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ORIGINAL ARTICLE

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The influence of temperature, relative humidity and rainfall on the occurrence of pollen allergens (*Betula*, *Poaceae*, *Ambrosia artemisiifolia*) in the atmosphere of Bratislava (Slovakia)

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Abstract The occurrence of pollen grains in the atmosphere markedly relates to meteorological factors. In the study we have evaluated a correlation between the concentration of pollen grains in the atmosphere of Bratislava and temperature, relative humidity and rainfall during the vegetation period of 1995 and 1997. For our analysis we have selected one representative of each phytoallergen group (trees, grasses, weeds). We have chosen the *Betula* genus of trees, the whole *Poaceae* family of grasses and ragweed *Ambrosia artemisiifolia* L. to represent weeds. The taxons mentioned represent the most significant allergens in Slovakia. The concentration of pollen grains has been monitored by a Lanzoni volumetric pollen trap. The data obtained, the average daily concentration in 1 m^3, have been included in the statistical analysis together with values for the average daily temperature, relative humidity and total rainfall in 24 h. The correlation between the concentration of pollen grains in the atmosphere and selected meteorological variables from daily monitoring has been studied with the help of linear regression and correlation coefficients. We have found the average daily temperature and relative humidity (less than temperature) to be significant factors influencing the occurrence of pollen grains in the atmosphere of Bratislava. The total daily rainfall does not seem to be significant from the statistical point of view.

Keywords Aeropalynology · Temperature · Relative humidity · Rainfall · Slovakia

Introduction

Phytoallergens include taxons of various botanical families. According to their migration they are classified as anemophilous or entomophilous allergens. Anemophilous species often causing allergic diseases produce a huge quantity of readily airborne pollen grains. They gently disperse in the air and are carried a long distance. Those of entomophilous species are usually bigger and heavier, so that they rapidly drop onto a soil surface, where they are usually inactivated. Meteorological factors are very important for the occurrence of pollen grains in the air. Dry and hot weather speeds up maturation and the loosening of pollen grains from anthers, and the concentration of pollen grains is considerably higher than in cold and wet weather.

In 1994 the Pollen Information Service was founded in Bratislava (Zlinská 1995). Its work in 1995 and 1997, as well as the monitoring of average daily concentration of pollen grains in the atmosphere, helped us to study weather variables and their effects on the atmospheric concentration of pollen grains. We have assumed that temperature, relative humidity and rainfall represent the most significant factors for pollen concentration.

The monitoring station is located on the roof of the Ružinov Hospital (Fig. 1) between two meteorological stations (Bratislava-Airport, Bratislava-Petržalka) that provided data for our analysis. Meteorological characteristics vary in a daily cycle in the whole area of Bratislava as well as in all the districts. We have therefore used data from two meteorological stations to obtain adequate information on the meteorological conditions at the site where the pollen trap was situated (on the roof of the Ružinov Hospital).

The meteorological station Bratislava-Airport, situated in the NE part of the city, is about 3.5 km north of Ružinov Hospital. It is located in an open landscape experiencing meteorological conditions that are somewhat different from those of the urban area. It lies at an altitude of 133 m above sea level (geographically 48°10′ north and 17 °12′ east). The Bratislava-Petržalka meteorological station is located 4.5 km south of the Hospital of Ružinov and is surrounded by blocks of flats. It provides a more adequate projection of the meteorological variables typical of the urban area. It lies at an

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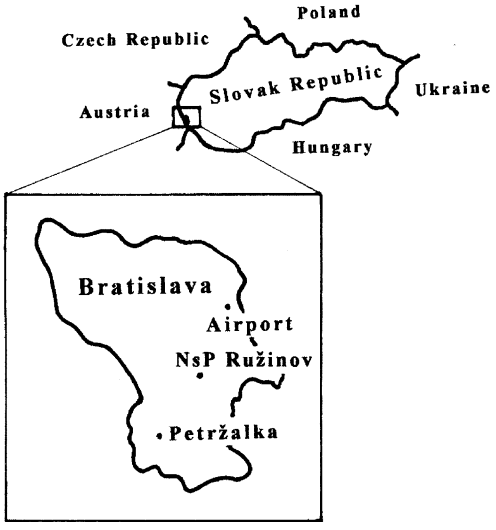

Fig. 1 Geographical location of Bratislava

altitude of 137 m above sea level (geographically 48°07′ north and 17°07′ east).

Material and methods

For the evaluation of allergenic plants we have chosen those occurring in the vegetation of Bratislava and widespread in Slovakia. To monitor the whole vegetation period (the flowering periods of pollinose species are distributed over a whole year) we have selected representatives of each pollen allergen group (trees, grasses, weeds) from various phenological periods (Jurko 1990). During each phenological period some climatic variables have greater or lesser effects on the concentration of pollen grains in the atmosphere. Aggressive phytoallergens were selected for the study, on the basis of skin tests carried out in Bratislava (Hrubiško 1996). According to this criterion, the trees *Alnus glutinosa, Betula pendula* and *Carpinus betulus*, the grasses *Lolium perenne, Agrostis alba* and *Secale cereale* (*Poaceae*) and the weeds *Artemisia vulgaris, Matricaria chamomilla* and *Ambrosia artemisiifolia* represent the strongest phytoallergens in Bratislava. The high concentration of the pollen species in the atmosphere and hence high allergisation potential were also important and we chose species with characteristic and easily determinable pollen grains. For the trees we chose the genus *Betula* (*B. pendula* and *B. pubescens*), flowering in the middle of spring (3rd decade of April to 1st decade of June). The *Betula* genus represents the strongest tree allergens in Central and Northern Europe (Eriksson et al. 1984, 1987; D'Amato and Spieksma 1992; Welten and Sutter 1982; Oei et al. 1986; Hrubiško 1996). For grasses we selected the whole family of *Poaceae*, since determining the species of pollen grains by this method is thought impossible because of their considerable variability. Grasses of the *Poaceae* family bloom in late spring, from the second half of May till the second half of June. Their pollen is a dominating allergen in Central Europe as well as in Great Britain and a large area of Asia (D'Amato et Spieksma 1990; Zawisza et Samolinska-Zawisza 1991; Jäger et al. 1991, Galán et al. 1995). The neophytic plant *Ambrosia artemisiifolia* of the *Asteraceae* family, flowering in autumn (from the 3rd decade of August), seemed to be suitable for our analysis. From the allergological point of view it is one of the most important pollen allergens in North America (Rogers et al. 1996). Also it is a significant allergen in Central Europe (Hungary, former Yugoslavia, Czech Republic, Slovakia, Austria) and occasionally in France and Switzerland (Rybníček and Jäger 2001). All of the three pollen types (*Betula, Poaceae* and *A. artemisiifolia*) are considered anemophilous phytoallergens.

The average daily concentrations of pollen allergens have been taken from the database of pollen allergens in Bratislava, providing data for the Pollen Information Service. The years 1995 and 1997 have been selected for the analysis. Monitoring took place from the 3 April to the 30 September 1995 with an interruption between 12 and 18 June, while in 1997 it took place from 3 March to the 19 October.

The number of pollen grains in the atmosphere was monitored by a Lanzoni volumetric pollen trap, situated on the roof of the Ružinov Hospital in the 2nd Bratislava district at a height of 12 m above ground and an altitude of 145 m above sea level; the geographical location was 48°09′14″ north and 17°09′14″ east (Fig. 1). The capacity (10 l air/min) through the sampling gap (2 × 14.4 mm) meant a volume of 14.4 m^3 day, an international standard used for monitoring pollen counts in the atmosphere. To count the pollen grains in a daily sample the method of four longitudinal transects has been used. Counting four lines with a view size of 250 μm for a daily sample (1 mm in total) represents an average daily content of pollen and spores in 1 m^3 air (Lux and Erdelská 1998). The pollen grains were determined according to Erdtman (1969) using an optical microscope.

To explain the quantity of pollen grains in the atmosphere, apart from biological factors, three meteorological variables, recorded at two meteorological stations Bratislava-Airport and Bratislava-Petržalka during 1995 and 1997 (Archive of the Slovak Hydrometeorological Institute, SHMU), were considered to be the most important: temperature (°C), percentage relative humidity (%) – average values of data measured at 7 a.m., 2 p.m. and 9 p.m. local time, and rainfall (mm) for 24 h (7 a.m. till 7 a.m.).

The relation between the concentration of pollen grains in the atmosphere and selected meteorological variables, monitored daily, has been studied by linear regression analysis and by establishing Pearson's correlation coefficients, reflecting the extent of correlation. The importance of the correlation coefficients was judged with error probability levels (10%, 5%, 1%, 0.1%) in relation to the number of degrees of freedom, $v = n - 2$ (n = number of cases). Pollen grains of the *Betula* genus were captured in our pollen trap from 3 April to 5 May (n = 32) in 1995 and from the 2 April to 4 May (n = 32) in 1997. In 1995 we started sampling airborne particles when the birch pollen season began. We do not ignore the possibility of birch pollen appearing before sampling, but the quantity would be insignificant. Pollen grains of *Poaceae* species were captured from 26 May to 6 July (n = 41) in 1995 and from 19 May to 9 July (n = 51) in 1997, those of *A. artemisiifolia* from 9 August to 19 September (n = 31) in 1995 and from 17 August to 12 October (n = 56) in 1997.

Results

Using the linear regression method to evaluate any correlation between the concentration of pollen grains in the atmosphere of Bratislava and temperature, relative humidity and rainfall, we obtained the following data (Table 1).

Of the three meteorological variables analysed, air temperature seems to be the most significant for the occurrence of pollen grains in the atmosphere of Bratislava in 1995 and 1997, because all correlation coefficients (Table 1) show significant and positive correlations with an error probability between 0.1% and 5% (Fig. 2a–c, 3a–c). Relative humidity (Table 1) seems to correlate significantly with the occurrence of pollen grains in both 1995 and 1997, because all correlation coefficients were significant and negative with an error probability between 1% and more than 10% (Fig. 2d–f,

Table 1 Evaluation of statistical significance in the correlation studied, using the error prabability (*r* correlation coefficient, *T* temperature, *H* relative humidity, *R* rainfall, $\alpha_{(\%)}$ error probabilty, *Bet Betula*, *Poa Poaceae*, *Amb Ambrosia artemisiifolia*), *BA-Airport* Bratislava-Airport, *BA-Petržalka* Bratislava-Petržalka

Station and year	Taxon	Temperature		Humidity		Rainfall	
		r_T	$\alpha_{(\%)}$	r_H	$\alpha_{(\%)}$	r_R	$\alpha_{(\%)}$
BA-Airport 1995	Bet	0.52	0.1–1	–0.37	1–5	–0.29	5–10
	Poa	0.37	1–5	–0.42	0.1–1	–0.11	>10
	Amb	0.41	1–5	–0.34	5–10	–0.24	>10
BA-Petržalka 1997	Bet	0.67	<0.1	–0.23	>10	–0.06	>10
	Poa	0.43	0.1–1	–0.38	0.1–1	–0.24	5–10
	Amb	0.65	<0.1	–0.14	>10	0.18	>10

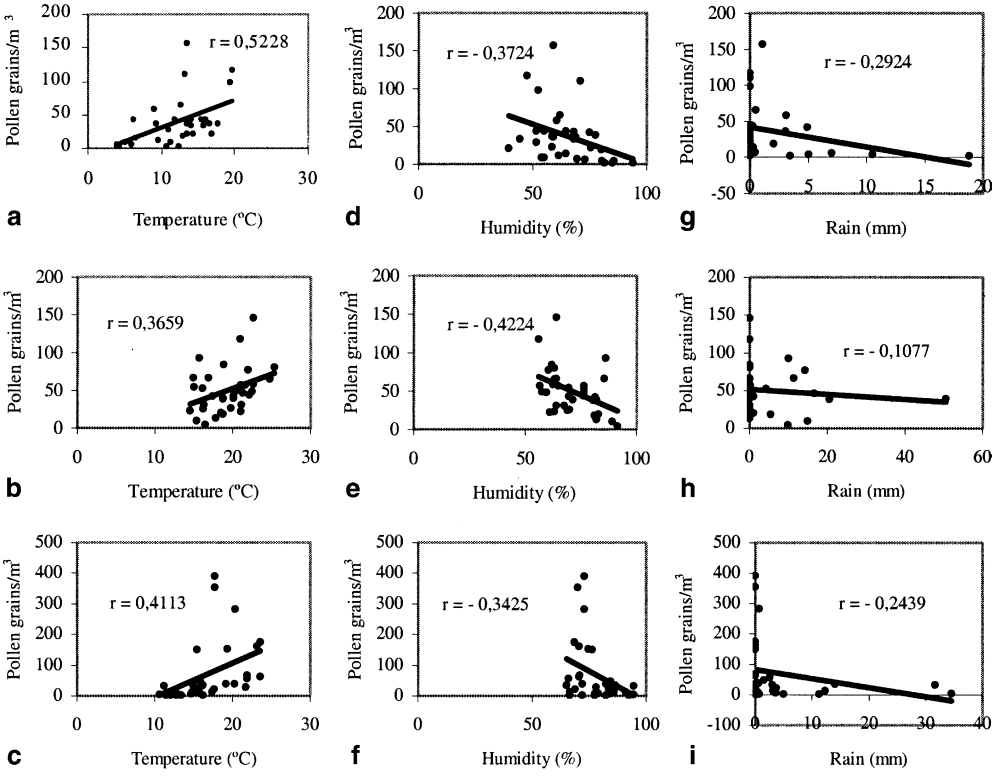

Fig. 2a–i Concentration of pollen grains (*Betula* **a, d, g**, *Poaceae* **b, e, h**, *Ambrosia* **c, f, i**) in relation to temperature, relative humidity and rainfall in Brastilava in 1995

3d–f). Correlation between rainfall and the concentration of pollen is lower and not significant, because all correlation coefficients show weak negative correlations with an error probability between 5% and more than 10% (Fig. 2g–i, 3g–i). Higher relative humidity and more rain corresponded with a lower concentration of pollen grains in the atmosphere. A heterogeneous timing of rainfall during a day would probably cause these lower correlations. For example, if it started to rain in the afternoon and it had been sunny in the morning, a daily sample could include a significant amount of pollen grains. To obtain more representative data it would be necessary to study not only the total rainfall in 24 h but also the duration and intensity of the rainfall during exactly timed periods in a day. In comparison with the statistical analysis, graphs of the total *Betula, Poaceae* and *A. artemisiifolia* pollen grains over time seem to be more representative (Fig. 4a, b) showing a negative correlation between the concentration of pollen grains and rainfall for shorter periods during the vegetation period in 1995. The line charts show that the occurrence of pollen grains in the atmosphere is considerably influenced by longer periods (several hours or even days) of rain when there is a decrease in concentration of pollen grains in the atmosphere.

Discussion and conclusion

The analysis of a statistical correlation of meteorological variables with occurrence of pollen allergens in the atmosphere of Bratislava during 1995 and 1997 shows that the most important variable studied was temperature, which markedly influenced the production of pollen grains in the atmosphere.

Relative humidity represents an important factor as well. Its effect is considerable but not as high as that of temperature. Rainfall does not seem to be significant. Barnes et al. (2001) studied the influence of temperature, relative humidity and rainfall on the occurrence of ragweed pollen grains in the atmosphere. They concluded

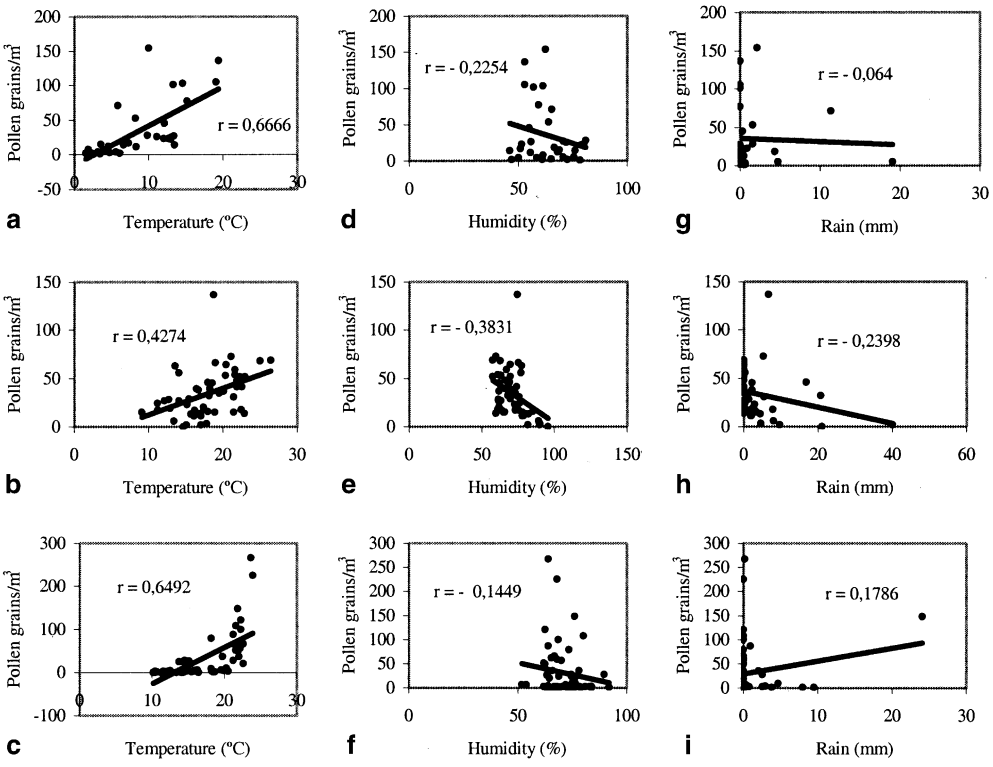

Fig. 3a–i Concentration of pollen grains (*Betula* **a, d, g**, *Poaceae* **b, e, h**, *Ambrosia* **c, f, i**) in relation to temperature, relative humidity and rainfall in Brastilava in 1997

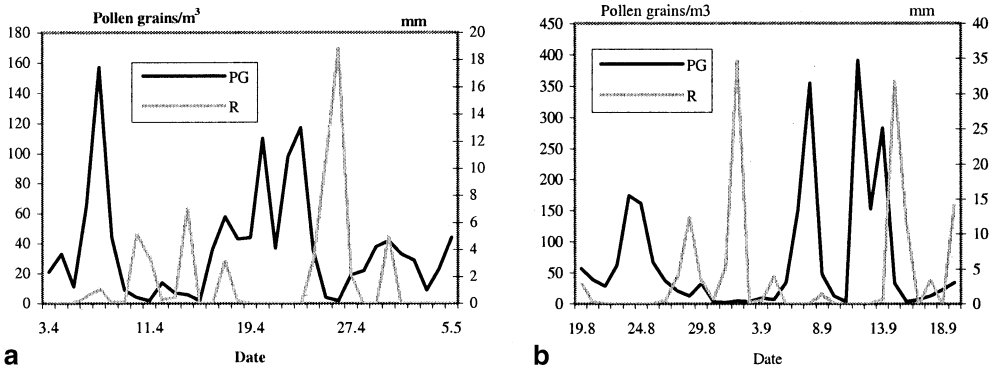

Fig. 4a, b Total concentration of pollen grains in the atmosphere of Bratislava in relation to rainfall on certain days of 1995 (*PG* pollen grains, *R* rain)

that, under normal weather conditions, temperature and relative humidity have minimal effects on the day-to-day ragweed pollen counts; however, unstable atmospheric conditions, such as the passing of a cold front, had the greatest impact of all the weather-related events on airborne ragweed pollen counts. According to the authors, rainfall, except for heavy and intens rain, does not markedly influence the amount of pollen in the atmosphere. These facts support our assumptions, apart from the effect of rainfall where we had supposed a higher correlation; but, as we have already mentioned, only daily rainfall was measured. The correlation may be higher with shorter periods, which would allow us to establish the number of pollen grains exactly during rainy hours and also during hours with no rain. Of course we emphasise any remarkable correlation according to the cumulative influence of all the factors analysed, because none of them work individually in nature. We also realise a certain relativity in our conclusions because of the remarkable geomorphological complexity of Bratislava as well as considerable meteorological heterogeneities.

We suggest that the results of this study will be helpful for future investigations of the factors influencing pollen grains in the atmosphere and hence also of the occurrence of allergic diseases.

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