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INTERDIURNAL VARIABILITY OF ARTEMISIA, BETULA AND POACEAE POLLEN COUNTS AND THEIR ASSOCIATION WITH METEOROLOGICAL PARAMETERS

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Abstract: The aim of the study is to analyze the potential reasons of the interdiurnal variations of the pollen counts of *Artemisia*, *Betula* and Poaceae for Szeged area of Southern Hungary in association with meteorological elements. The database includes a ten-year period (1997-2006) comprising the daily ratios of the pollen counts of the above-mentioned taxa (A) (value on the given day per value on the day before) for their pollen season. At the same time, daily values (value on the given day minus 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. Factor analysis with special transformation is used in order to determine the rank of importance, as well as the significance of the meteorological elements in determining the pollen variables for all the three taxa. As a result, irradiance (I), minimum temperature (T_{min}) and wind speed (WS) are found to be the most significant, while mean temperature and relative humidity are the least relevant meteorological variables influencing daily pollen ratios, in decreasing order of their importance, respectively. After dividing the total data set into two groups, definitely stronger associations between the meteorological variables and the pollen variable are found in the data sets for which $A \leq 1.00$, compared to those for which $A > 1$. This is due to the difference in the behaviour of the plants to stand environmental stress. Namely, the data sets for which $A \leq 1.00$ can be associated to lower summer temperatures with near-optimum phyto-physiological processes, while the category of $A > 1.00$ is involved with high and extreme high temperatures modifying life functions and, accordingly, interrelationships of the meteorological and pollen variables.

Keywords: allergenic pollen, respiratory disease, climate elements, physiological processes, pollen transport

1. INTRODUCTION

1.1. Characteristics and importance of pollen grains

Biological air pollutants, mainly pollen, have also a relevant role besides chemical pollutants in developing allergic respiratory diseases. However, an important difference is that while chemical air pollutants (1) occur in the ambient air during the whole year, (2) their concentrations can be characterized by different annual cycles and (3) their enrichment is substantial only over large cities or industrial areas; at the same time pollen (1) is a substance appearing periodically, (2) their occurrence is associated with the flowering of the given taxon and (3) they are connected not to settlements but to habitats.

Pollen grains are one of the most important groups of atmospheric biological particles that originate from allergic processes. Parallel to a major increase of pollen levels, the prevalence of allergic respiratory diseases also increased extensively during the last three decades (D'Amato, 2002). Due to a historical record the prevalence of allergic rhinitis and allergic asthma significantly increased over the past two centuries. Accordingly, monitoring of airborne pollen types and concentrations during the pollen season is of major medical importance.

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 (European Environment Agency, 2013); in addition, airborne pollen levels here are also high. The Pannonian Plain containing Hungary is heavily polluted with Poaceae pollen; furthermore, pollen load of *Artemisia* and *Betula* is also noticeable (Fig. 1).

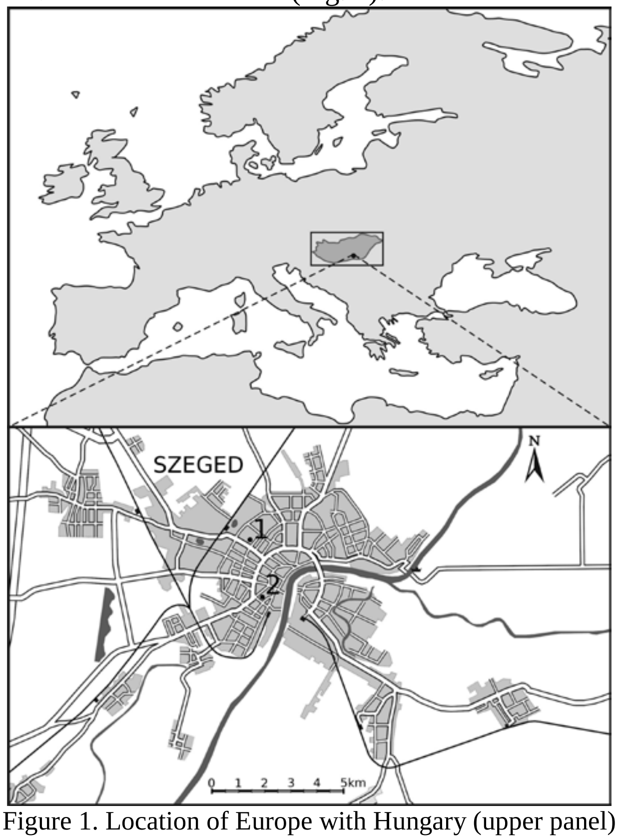


Figure 1. Location of Europe with Hungary (upper panel) and the urban web of Szeged with the positions of the data sources (lower panel). 1: meteorological monitoring station; 2: aerobiological station

In spite of the relatively low atmospheric pollen levels of the above-mentioned taxa, sensitisation and allergy due to *Artemisia*, *Betula* and Poaceae has been reported widely (Kadocsa & Juhász, 2000). Recently, 20% of the total population of Hungary suffers from allergic illnesses and for one-third of these patients allergic asthma has also been developed (Strausz et al., 2010). The number of patients with registered allergic illnesses has doubled and the number of cases of allergic asthma has become four times higher in Southern Hungary by the late 1990s over the last 40 years (Makra et al., 2004).

1.2. Weather-dependence of pollen grains

In the knowledge of its weather-dependence, analysis of association of daily pollen counts of *Artemisia*, *Betula* and Poaceae with daily climate parameters has of great practical importance.

Concerning *Artemisia*, higher summer temperatures delayed the start of flowering and brought forward the end of flowering, thus shortened the pollen season (Cariñanos et al., 2013). Relevant proportional association was found between *Artemisia* pollen counts and air temperature (García-Mozo et al., 2006), at the same time significant negative correlation can be experienced between pollen counts and relative humidity (Puc, 2006). However, the role of rainfall is unsure. The Annual Pollen Index is substantially influenced by rainfall over the months immediately prior to flowering (proportional association with the annual pollen counts) (Cariñanos et al., 2013). At the same time, rainfall in the first fortnight of July is highly influenced the severity of the pollen season (inverse association with the annual pollen counts) (Cariñanos et al., 2013).

The timing of the birch pollen season is very sensitive to spring temperatures (Newnham et al., 2013). Piotrowska & Kubik-Komar (2012) reported that minimum temperature of February and March and total rainfall in June in the year preceding pollen release have the greatest effect on the annual birch pollen counts in Lublin (Poland). Low temperatures in February promote the occurrence of high pollen concentrations. *Betula* pollen level in the pollen season is positively correlated with mean air temperature (Bartková-Scevková, 2003; Puc, 2011; Puc, 2012), maximum air temperature (Puc, 2011), wind speed (Puc, 2012), air pressure (Puc, 2012) and irradiance (Puc, 2012), while it is inversely correlated with daily rainfall (Puc, 2011) and relative humidity (Bartková-Scevková, 2003).

Grass pollen season usually starts when the mean daily temperature exceeds 13.5°C (maximum daily temperature is 19.5°C) on non-rainy days (Peternel et al., 2006). Matyasovszky et al., (2011) found that both for Szeged and Győr (both in

Hungary) high daily mean Poaceae pollen levels are favoured by anticyclone ridge weather situations involving undisturbed irradiance with calm weather. Grass pollen concentrations show significant positive correlations with mean air temperature (Bartková-Scevková, 2003; Peternel et al., 2006; Kasprzyk & Walanus, 2010), maximum air temperature (Kasprzyk & Walanus, 2010), irradiance (Kasprzyk & Walanus, 2010), relative humidity (Bartková-Scevková, 2003; Peternel et al., 2006) and rainfall (Peternel et al., 2006). However, meteorological elements affect pollen concentration not by means of their individual values but through their interrelationships. Hence, it is practical to study the association of daily pollen concentrations with daily values of meteorological elements as a whole.

1.3. Objectives

The aim of the study is to analyze the potential reasons of interdiurnal variability of *Artemisia* (or *Betula* or Poaceae) 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 climíatic elements on one hand and *Artemisia* (or *Betula* or Poaceae) pollen data on the other, in order to detect the strength and sign of associations between meteorological (explanatory) variables and *Artemisia* (or *Betula* or Poaceae) pollen (resultant) variable. Factor analysis with special transformation is a unique procedure in the special literature that has not yet been applied for studying these pollen types.

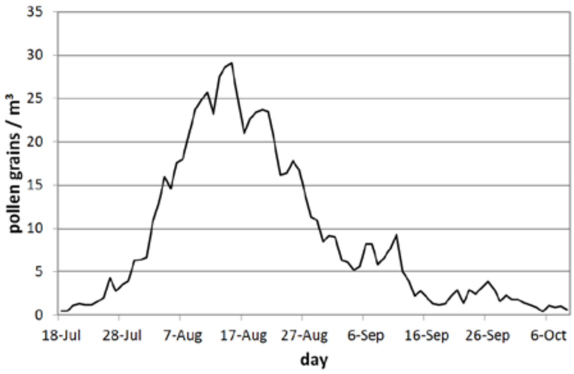
2. MATERIALS AND METHODS

2.1. Location

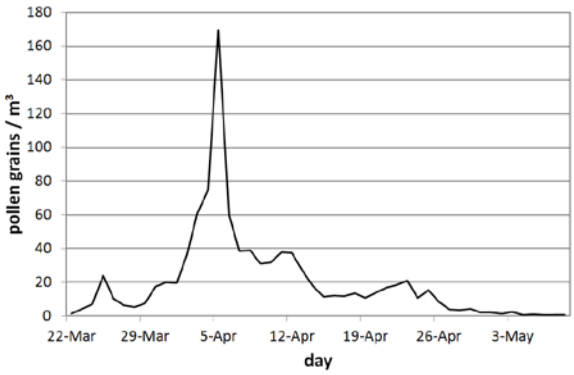
Szeged (46.25°N; 20.10°E) is the largest town in South-eastern Hungary (Fig. 1). The area is an extensive flat landscape over the Pannonian Plain with an elevation of 79 m above sea level. The territory of the built-up area is 46 km^2. Szeged city with 203,000 inhabitants, is characterized by the **Ca** type (warm temperate climate) in the Köppen system with relatively mild and short winters and hot summers (Köppen, 1931). 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).

2.2. Data

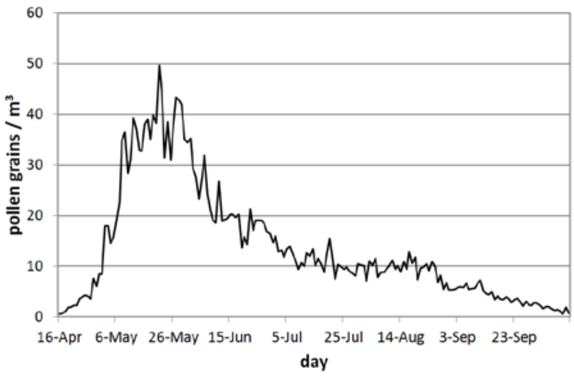
The analysis was performed for a ten-year period 1997-2006. Within this term, daily pollen counts of *Artemisia* (mugwort), *Betula* (birch) and Poaceae (grasses) were analysed for their pollen season (Jul 18 – Oct 9, Mar 22 – May 8 and Apr 16 – Oct 12, respectively) (Fig. 2). At the same time, daily values of 8 meteorological variables [mean temperature, T_{mean} (°C); minimum temperature, T_{min} (°C); maximum temperature, T_{max} (°C); temperature range, as the difference of maximum and minimum temperatures, $\Delta T(=T_{max}-T_{min}$, °C); irradiance, I ($W \cdot m^{-2}$); relative humidity, RH (%); wind speed, WS ($m \cdot s^{-1}$) and rainfall, R (mm)] were also considered.



Artemisia



Betula



Poaceae

Figure 2. Mean daily pollen counts, Szeged, 1997-2006

The pollen season is defined by its start and end dates. For the start (end) of the season we used the first (last) date on which at least 1 pollen grain · m^{-3} of air is recorded and at least 5 consecutive (preceding) days also show 1 or more pollen grains m^{-3} (Galán et al., 2001). Evidently, the pollen season varies from year to year. Here the longest observed pollen season during the ten-year period was considered for each taxon and each year, even if the remaining years involve substantially different pollen seasons with either remarkably later start or notably earlier end of the pollen release.

2.3. Methods

The method of Factor analysis with special transformation is used. 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 *Artemisia* (or *Betula* or Poaceae) pollen counts as resultant variables) 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 – *Artemisia* (or *Betula* or Poaceae) 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 & 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 & Vahle, 1968). This latter procedure is called special transformation.

3. RESULTS

For each day of the analysis daily differences in climatic variables (value on the given day minus value on the day before) were assigned to the daily ratios of *Artemisia* (or *Betula* or Poaceae) pollen counts (A) (value on the given day per value on the day before). Three data sets were subjected to an analysis: (1) the total data set, (2) those daily differences in climatic variables for which $A \leq 1$ and (3) those for which $A > 1$. For the data sets, the days examined were classified into four categories. These categories are as follows: (a) rainy day, preceded by a rainy day; (b) rainy day, preceded by a non-rainy day; (c) non-rainy day, preceded by a rainy day; (d) non-rainy day, preceded by a non-rainy day.

Altogether 3x3x4=36 factor analyses were performed on all three taxa and their all three data sets (Tables 1-3). In order to calculate the rank of importance of the explanatory (meteorological) variables for determining the resultant variable [daily ratios of *Artemisia* (or *Betula* or Poaceae) pollen counts], loadings of the retained factors were projected onto Factor 1 for all 36 factor analyses with a special transformation (Tables 1-3) (Jahn & Vahle, 1968). For each taxon, those relationships between the meteorological and pollen variables are only analysed for their all data sets that were significant at 10%, 5% or 1% probability levels, respectively. The meteorological parameters as explanatory variables are mentioned below in decresing order of their importance in influencing the pollen variables for all data sets.

As for *Artemisia*, (1) the total data set, for category (a) only the role of irradiance (I) is important indicating an inverse association with daily ratios of the pollen counts, while for categories (b) and (c) minimum temperature (T_{min}) and again irradiance (I) are the only weak and relevant meteorological parameters, respectively; both influencing proportionallly the resultant variable. For category (d) no significant explanatory variables occur (Table 1a). In the case of (2) the daily ratios of *Artemisia* pollen counts (A), when $A \leq 1.00$, for category (a) minimum temperature (T_{min}) with a substantial inverse connection, while both daily temperature range (ΔT) and irradiance (I) with a weak positive connection influence daily ratios of the pollen counts, respectively. For category (b), wind speed (WS), rainfall (R) and relative humidity (RH) are the most relevant explanatory variables, all with negative signs. For category (c) wind speed (WS), irradiance (I) and minimum temperature (T_{min}) have significant weight, while relative humidity (RH) and daily temperature range (ΔT)

indicate weak role. Except for relative humidity, they show proportional association with the resultant variable. For category (d), only minimum temperature (T_{min}) denotes a relevant positive connection with daily pollen ratios (Table 1b).

Regarding (3) the daily ratios of *Artemisia* pollen counts (A), when A>1.00, for categories (a) only irradiance (I) can be mentioned with a weak weight and positive sign, while for category (c) relative humidity (RH) and wind speed (WS) are important influencing variables both with negative signs. For category (d) irradiance (I) has a substantial positive role, whereas for category (b) none of the meteorological variables are important (Table 1c).

Table 1a. Special transformation. Effect of the daily differences in meteorological variables[1] on the daily ratios of *Artemisia* pollen counts (A) [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, total data set (thresholds of significance: *italic:* $x_{0.10}$; **bold:** $x_{0.05}$; **bold:** $x_{0.01}$)

[1]Daily differences in meteorological variables	[2]Daily ratios of *Artemisia* pollen counts (A)							
	a		b		c		d	
	thresholds of significance							
	0.165		*0.166*		*0.166*		*0.165*	
	0.197		**0.199**		**0.199**		**0.197**	
	0.260		**0.263**		**0.273**		**0.260**	
	weight	rank	weight	rank	weight	rank	weight	rank
Artemisia	0.954	–	-0.989	–	-0.993	–	-0.994	–
T_{mean}	0.144	2	0.006	8	0.117	3	0.060	3
T_{min}	0.128	3	*0.179*	1	0.049	7	-0.012	5
T_{max}	0.057	5-7	-0.060	6	0.059	6	-0.008	6
ΔT	0.002	8	-0.086	4	0.089	4	-0.085	2
I	**-0.197**	1	-0.016	7	**0.206**	1	-0.006	7
RH	0.057	5-7	-0.066	5	0.075	5	0.162	1
WS	0.116	4	-0.105	3	0.121	2	-0.036	4
R	0.057	5-7	-0.066	5	0.075	5	0.162	1

[1]: value on the given day – value on the day before; [2]: value on the given day per value on the day before; a: rainy day, preceded by a rainy day; b: rainy day, preceded by a non-rainy day; c: non-rainy day, preceded by a rainy day; d: non-rainy day, preceded by a non-rainy day; T_{mean} = daily mean temperature; T_{min} = daily minimum temperature, T_{max} = daily maximum temperature, ΔT = daily temperature range;I = irradiance, RH = relative humidity; WS = wind speed; R = rainfall;

Table 1b. Special transformation. Effect of the daily differences in meteorological variables[1] on the daily ratios of *Artemisia* pollen counts (A)[2], A ≤ 1.00 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:* $x_{0.10}$; **bold:** $x_{0.05}$; **bold:** $x_{0.01}$)

[1]Daily differences in meteorological variables	[2]Daily ratios of *Artemisia* pollen counts (A)							
	a		b		c		d	
	thresholds of significance							
	0.166		*0.167*		*0.167*		*0.165*	
	0.198		**0.200**		**0.200**		**0.197**	
	0.263		**0.266**		**0.267**		**0.260**	
	weight	rank	weight	rank	weight	rank	weight	rank
Artemisia	-0.929	–	-0.807	–	-0.843	–	0.977	–
T_{mean}	-0.062	6	0.124	4	-0.005	7	-0.022	7
T_{min}	**-0.327**	1	0.037	7	**0.338**	3	**0.209**	1
T_{max}	0.039	7	0.003	8	-0.093	6	-0.046	6
ΔT	*0.186*	2	0.075	5	*0.169*	5	0.055	5
I	*0.170*	3	0.059	6	**0.382**	2	0.093	4
RH	-0.123	4	**-0.354**	3	*-0.192*	4	0.147	2
WS	-0.116	5	**-0.666**	1	**0.547**	1	-0.121	3
R	-0.005	8	**-0.381**	2	–	–	–	–

[1]: value on the given day – value on the day before; [2]: value on the given day per value on the day before; a: rainy day, preceded by a rainy day; b: rainy day, preceded by a non-rainy day; c: non-rainy day, preceded by a rainy day; d: non-rainy day, preceded by a non-rainy day; T_{mean} = daily mean temperature; T_{min} = daily minimum temperature, T_{max} = daily maximum temperature, ΔT = daily temperature range; I = irradiance, RH = relative humidity; WS = wind speed; R = rainfall;

Table 1c. Special transformation. Effect of the daily differences in meteorological variables[1] on the daily ratios of *Artemisia* pollen counts (A)[2], A > 1.00 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:* $x_{0.10}$; **bold:** $x_{0.05}$; **bold:** $x_{0.01}$)

[1]Daily differences in meteorological variables	[2]Daily ratios of *Artemisia* pollen counts (A)							
	a		b		c		d	
	thresholds of significance							
	0.166		*0.169*		*0.170*		*0.166*	
	0.199		**0.203**		**0.205**		**0.198**	
	0.263		**0.272**		**0.276**		**0.263**	
	weight	rank	weight	rank	weight	rank	weight	rank
Artemisia	-0.996	–	0.996	–	0.948	–	0.975	–
T_{mean}	0.008	8	0.002	8	-0.092	5	-0.082	6
T_{min}	0.059	5	0.057	4	-0.120	3	-0.112	3
T_{max}	0.035	6	0.030	6	0.036	7	0.091	5
ΔT	0.085	4	0.117	2	0.039	6	0.094	4
I	*0.174*	1	0.093	3	0.097	4	**0.313**	1
RH	-0.143	2	-0.162	1	**-0.431**	1	-0.149	2
WS	0.097	3	-0.042	5	**-0.350**	2	-0.007	7
R	0.017	7	0.007	7	–	–	–	–

[1]: value on the given day – value on the day before; [2]: value on the given day per value on the day before; a: rainy day, preceded by a rainy day; b: rainy day, preceded by a non-rainy day; c: non-rainy day, preceded by a rainy day; d: non-rainy day, preceded by a non-rainy day; T_{mean} = daily mean temperature; T_{min} = daily minimum temperature, T_{max} = daily maximum temperature, ΔT = daily temperature range;I = irradiance, RH = relative humidity; WS = wind speed; R = rainfall;

Table 2a. Special transformation. Effect of the daily differences in meteorological variables[1] on the daily ratios of *Betula* pollen counts (A)[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, total data set (thresholds of significance: *italic:* $x_{0.10}$; **bold:** $x_{0.05}$; **bold:** $x_{0.01}$)

[1]Daily differences in meteorological variables	[2]Daily ratios of *Artemisia* pollen counts (A)							
	a		b		c		d	
	thresholds of significance							
	0.166		*0.168*		*0.168*		*0.166*	
	0.198		**0.201**		**0.201**		**0.198**	
	0.263		**0.269**		**0.268**		**0.263**	
	weight	rank	weight	rank	weight	rank	weight	rank
Betula	0.985	–	0.985	–	0.979	–	1.000	–
T_{mean}	0.030	7	0.092	4	0.060	6	0.069	5
T_{min}	*-0.196*	1	0.033	7	**-0.278**	1	-0.073	4
T_{max}	0.098	4	0.110	3	0.161	3	0.078	2
ΔT	-0.030	6	-0.159	2	0.109	5	-0.005	7
I	0.103	3	-0.055	6	-0.017	7	0.078	3
RH	-0.038	5	0.021	8	**0.211**	2	-0.127	1
WS	-0.020	8	-0.167	1	0.144	4	-0.050	6
R	0.106	2	-0.077	5	–	–	–	–

[1]: value on the given day – value on the day before; [2]: value on the given day per value on the day before; a: rainy day, preceded by a rainy day; b: rainy day, preceded by a non-rainy day; c: non-rainy day, preceded by a rainy day; d: non-rainy day, preceded by a non-rainy day; T_{mean} = daily mean temperature; T_{min} = daily minimum temperature, T_{max} = daily maximum temperature, ΔT = daily temperature range;I = irradiance, RH = relative humidity; WS = wind speed; R = rainfall;

For *Betula*, (1) the total data set, for category (a) and (c) a weak negative effect of minimum temperature (T_{min}), as well as a substantial negative and positive weight of minimum temperature (T_{min}) and relative humidity (RH), respectively influence mostly the resultant variable. For categories (b) and (d) no relevant meteorological parameters are received (Table 2a). In the case of (2) the daily ratios of *Betula* pollen counts (A), when A≤1.00, for category (a) rainfall (R) and irradiance (I) are the most important explanatory variables in determining the daily pollen ratios with negative and positive associations, respectively. For category (b) daily temperature range (ΔT) and minimum temperature (T_{min}) both with strong inverse, as well as wind speed (WS) and maximum temperature (T_{max}) both with weak proportional associations affect the resultant variables, respectively. At the same time, for category (c) wind speed (WS), daily temperature range (ΔT), relative humidity (RH) and irradiance (I) are the most important influencing variables with the weak effect of minimum temperature (T_{min}). The sign of their association with the daily pollen ratios is positive, except for wind speed. For category (d) only the role of maximum temperature (T_{max}) is important with a positive sign (Table 2b). In terms of (3) the daily ratios of *Betula* pollen counts (A), when A>1.00, for category (a) only rainfall (R) and minimum temperature (T_{min}) have a weak effect to the daily pollen ratio with both signs, respectively.

Table 2b. Special transformation. Effect of the daily differences in meteorological variables[1] on the daily ratios of *Betula* pollen counts (A)[2], A ≤ 1.00 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:* $x_{0.10}$; **bold:** $x_{0.05}$; **bold:** $x_{0.01}$)

[1]Daily differences in meteorological variables	[2]Daily ratios of *Artemisia* pollen counts (A)							
	a		b		c		d	
	thresholds of significance							
	0.166		*0.172*		*0.169*		*0.167*	
	0.199		**0.207**		**0.203**		**0.200**	
	0.263		**0.282**		**0.272**		**0.267**	
	weight	rank	weight	rank	weight	rank	weight	rank
Betula	0.953	–	0.853	–	-0.853	–	-0.983	–
T_{mean}	-0.121	4	0.045	5	0.041	7	0.119	4
T_{min}	-0.082	6	**-0.543**	2	*0.183*	5	-0.043	7
T_{max}	-0.045	7	*0.179*	4	0.092	6	**0.226**	1
ΔT	0.118	5	**-0.634**	1	**0.430**	2	-0.107	5
I	**0.248**	2	0.018	7	**0.224**	4	0.152	2
RH	-0.123	3	-0.010	8	**0.254**	3	0.082	6
WS	0.033	8	*0.198*	3	**-0.710**	1	-0.132	3
R	**-0.354**	1	-0.022	6	–	–	–	–

[1]: value on the given day – value on the day before; [2]: value on the given day per value on the day before; a: rainy day, preceded by a rainy day; b: rainy day, preceded by a non-rainy day; c: non-rainy day, preceded by a rainy day; d: non-rainy day, preceded by a non-rainy day; T_{mean} = daily mean temperature; T_{min} = daily minimum temperature, T_{max} = daily maximum temperature, ΔT = daily temperature range;I = irradiance, RH = relative humidity; WS = wind speed; R = rainfall;

Table 2c. Special transformation. Effect of the daily differences in meteorological variables[1] on the daily ratios of *Betula* pollen counts (A)[2], A > 1.00 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:* $x_{0.10}$; **bold:** $x_{0.05}$; **bold:** $x_{0.01}$)

[1]Daily differences in meteorological variables	[2]Daily ratios of *Artemisia* pollen counts (A)							
	a		b		c		d	
	thresholds of significance							
	0.167		*0.171*		*0.173*		*0.167*	
	0.200		**0.206**		**0.210**		**0.200**	
	0.266		**0.279**		**0.288**		**0.267**	
	weight	rank	weight	rank	weight	rank	weight	rank
Betula	-0.983	–	-0.996	–	0.968	–	0.998	–
T_{mean}	0.059	5	-0.087	4	-0.123	6	-0.005	6
T_{min}	*0.174*	2	0.074	5	**-0.379**	2	-0.081	4
T_{max}	0.002	8	-0.113	3	**0.215**	4	0.056	5
ΔT	-0.089	4	**0.231**	1	**0.606**	1	0.000	7
I	-0.154	3	0.012	8	**0.290**	3	0.129	2
RH	-0.058	6	0.158	2	0.030	7	-0.096	3
WS	0.022	7	0.016	7	-0.149	5	-0.154	1
R	*-0.190*	1	0.020	6	–	–	–	–

[1]: value on the given day – value on the day before; [2]: value on the given day per value on the day before; a: rainy day, preceded by a rainy day; b: rainy day, preceded by a non-rainy day; c: non-rainy day, preceded by a rainy day; d: non-rainy day, preceded by a non-rainy day; T_{mean} = daily mean temperature; T_{min} = daily minimum temperature, T_{max} = daily maximum temperature, ΔT = daily temperature range;I = irradiance, RH = relative humidity; WS = wind speed; R = rainfall;

Table 3a. Special transformation. Effect of the daily differences in meteorological variables[1] on the daily ratios of Poaceae pollen counts (A) [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, total data set (thresholds of significance: *italic:* $x_{0.10}$; **bold:** $x_{0.05}$; **bold:** $x_{0.01}$)

[1]Daily differences in meteorological variables	[2]Daily ratios of *Artemisia* pollen counts (A)							
	a		b		c		d	
	thresholds of significance							
	0.165		*0.167*		*0.165*		*0.165*	
	0.196		**0.197**		**0.197**		**0.196**	
	0.259		**0.260**		**0.260**		**0.259**	
	weight	rank	weight	rank	weight	rank	weight	rank
Poaceae	0.999	–	0.996	–	-0.982	–	-0.994	–
T_{mean}	0.052	2	0.073	4	-0.116	2	0.052	3
T_{min}	-0.021	6	-0.039	6	0.026	7	0.020	7
T_{max}	0.045	3	0.111	2	-0.045	6	0.040	5
ΔT	-0.041	5	0.035	7	0.074	3	0.047	4
I	0.044	4	*0.169*	1	0.071	4	0.082	2
RH	0.006	8	0.013	8	-0.062	5	0.037	6
WS	0.017	7	0.060	5	**-0.202**	1	-0.136	1
R	-0.064	1	-0.103	3	–	–	–	–

[1]: value on the given day – value on the day before; [2]: value on the given day per value on the day before; a: rainy day, preceded by a rainy day; b: rainy day, preceded by a non-rainy day; c: non-rainy day, preceded by a rainy day; d: non-rainy day, preceded by a non-rainy day; T_{mean} = daily mean temperature; T_{min} = daily minimum temperature, T_{max} = daily maximum temperature, ΔT = daily temperature range;I = irradiance, RH = relative humidity; WS = wind speed; R = rainfall;

For category (b) only daily temperature range (ΔT) has a strong positive association with the resultant variable. In category (c) daily temperature range (ΔT), minimum temperature (T_{min}), irradiance (I) and maximum temperature (T_{max}) affect substantially the daily pollen ratios with positive signs, but minimum temperature. Category (d) does not contain any important cliamtic variables (Table 2c).

In view of Poaceae, (1) the total data set, for categories (b) and (c) the only influencing variable is irradiance (I) and wind speed (WS) in determining the resultant variable with a weak positive and a strong negative sign, respectively. Categories (a) and (d) are free of important meteorological parameters (Table 3a). In the case of (2) the daily ratios of Poaceae pollen counts (A), when A≤1.00, for category (a) only rainfall with a strong negative effect, while for category (b) rainfall (R) with a strong negative, wind speed (WS) with a strong positive, while daily temperature range (ΔT) and irradiance (I) both with weak negative effects influence the daily pollen ratios. For both categories (c) and (d) only irradiance (I) affects weakly the resultant variable with positive and negative signs, respectively (Table 3b). Regarding (3) the daily ratios of Poaceae pollen counts (A), when A>1.00, for category (a) a weak effect of rainfall (R) and wind speed (WS) can be detected with negative and positive signs, respectively.

For category (b) irradiance (I) and maximum temperature (T_{max}) both with important proportional associations and rainfall with a strong inverse connection affect substantially the resultant variable, respectively. Furthermore, a weak negative and positive effect of relative humidity (RH) and mean temperature (T_{mean}) was also observed. At the same time, for category (c) irradiance (I) with a significant weight, while wind speed (WS) with a weak effect influenced the daily pollen ratio, both with negative signs. For category (d) no important meteorological elements were found (Table 3c).

4. DISCUSSIONS

The analysis of interdiurnal variability of *Artemisia*, *Betula* and Poaceae pollen counts is a relevant area of pollen researches due to its immediate association with public health. The study can be regarded specific, since only a single similar paper (Matyasovszky et al., 2012) have been published so far in this respect in the international literature, studying *Ambrosia* pollen. In this study, *Artemisia*, *Betula* and Poaceae were selected due to their high or medium allergenicity a four-score scale found in the Hungarian pollen index. Allergenicity of both *Artemisia* and Poaceae is the highest indicated by score four, while that of *Betula* is moderately high indicated by score three] and to their more or less permanently high pollen concentrations. The here-mentioned highly allergenic three pollen types have not yet been studied from this point of view. A novel procedure is applied in our study; namely, factor analysis with special transformation.

Table 3b. Special transformation. Effect of the daily differences in meteorological variables[1] on the daily ratios of Poaceae pollen counts (A)[2], A ≤ 1.00 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: <u>*italic:*</u> $x_{0.10}$; **bold:** $x_{0.05}$; <u>**bold:**</u> $x_{0.01}$)

[1]Daily differences in meteorological variables	[2]Daily ratios of *Artemisia* pollen counts (A)							
	a		b		c		d	
	thresholds of significance							
	<u>*0.165*</u>		<u>*0.166*</u>		<u>*0.166*</u>		<u>*0.165*</u>	
	0.196		**0.199**		**0.198**		**0.197**	
	<u>**0.260**</u>		<u>**0.263**</u>		<u>**0.263**</u>		<u>**0.260**</u>	
	weight	rank	weight	rank	weight	rank	weight	rank
Poaceae	0.970	–	-0.938	–	-0.992	–	0.987	–
T_{mean}	0.078	3	0.005	8	-0.016	7	0.053	3
T_{min}	0.043	5	-0.016	7	0.067	2	-0.047	5
T_{max}	0.039	6	0.028	6	0.047	5	0.050	4
ΔT	0.013	8	<u>*-0.192*</u>	3	-0.059	3	-0.003	7
I	-0.045	4	<u>*-0.182*</u>	4	<u>*0.193*</u>	1	<u>*-0.172*</u>	1
RH	0.025	7	0.051	5	-0.059	4	-0.038	6
WS	0.153	2	**0.224**	2	-0.035	6	0.068	2
R	**-0.232**	1	<u>**-0.285**</u>	1	–	–	–	–

[1]: value on the given day – value on the day before; [2]: value on the given day per value on the day before; a: rainy day, preceded by a rainy day; b: rainy day, preceded by a non-rainy day; c: non-rainy day, preceded by a rainy day; d: non-rainy day, preceded by a non-rainy day; T_{mean} = daily mean temperature; T_{min} = daily minimum temperature, T_{max} = daily maximum temperature, ΔT = daily temperature range;I = irradiance, RH = relative humidity; WS = wind speed; R = rainfall;

Table 3c. Special transformation. Effect of the daily differences in meteorological variables[1] on the daily ratios of Poaceae pollen counts (A)[2], A > 1.00 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: <u>*italic:*</u> $x_{0.10}$; **bold:** $x_{0.05}$; <u>**bold:**</u> $x_{0.01}$)

[1]Daily differences in meteorological variables	[2]Daily ratios of *Artemisia* pollen counts (A)							
	a		b		c		d	
	thresholds of significance							
	<u>*0.165*</u>		<u>*0.166*</u>		<u>*0.166*</u>		<u>*0.165*</u>	
	0.196		**0.199**		**0.198**		**0.197**	
	<u>**0.260**</u>		<u>**0.263**</u>		<u>**0.263**</u>		<u>**0.260**</u>	
	weight	rank	weight	rank	weight	rank	weight	rank
Poaceae	-0.965	–	0.995	–	-0.982	–	-1.000	–
T_{mean}	0.057	4	<u>*0.184*</u>	5	0.109	4	0.043	3
T_{min}	0.151	3	-0.033	8	-0.016	6	0.062	2
T_{max}	-0.026	6	**0.232**	2	0.094	5	0.030	4
ΔT	-0.010	7	-0.048	7	0.141	3	0.070	1
I	-0.009	8	**0.249**	1	**-0.209**	1	0.024	7
RH	-0.037	5	<u>*-0.186*</u>	4	-0.010	7	0.027	5
WS	<u>*0.186*</u>	2	0.136	6	<u>*-0.183*</u>	2	-0.024	6
R	<u>*-0.187*</u>	1	**-0.226**	3	–	–	–	–

[1]: value on the given day – value on the day before; [2]: value on the given day per value on the day before; a: rainy day, preceded by a rainy day; b: rainy day, preceded by a non-rainy day; c: non-rainy day, preceded by a rainy day; d: non-rainy day, preceded by a non-rainy day; T_{mean} = daily mean temperature; T_{min} = daily minimum temperature, T_{max} = daily maximum temperature, ΔT = daily temperature range;I = irradiance, RH = relative humidity; WS = wind speed; R = rainfall;

Artemisia pollen can stem from fallows, stubbles and neglected urban weedy dry grasses, furthermore from pure mugwort fallows of old however small saline areas in the plain Szeged region. Mugwort fallows occur mainly east and north-east of the Szeged area, around 50 km of the city. On the contrary, *Betula* pollen originates exclusively from issues planted into parks, public places and gardens, since this species has no natural habitats in Szeged region. Poaceae species represent a substantial ratio in Szeged area that is not exceptional, since they comprise all grass species, even some marsh-species like reed. Poaceae is the largest family consisting of more than 70 species in the Pannonian Plain. Poaceae pollen may spring from receding and slowly passing grasses from sand ridges, from saline areas in the plain Szeged region, as well as from arable lands temporarily covered by inland water, furthermore stubbles around the city, respectively. Recently, areas of loess grassland and floodplain grasslands have decreased dramatically. Over sand ridges, due to extending fallows, a re-grassing has been occurring. Though this process reduces the ratio of ragweed; however, this spontaneous and natural regeneration process increases the presence of Poaceae being important components of natural grasses (Deák, 2011).

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

Rainfall (R) is considered an important meteorological parameter for *Artemisia*, A≤1.00: category (b), rank of importance: 2 (Table 1b); for *Betula*, A≤1.00 and A>1.00: in both cases category (a) and rank of importance: 1, respectively (Tables 2b-c); for Poaceae, A≤1.00 and A>1.00: in both cases categories (a) and (b) and rank of importance: 1, 1 and 1, 3, respectively (Tables 3b-c). For all data sets listed above, rainfall is inversely associated with daily pollen ratios (Tables 1b, 2b-c, 3b-c). The reason of this relationship can be explained as follows. Rainfall on the given day, depending on its intensity, may substantially reduce airborne pollen counts (negative effect) due to the "wash-out" effect.

This association can be explained (1) by the well-known wash-out effect: after rainfall the pollen content of the air reduces sharply (Déchamp & Penel, 2002; Kasprzyk, 2008; Hernández-Ceballos et al., 2011); (2) another reason of a negative association between rainfall and the pollen variable is the fact that rainfall is accompanied with a fall in temperature, which slows the metabolism of the taxon down (Deák, 2011) (Tables 1b, 2b-c, 3b-c). Based on the international literature, the role of rainfall is not clear in influencing daily pollen counts. Fornaciari et al., (1992) and Galán et al., (2000) found the impact of rainfall complicated just because of the negative effect of rain intensity on pollen counts. Fornaciari et al., (1992) computed the best correlation by comparing pollen concentrations (Urticaceae) and meteorological parameters on non-rainy days. For several cases pollen grains were negatively correlated with rainfall (Barnes et al., 2001; Déchamp & Penel, 2002; Kasprzyk, 2008); at the same time, Bartková-Scevková (2003) did not find statistically significant association.

Importance of mean temperature (T_{mean}) is very low for the three taxa examined. Its role is noticeable solely for Poaceae, A>1.00, category (b), rank of importance: 5, involving a positive association with daily pollen ratios (Table 3c). This relationship can be explained as follows. In the case of adequate humidity conditions an increase in mean temperature (T_{mean}), if it is not too far from its optimum value, can accelerate vegetative and hence generative functions. Accordingly, it involves an increase in pollen concentrations, indicating a proportional association (confirmed by Bartková-Scevková, 2003; Gioulekas et al., 2004; Kasprzyk, 2008).

Minimum temperature (T_{min}) is a relevant parameter for *Artemisia*, total data set: category (b), rank of importance: 1 (Table 1a); A≤1.00: for both category (a) and (d), rank of importance: 1, respectively; category (c), rank of importance: 3 (Table 1b) and for *Betula*, total data set: for both categories (a) and (c), rank of importance: 1, respectively; (Table 2a); A≤1.00: category (b), rank of importance: 2; category (c), rank of importance: 5 (Table 2b); A>1.00: for both category (a) and (c), rank of importance: 2, respectively (Table 2c). However, for Poaceae minimum temperature is not significant in either data set in influencing daily ratios of the pollen counts (Tables 3a-c). For *Artemisia* and *Betula*, minimum temperature shows both inverse (Tables 1b, 2a-c), and proportional (Tables 1a-b, 2b-c), associations with the daily pollen ratios, respectively. The inverse relationship can be explained by the following reason. If preceding day is rainy, the cooling effect of rainfall can make a low temperature early in the morning; however, daily pollen ratio increases, since the given-day-related pollen count increase associated with the preceding-day rainfall has a higher weight compared to the given-day-related decrease in pollen counts induced by a low minimum temperature on the given day (Tables 1b, 2a-c). The potential reason of the proportional association between these variables is that very low minimum temperatures can be a barrier of the pollen production as low temperatures make the life functions of the species slower (Tables 1a-b, 2b-c).

Maximum temperature (T_{max}) is an important parameter for *Betula*, A≤1.00: category (b), rank of importance: 4; and category (d), rank of importance: 1 (Table 2b) and A>1.00: category (c), rank of importance: 4 (Table 2c); and for Poaceae, A>1.00: category (b), rank of importance: 2 (Table 3c). Note that for *Artemisia*, maximum temperature is not a relevant variable in influencing daily ratios of the pollen counts (Tables 1a-c). The association of this parameter is exclusively proportional (Tables 2b-c, 3c) to the daily ratios of the pollen counts, explanation of which is as follows. Dehiscence of anthers and release of pollen result from dehydration of walls of anther sacs (Kozlowski & Pallardy, 2002) that is facilitated by higher maximum temperatures. Accordingly, higher values of this explanatory variable contribute to higher pollen release. However, in summer time, extreme high maximum temperatures may indicate a limit for pollen production. In this period the loss of water can mean a barrier for the plant, so for preserving water it may decrease pollen production (Makra et al., 2011).

Temperature range (ΔT) is in a significant association with daily ratios of the pollen counts for *Artemisia*, A≤1.00: category (a), rank of importance: 2 and category (c) rank of importance: 5 (Table 1b); for *Betula*, A≤1.00: category (b), rank of importance: 1 and category (c), rank of importance: 2; (Table 2b); and for A>1.00: for both categories (b) and (c), rank of importance: 1, respectively (Table 2c); and for Poaceae A≤1.00: category (b), rank of importance: 3 (Table 3b). This parameter indicates both proportional (Tables 1b, 2b-c) and inverse (Tables 2b, 3b) association with daily pollen ratios, respectively. 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 (Makra et al., 2011). Accordingly, an increase in temperature range (ΔT) is inversely associated with daily ratios of *Ambrosia* pollen counts. However, if an increase in temperature range (ΔT) remains within a limit, it may show a proportional relationship with daily pollen ratios.

Irradiance (I) represents both proportional (Tables 1a-c, 2b-c, 3a-c) and inverse (Tables 1a-c, 3b-c) associations with daily ratios of the pollen counts, respectively. Namely, for *Artemisia*, total data set: for both categories (a) and (c), rank of importance: 1, respectively (Table 1a); A≤1.00: category (a), rank of importance: 3 and category (c) rank of importance: 2 (Table 1b); A>1.00: for both categories (a) and (d), rank of importance: 1, respectively (Table 1c); for *Betula*, A≤1.00: category (a), rank of importance: 2 and category (c) rank of importance: 4 (Table 2b); and for A>1.00: category (c), rank of importance: 3 (Table 2c); for Poaceae, total data set: category (b), rank of importance: 1 (Table 3a); A≤1.00: categories (b), (c) and (d), rank of importance: 4, 1 and 1, respectively (Table 3b); and A>1.00: for both categories (b) and (c), rank of importance: 1, respectively (Table 3c). 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. However, the inverse association can be connected to an extreme high irradiance (I) related excessive increase in mean temperature (T_{mean}), when the plant concentrates on preserving of water and maintaining of its vegetative life functions and is pressed to restrict its generative functions (Deák, 2011).

Relative humidity (RH) substantially influences daily ratios of the pollen counts for *Artemisia*, A≤1.00: categories (b) and (c), rank of importance: 3 and 4, respectively (Table 1b); A>1.00: category (c), rank of importance: 1 (Table 1c); for *Betula*, total data set: category (c), rank of importance: 2 (Table 2a); A≤1.00: category (c), rank of importance: 3 (Table 2b); and for Poaceae, A>1.00: category (b), rank of importance: 4 (Table 3c). Relative humidity (RH) is both inversely (Tables 1b-c and 3c) and proportionally (Tables 2a-b) associated with daily pollen ratios, respectively. Concerning the inverse connection, in general, pollen shedding is associated with shrinkage and rupture of anther walls by low relative humidity (Kozlowski & Pallardy, 2002). Hence, relative humidity is inversely associated with pollen release (Bartkova-Scevkova, 2003; Gioulekas et al., 2004). Furthermore, humid air promotes sticking of pollen grains, which also contributes to an inverse association (affirmed by Kasprzyk, 2008). Proportional association can be experienced only for *Betula*. The species living in the research area are taller arboreal-deciduous plants and their pollen release occurs at a well bigger hight, than that of *Artemisia* and Poaceae. *Betula* favours humid environment. High relative humidity facilitates generative and vegetative processes of the plant. Its pollen release occurs at early spring, when temperature and available water does not limit pollen production.

Wind speed (WS) shows both substantial positive (Tables 1b, 2b and 3b-c) and negative (Tables 1b-c, 2b, 3a and 3c) associations with daily ratios of the pollen counts for the three taxa examined. Relevant connections were detected for *Artemisia*, A≤1.00: for both categories (b) and (c), rank of importance: 1, respectively (Table 1b); A>1.00: category (c), rank of importance: 2 (Table 1c); For *Betula*, categories (b) and (c), rank of importance: 3 and 1, respectively (Table 2b); and for Poaceae, total data set, category (c), rank of importance: 1 (Table 3a); A≤1.00: category (b), rank of importance: 2 (Table 3b). When analysing the role of wind speed a (1) physical (Deák, 2011), a (2) physiological (Deák, 2011) and a (3) transport factor (Makra et al., 2010) should be considered. (1) Wind speed can hinder sticking of pollen grains (positive effect for pollen release); at the same time, (2) higher wind speed increases evapotranspiration leading to loss of water in the plant and the soil. This can be a limiting factor for pollination indirectly, since the plant is forced to preserve water that is more important for its life functions than producing pollen grains (negative effect for pollen release). Furthermore, (3) long range pollen transport may also have a substantial effect to local pollen counts (Makra et al., 2010). As a proportional association, low mean temperature related slow life functions of the taxon, in accordance with factor (2), reduce pollen production. Parallel to this, long range transport together with its physical effect in factor (1) may have a higher weight in increasing pollen counts than the physiological factor through its decreasing effect. A positive association between wind speed and daily pollen ratios is confirmed by Gioulekas et al., (2004), Kasprzyk (2008) and Hernández-Ceballos et al., 2011). Reversely, an inverse relationship can be explained as follows. If mean temperature (T_{mean}) is around its optimum for the three taxa examined, it facilitates to produce a substantial amount of pollen. Then, wind transports away locally produced pollen and instead a smaller amount of pollen is transported from far away to the local environment. A further possibility for an inverse association can be traced back to an extremely high mean temperature (T_{max}), which can result in a significant decrease in available water, leading to a limited pollen production. In this case, transported pollen from far away may have a higher weight in total pollen amount then locally produced pollen (Deák, 2011; Makra et al., 2011).

5. CONCLUSIONS

When using factor analysis with special transformation for all the four categories and the three data sets of the three taxa examined, irradiance (I), minimum temperature (T_{min}) and wind speed (WS) were the most important variables with 15, 10 and 9 significant associations with daily ratios of the pollen counts, respectively. At the same time, mean temperature (T_{mean}), with 1, while relative humidity (RH) with 6 relevant associations was the least important meteorological parameters influencing the resultant variable. After dividing the total data set into two groups, definitely stronger associations between the meteorological variables and the pollen variable were found in the data sets for which A≤1.00 (Tables 1b, 2b and 3b), compared to those for which A>1 (Tables 1c, 2c and 3c). This is due to the difference in the behaviour of the plants to stand environmental stress. Namely, the data sets for which A≤1.00 can be associated to lower summer temperatures with near-optimum phyto-physiological 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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