method of 30 grains has been found to be more effective for prediction of the beginning of the highest exposure period to grass pollen allergens than the method of the 75 grains sum.
- In most of the seasons studied, the pollen count of Poaceae was statistically significantly correlated with the weather factors analysed. Only in the case of relative humidity was a statistically significant correlation observed in all pollen seasons studied.
- Analysis of the pollen distribution in different Szczecin city districts has shown that the highest exposure to grass pollen allergens occurs in the districts Żelechowa and Śródmieście, in the area with parks, villas and gardens or garden allotments, rather than in the district Majowe, characterised by closely built blocks.

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