Daily changes of ragweed pollen concentrations in the function of climate parameters at Szeged, Hungary

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Abstract The paper analyzes daily changes of *Ambrosia* pollen counts for Szeged (July 15 – October 16, 1997-2006), Southern Hungary in the function of climate parameters. The database comprises the daily ratios of Ambrosia pollen counts (A) (value on the given day per value on the day before) for its pollen season. However, daily values (value on the given day – value on the day before) of 8 meteorological variables (mean temperature, minimum temperature, maximum temperature, temperature range, irradiance, relative humidity, wind speed and rainfall) are considered for the period April 1 – October 31, 1997-2006. When using a novel procedure, factor analysis with special transformation, wind speed, rainfall and temperature range are the most significant, while minimum temperature and irradiance are the least important meteorological variables influencing daily pollen ratios, respectively. After dividing the total data set into two groups, a tendency of stronger associations between the meteorological variables and the pollen variable is found in the data set for which $A \leq 1.00$, compared to that for which $A > 1$. Its reason is that the data set for which $A \leq 1.00$ can be associated to lower summer temperatures with near-optimum phyto-physiological processes, while the category $A > 1.00$ is involved with high and extreme high temperatures modifying life functions and, hence, interrelationships of the meteorological and pollen variables.

Keywords: ragweed, allergenic pollen, respiratory diseases, meteorological elements, physiological processes, pollen transport

1 Introduction

Air pollution, as a major and ever increasing hazard for the environment and is associated with persistent increases in expenses of social insurance (Cohen et al. 2005). The prevalence of allergic respiratory diseases has also increased extensively during the last three decades, (D'Amato 2002).

Pollen allergy has become a widespread disease by the end of the 20th century. Recently, around 20% of the population, as an average, suffers from this immune system disease in Europe (D'Amato et al. 2007). Hungary is exposed to one of the most severe air pollution in Europe (Ågren 2010); in addition, airborne pollen levels here are also high. The Carpathian basin, comprising Hungary (Fig. 1) is considered the most polluted region with airborne ragweed (*Ambrosia*) pollen in Europe (Štefanič et al. 2005, Peternel et al. 2006, Ianovici and Sîrbu 2007, Chrenová et al. 2009, Šikoparija et al. 2009).

However, meteorological elements affect pollen concentration not by means of their individual values but through their interrelationships. Accordingly, it is practical to study the association of daily ragweed pollen concentration with daily values of meteorological elements as a whole. Only relatively few papers have reported results of such approaches using multivariate statistical analysis techniques. They generally define the most homogeneous groups as objective classes of meteorological elements (Makra et al. 2006, Hart et al. 2007, Makra et al. 2008, Tonello and Prieto 2008) using factor and cluster analyses in order to associate them with a given pollen variable.

The aim of the study is to analyze the potential reasons of day-to-day variations of *Ambrosia* pollen counts for Szeged region of Southern Hungary in association with meteorological elements. For this purpose, a factor analysis with special transformation is performed on the daily meteorological and *Ambrosia* pollen data in order to find out the strength and sign of associations between meteorological (explanatory) variables and *Ambrosia* pollen (resultant) variable. Factor analysis with special transformation is a unique procedure in the special literature that has not yet been applied for studying this kind of task.

2. Materials and methods

2.1 Location and data

Szeged (46.25°N; 20.10°E) is the largest settlement in South-eastern Hungary (Fig. 1). The area is characterized by an extensive flat landscape of the Great Hungarian Plain with an elevation of 79 m above mean sea level. The built-up area covers a region of about 46 km^2. The city is the centre of the Szeged region with 203,000 inhabitants. The pollen content of the air was measured using a 7-day recording “Hirst-type” volumetric trap (Hirst 1952). The air sampler is located about 20 m above the ground (Fig. 1, lower panel).

Fig. 1 Location of Europe with Hungary and the urban web of Szeged with the positions of the data sources.1: meteorological monitoring station; 2: aerobiological station

The analysis was performed for a ten-year period 1997-2006. Within this term, daily *Ambrosia* pollen counts were analyzed for its pollen season (July 15 – October 16) (Fig. 2). At the same time, daily values of 8 meteorological variables [mean temperature, T_{mean}; minimum temperature, T_{min}; maximum temperature, T_{max}; temperature range, as the difference of maximum and minimum temperatures, $\Delta T(=T_{max}-T_{min})$; irradiance, I; relative humidity, RH; wind speed, V and rainfall, R] were considered between April 1 and October 31 for the above-mentioned 10-year period.

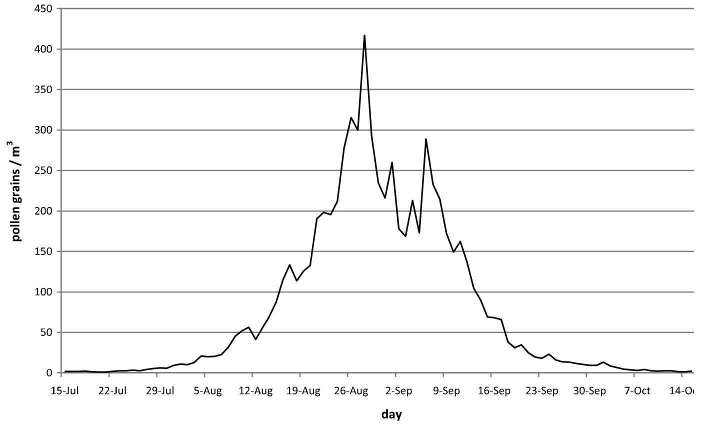

Fig. 2 Mean daily *Ambrosia* pollen counts in its pollen season (July 15 – October 16), Szeged, 1997-2006

2.2 Methods

2.2.1 Factor analysis with special transformation

Factor analysis identifies any linear relationships among subsets of examined variables and this helps to reduce the dimensionality of the initial database without substantial loss of information. First, a factor analysis was applied to the initial dataset consisting of 8 variables (7 meteorological parameters as explanatory variables and daily ratios of *Ambrosia* pollen counts as resultant variable) in order to transform the original variables to fewer variables. These new variables (called factors) can be viewed as latent variables explaining the joint behaviour of meteorological – *Ambrosia* pollen variables. The optimum number of retained factors can be determined by different statistical criteria (Jolliffe 1993). The most common and widely accepted one is to specify a least percentage (80%) of the total variance in the original variables that has to be achieved (Liu 2009). After performing the factor analysis, a special transformation of the retained factors was made to discover to what degree the above-mentioned explanatory variables affect the resultant variable, and to give a rank of their influence (Jahn and Vahle 1968). When performing factor analysis on the standardized variables, factor loadings received are correlation coefficients between the original variables and, after rotation, the coordinate values belonging to the turned axes (namely, factor values). Consequently, if the resultant variable is strongly correlated with the factor; that is to say, if the factor has high factor loading at the place of the resultant variable, and within the same factor an influencing variable is highly correlated with the factor, then the influencing variable is also highly correlated with the resultant variable. Accordingly, it is advisable to combine all the weights of the factors, together with the resultant variable, into one factor. Namely, it is effective to rotate so that only one factor has great load with the resultant variable. The remaining factors are uncorrelated with the resultant variable; that is to say, are of 0 weights (Jahn and Vahle 1968). This latter procedure is called special transformation.

3. Results and Discussion

The analysis of day-to-day variations of *Ambrosia* pollen counts is an important area of pollen researches, due to its immediate association with public health. Our study can be considered specific, since these kinds of papers have not been found in the international literature, accordingly *Ambrosia* pollen, the most allergenic pollen type has neither been studied from this point of view. A novel procedure is applied in our study; namely, factor analysis with special transformation.

Factor analysis with special transformation was applied in order to examine the role of the meteorological variables in day-to-day variations of *Ambrosia* pollen concentrations and to determine their rank of importance in influencing daily ratios of *Ambrosia* pollen counts.

Rainfall (R) belongs to the first two most important meteorological parameters for all three data sets, except for category (b) for which $A \leq 1.00$ (Table 2). However its association with daily ratios of *Ambrosia* pollen counts is different for categories (a) and (b). Namely, for category (a) rainfall is proportionally associated with daily pollen ratios in all three data sets (Tables 1-3). At the same time, for category (b) in the total data set (Table 1) and in that for which $A > 1.00$ (Table 3) rainfall is in an inverse association with daily pollen ratios.

Importance of mean temperature (T_{mean}) is varying and its role is ambivalent for the different data sets and categories (Tables 1-3). For category (a) in the total data set (Table 1) it is in a positive, while for categories (a) and (d) in the data set for which $A \leq 1.00$ (Table 2) it is in a negative association with daily pollen ratios, respectively.

Minimum temperature (T_{min}) is a relevant parameter for category (c) both in the data set for which $A \leq 1.00$ (Table 2) and for which ($A > 1.00$) (Table 3), indicating an inverse and a proportional association, respectively.

Maximum temperature (T_{max}) is an important variable representing a proportional association with daily pollen ratios for category (a) in the total data set (Table 1); at the same it is in a proportional and an inverse relationship with the resultant variable for categories (c) and (d) in the data sets for which $A \leq 1.00$ (Table 2) and for which ($A > 1.00$) (Table 3), respectively.

Temperature range (ΔT) is in a significant positive relationship with daily ratios of *Ambrosia* pollen counts for category (a) in the total data set (Table 1) and for category (c) in the data set for which $A \leq 1.00$ (Table 2). At the same time, these variables indicate an inverse association for categories (a) and (d) in the data set for which $A \leq 1.00$ (Table 2) and for category (c) in the data set for which $A > 1.00$ (Table 3). An increase in temperature range (ΔT) may occur through a decrease in minimum temperature (T_{min}) or an increase in maximum temperature (T_{max}) or both. The reason of an inverse relationship is that very low temperatures make a slower metabolism in the plant inducing a smaller pollen production, while in the case of extreme high temperatures the plant is forced to preserve water in its body for survival and, hence, decreases its pollen production.

Irradiance (I) represents a proportional and an inverse association with daily ratios of *Ambrosia* pollen counts for category (c) in the data sets for which $A \leq 1.00$ (Table 2) and for which $A > 1.00$ (Table 3), respectively. The proportional association is due to the fact that this variable contributes to maintaining elementary vegetative phyto-physiological processes that are important for producing pollen grains (Deák 2010).

Relative humidity (RH) is inversely associated with daily pollen ratios for category (c) in all three data sets, respectively (Tables 1-3). In general, pollen shedding is associated with shrinkage and rupture of anther walls by low relative humidity (Kozlowski and Pallardy 2002). Hence, relative humidity is inversely associated with pollen release (Bartkova-Ščevková 2003). Furthermore, humid air promotes sticking of pollen grains, which also contributes to an inverse association (affirmed by Kasprzyk 2008).

Wind speed (V) is associated with daily ratios of *Ambrosia* pollen counts inversely for category (a) in the total data set (Table 1), for category (b) in the total data set (Table 1) and in the data set for which $A > 1.00$ (Table 3) and for category (c) in the data sets for which $A \leq 1.00$ (Table 2), respectively. At the same time, this association is proportional for categories (a), (b) and (d) in the data set for which $A \leq 1.00$, respectively (Table 2).

Table 1 Special transformation. Effect of the daily differences in meteorological variables[1] on t
pollen counts[2] as resultant variables and the rank of importance of the explanatory variables on
formed to Factor 1 for determining the resultant variable (thresholds of significance: *italic:* x
bold: $x_{0.01}$)

[1]Daily differences in meteorological variables	[2]Daily ratios of *Ambrosia* pollen counts (A)	
	thresholds of significance	
	0.042	
	0.054	
	0.064	
	0.084	
	weight	rank
Ambrosia	-0.906	–
T_{mean}	**0.117**	2
T_{min}	**-0.088**	5
T_{max}	0.038	7
ΔT	*-0.046*	6
I	**-0.112**	4
RH	**-0.115**	3
V	-0.024	8
R	**0.393**	1

[1]: value on the given day – value on the day before;
[2]: value on the given day per value on the day before;
T_{mean} = daily mean temperature; T_{min} = daily minimum temperature, T_{max} = daily maximum temperature, ΔT = daily temperature range; I = irradiance, RH = relative humidity; V = wind speed; R = rainfall;

Table 2 Special transformation. Effect of the daily differences in meteorological variables[1] on the daily ratios of *Ambrosia* pollen counts[2] as resultant variables and the rank of importance of the explanatory variables on their factor loadings transformed to Factor 1 for determining the resultant variable (thresholds of significance: *italic:* $x_{0.20}$; *italic:* $x_{0.10}$; **bold:** $x_{0.05}$; **bold:** $x_{0.01}$)

[1]Daily differences in meteorological variables	[2]Daily ratios of *Ambrosia* pollen counts (A)			
	A ≤ 1		A > 1	
	thresholds of significance			
	0.059		*0.064*	
	0.076		*0.083*	
	0.090		**0.098**	
	0.118		**0.131**	
	weight	rank	weight	rank
Ambrosia	-0.838	–	-0.976	–
T_{mean}	**-0.415**	2	**0.147**	2
T_{min}	0.006	7	*-0.076*	3
T_{max}	*-0.083*	3	*0.072*	5
ΔT	0.043	4	*-0.073*	4
I	-0.002	8	-0.041	8
RH	0.021	6	*-0.069*	6
V	-0.039	5	0.047	7
R	**0.436**	1	**0.174**	1

[1]: value on the given day – value on the day before;
[2]: value on the given day per value on the day before;
T_{mean} = daily mean temperature; T_{min} = daily minimum temperature, T_{max} = daily maximum temperature, ΔT = daily temperature range;I = irradiance, RH = relative humidity; V = wind speed; R = rainfall;

Table 3 Special transformation. Effect of the daily differences in meteorological variables[1] on the daily ratios of *Ambrosia* pollen counts[2] as resultant variables and the rank of importance of the explanatory variables on their factor loadings transformed to Factor 1 for determining the resultant variable (thresholds of significance: *italic:* $x_{0.20}$; *italic:* $x_{0.10}$; **bold:** $x_{0.05}$; **bold:** $x_{0.01}$)

[1]Daily differences in meteorological variables	[2]Daily ratios of *Ambrosia* pollen counts (A)							
	A < 0.75		0.75< A ≤ 1.00		1.00 < A ≤ 1.25		A > 1.25	
	thresholds of significance							
	0.074		*0.099*		*0.124*		*0.075*	
	0.094		*0.127*		*0.159*		*0.097*	
	0.112		**0.151**		**0.189**		**0.115**	
	0.148		**0.197**		**0.248**		**0.151**	
	weight	rank	weight	rank	weight	rank	weight	rank
Ambrosia	0.870	–	-0.824	–	-0.960	–	-0.979	–
T_{mean}	**0.315**	2	-0.095	4	-0.005	8	**0.166**	1
T_{min}	-0.058	6	-0.012	8	0.094	4	-0.061	6
T_{max}	*0.096*	5	**-0.234**	2	**-0.209**	2	0.072	4
ΔT	**-0.131**	3	0.054	6	0.066	5	*-0.078*	3
I	-0.017	8	0.059	5	0.036	7	-0.034	8
RH	-0.055	7	*0.109*	3	*0.141*	3	-0.070	5
V	*0.102*	4	-0.017	7	-0.051	6	0.051	7
R	**-0.412**	1	**0.643**	1	**0.262**	1	**0.139**	2

[1]: value on the given day – value on the day before;

[2]: value on the given day per value on the day before;

T_{mean} = daily mean temperature; T_{min} = daily minimum temperature, T_{max} = daily maximum temperature, ΔT = daily temperature range; I = irradiance, RH = relative humidity; V = wind speed; R = rainfall;

5. Conclusions

When using factor analysis with special transformation, for all four categories examined in the three data sets, wind speed (V), rainfall (R) and temperature range (ΔT) were the most important parameters with 7, 5 and 5 significant associations with daily ratios of *Ambrosia* pollen counts, respectively. At the same time, minimum temperature (T_{min}) and irradiance (I) were the least important meteorological variables influencing the resultant variable. After dividing the total data set into two groups, a tendency of stronger associations between the meteorological variables and the pollen variable was found in the data set for which $A \leq 1.00$ (Table 2), compared to that for which $A > 1$. This is due to the difference in the behaviour of the plant to stand environmental stress. Namely, the data set for which $A \leq 1.00$ can be associated to lower summer temperatures with near-optimum phytophysiological processes, while the category of $A > 1.00$ is involved with high and extreme high temperatures modifying life functions and, hence, interrelationships of the meteorological and pollen variables (Tables 1-3).

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