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# INFLUENCE OF METEOROLOGICAL ELMENTS TO INTERDIURNAL VARIABILITY OF RAGWEED (AMBROSIA) POLLEN CONCENTRATIONS

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**Summary:** The purpose of the study is to analyze the potential reasons of day-to-day variations of *Ambrosia* pollen counts for the Szeged region of Southern Hungary in association with meteorological elements. The database includes a ten-year period (1997-2006) comprising the daily ratios of Ambrosia pollen counts (A) (value on the given day per value on the day before) for its pollen season (July 15 – October 16). At the same time, 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 relevant, while minimum temperature and irradiance are the least important meteorological variables influencing daily pollen ratios. Namely, the data set for which A≤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.

**Key words:** ragweed, allergenic pollen, respiratory disease, meteorological elements, physiological processes, pollen transport

## 1. INTRODUCTION

Air pollution, as a major and ever increasing hazard for the environment, 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). An examination of the historical record demonstrated that the prevalence of allergic rhinitis and allergic asthma have significantly increased over the past two centuries. Although the reasons for this increase are not fully disclosed, epidemiologic data presume that particular pollutants produced from the burning of fossil fuels may have played a substantial role in the prevalence changes (Peterson and Saxon 1996).

Pollen allergy has become a widespread disease by the end of the 20$^{th}$ 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 is considered the region most polluted with airborne ragweed (*Ambrosia*) pollen in Europe (Štefanič et al. 2005, Peternel et al. 2006, Ianovici and Sîrbu 2007, Šikoparija et al. 2009, Chrenová et al. 2010). *Ambrosia* in Hungary discharges the most pollen of all taxa (Járai-Komlódi and Juhász 1993, Makra et al. 2004); the ratio of its pollen release compared to the total pollen release in the late summer period is around 60-71% in Szeged (Juhász and Juhász 2002). Highest counts on peak days in Szeged, Southern Hungary, are about one order of magnitude higher than those over other cities in Europe (Makra et al. 2005). The sensitivity of patients to ragweed in Szeged is 83.7% (Kadocsa and Juhász 2000). Ragweed-related allergy and asthma have become the dominant disease in Hungary during the past few decades (Kazinczi et al. 2008, Páldy et al. 2010). Recently, 20% of the total population suffers from allergic illnesses and for one-third of these patients asthma can also be diagnosed (Strausz et al. 2009). 60-90% of patients with pollen allergy are exposed to ragweed allergy (Harsányi 2009). 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).

In the knowledge of its weather-dependence, the analysis of association of daily ragweed pollen concentrations with daily meteorological parameters is of great practical importance. Applying simple statistical analysis, several studies have detected significant positive correlations between daily ragweed pollen counts on one hand and daily maximum temperature (Stepalska et al. 2008), daily mean temperature (Bartkova-Scevkova 2003, Štefanič et al. 2005, Peternel et al. 2006, Puc 2006, Kasprzyk 2008), daily mean wind speed (Kasprzyk 2008) and daily maximum wind speed (Puc 2006) on the other, but negative correlations with relative humidity (Bartkova-Scevkova 2003, Puc 2006, Kasprzyk 2008) and rainfall (Peternel et al. 2005, Peternel et al. 2006, Kasprzyk 2008). Furthermore, Ziska et al. (2003) established that higher urban temperatures were associated with higher ragweed pollen counts at urban sites compared to rural locations. Based on wind direction analysis, in given cases either long range transport or local sources could have played an important role in actual ragweed pollen concentrations (Kasprzyk 2008, Stepalska et al. 2008).

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 the Szeged region of Southern Hungary in association with meteorological elements. Studying day-to-day variations of ragweed can be considered specific, since we have not found such papers in the international literature. Neither has *Ambrosia* pollen, the most allergenic pollen type, been studied from this point of view. 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 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. The area is characterised 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. In the Köppen system the climate of Szeged is the *Ca* type (warm temperate climate) 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.

The analysis was performed for the ten-year period 1997-2006. Within this term, daily *Ambrosia* pollen counts were analysed for its pollen season (July 15 – October 16). 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.

The *Ambrosia* genus has only one species, namely *Ambrosia artemisiifolia* (Common Ragweed) in the Szeged region. This appears both in the urban environment and in the countryside. Ragweed occurs especially frequently west of the city. The ruling north-western winds can easily transport pollen into the city. Since in the sandy region northwest of Szeged stubble stripping is not necessary for ground-clearance due to the mechanical properties of sandy soils, *Ambrosia* can spread unchecked. Owing to newly-built motorways around Szeged, several farmland areas have been left untouched for a long time that also favour the expansion of *Ambrosia.*

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 year, even if the remaining years involve substantially different pollen seasons with either a remarkably later start or a notably earlier end of the pollen release.

### *2.2. 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 weight (Jahn and Vahle 1968). This latter procedure is called special transformation.

## 3. RESULTS

For each day of the analysis daily differences in meteorological variables (value on the given day – value on the day before) were assigned to the daily ratios of *Ambrosia* 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 meteorological variables for which $A \leq 1$ and (3) those for which $A > 1$, respectively. For all three data sets, the days examined were classified into four categories, respectively. 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.

After performing a factor analysis on all three data sets (altogether 3x4=12 factor analyses) (Tables 1-3), 4, 5, 4 and 4 factors were retained for (a), (b), (c) and (d) categories in the total data set (Table 1); 4, 5, 3 and 4 factors were considered for (a), (b), (c) and (d) categories in the data set for which $A \leq 1$ (Table 2); while, for the remaining case (in the data set for which $A > 1.00$) altogether 4 factors were retained for each category, respectively (Table 3). In order to calculate the rank of importance of the explanatory (meteorological) variables for determining the resultant variable (daily ratios of *Ambrosia* pollen counts), loadings of the retained factors were projected onto Factor 1 for all 12 factor analyses with a special transformation (Tables 1-3) (Jahn and Vahle 1968).

The relationships between the meteorological and pollen variables are only analysed for all data sets that were significant at 10%, 5% or 1% probability levels. Considering the total data set (Table 1), for category (a) rainfall (R), maximum temperature ($T_{max}$), mean temperature ($T_{mean}$) and temperature range ($\Delta T$) in decreasing order of their importance are the most important variables denoting a proportional association with the daily ratios of *Ambrosia* pollen counts. At the same time, wind speed (V) indicates a weak inverse connection with the resultant variable. For category (b) rainfall (R) and wind speed (V) are the only relevant meteorological parameters, both inversely influencing the resultant variable. For category (c) no significant explanatory variables occur, while for category (d) only the role of relative humidity (RH) is substantial representing an inverse association with daily pollen ratios (Table 1).

Table 1 Special transformation. Effect of the daily differences in meteorological variables[1] on the daily ratios of *Ambrosia* 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 *Ambrosia* pollen counts (A) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | a | | b | | c | | d | |
| | thresholds of significance | | | | | | | |
| | *0.139* | | *0.140* | | *0.139* | | *0.073* | |
| | **0.165** | | **0.166** | | **0.166** | | **0.087** | |
| | **0.217** | | **0.218** | | **0.218** | | **0.115** | |
| | weight | rank | weight | rank | weight | rank | weight | rank |
| *Ambrosia* | 0.869 | – | 0.895 | – | 0.999 | – | 0.988 | – |
| $T_{mean}$ | **0.250** | 3 | 0.118 | 3 | 0.083 | 2 | -0.023 | 6 |
| $T_{min}$ | -0.029 | 8 | 0.063 | 6 | 0.117 | 1 | 0.059 | 3 |
| $T_{max}$ | **0.263** | 2 | 0.074 | 4 | 0.049 | 4 | -0.007 | 7 |
| ΔT | **0.199** | 4 | -0.009 | 8 | -0.082 | 3 | -0.058 | 4 |
| I | 0.108 | 6 | -0.069 | 5 | 0.029 | 6 | -0.071 | 2 |
| RH | 0.092 | 7 | 0.056 | 7 | 0.046 | 5 | **-0.166** | 1 |
| V | *-0.165* | 5 | **-0.291** | 2 | 0.002 | 7 | -0.034 | 5 |
| R | **0.548** | 1 | **-0.359** | 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; V = wind speed; R = rainfall

Regarding the data set for which daily ratios of *Ambrosia* pollen counts are smaller or equal to unit ($A \leq 1$) (Table 2), for category (a) rainfall (R) and wind speed (V) proportionally, while temperature range (ΔT) and mean temperature ($T_{mean}$) inversely influence the resultant variable. For category (b) wind speed (V) is the only substantial parameter indicating a positive association with daily pollen ratios. For category (c) wind speed (V) and minimum temperature ($T_{mean}$) are in an inverse, while temperature range (ΔT) and maximum temperature ($T_{max}$) are in a proportional association with daily ratios of *Ambrosia* pollen counts. For category (d) mean temperature ($T_{mean}$), maximum temperature ($T_{max}$), relative humidity (RH) and temperature range (ΔT) inversely, while irradiance (I) and wind speed (V) proportionally influence the resultant variable.

Concerning the data set for which daily ratios of *Ambrosia* pollen counts are higher than unit ($A \leq 1$) (Table 3), for category (a) a proportional association of rainfall (R), while for category (b) an inverse association of wind speed (V) and rainfall (R) with daily pollen ratios are the most important. For category (c) temperature range (ΔT) is negatively, while minimum temperature ($T_{mean}$) is positively associated with the resultant variable. For category (d) irradiance (I) and relative humidity (RH) are the most important, both inversely influencing daily pollen ratios.

Table 2 Special transformation. Effect of the daily differences in meteorological variables[1] on the daily ratios of *Ambrosia* 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 *Ambrosia* pollen counts (A), A ≤ 1.00 | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | a | | b | | c | | d | |
| | thresholds of significance | | | | | | | |
| | *0.185*<br>**0.220**<br>**0.286** | | *0.197*<br>**0.233**<br>**0.304** | | *0.191*<br>**0.225**<br>**0.294** | | *0.106*<br>**0.126**<br>**0.167** | |
| | weight | rank | weight | rank | weight | rank | weight | rank |
| *Ambrosia* | -0.790 | – | -0.813 | – | 0.656 | – | -0.929 | – |
| $T_{mean}$ | *0.193* | 4 | 0.087 | 5 | 0.181 | 5 | **0.260** | 1 |
| $T_{min}$ | -0.166 | 6 | 0.165 | 2 | **-0.316** | 4 | -0.023 | 7 |
| $T_{max}$ | 0.170 | 5 | 0.027 | 8 | **0.397** | 3 | **0.234** | 2 |
| ΔT | **0.249** | 2 | -0.129 | 4 | **0.553** | 2 | **0.151** | 4 |
| I | 0.000 | 8 | -0.156 | 3 | 0.160 | 6 | **-0.144** | 5 |
| RH | -0.072 | 7 | -0.064 | 6 | -0.084 | 7 | **0.176** | 3 |
| V | **-0.243** | 3 | **-0.657** | 1 | **-0.631** | 1 | *-0.119* | 6 |
| R | **-0.725** | 1 | -0.058 | 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; 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 (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 *Ambrosia* pollen counts (A), A > 1.00 | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | a | | b | | c | | d | |
| | thresholds of significance | | | | | | | |
| | *0.233*<br>**0.276**<br>**0.358** | | *0.218*<br>**0.258**<br>**0.335** | | *0.224*<br>**0.265**<br>**0.344** | | *0.105*<br>**0.125**<br>**0.164** | |
| | weight | rank | weight | rank | weight | rank | weight | rank |
| *Ambrosia* | -0.985 | – | 0.794 | – | -0.931 | – | 0.991 | – |
| $T_{mean}$ | 0.014 | 7 | 0.176 | 3 | 0.102 | 5 | 0.096 | 3 |
| $T_{min}$ | 0.031 | 6 | 0.107 | 5 | **-0.391** | 2 | 0.071 | 4 |
| $T_{max}$ | 0.067 | 5 | 0.138 | 4 | 0.153 | 4 | 0.066 | 5 |
| ΔT | 0.010 | 8 | -0.010 | 7 | **0.454** | 1 | -0.042 | 6 |
| I | 0.083 | 4 | -0.081 | 6 | 0.007 | 7 | **-0.127** | 1 |
| RH | -0.165 | 3 | 0.002 | 8 | 0.061 | 6 | *-0.117* | 2 |
| V | 0.185 | 2 | **-0.623** | 1 | 0.215 | 3 | -0.023 | 7 |
| R | **-0.294** | 1 | *-0.254* | 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; V = wind speed; R = rainfall

## 4. DISCUSSION

The analysis of day-to-day variations of *Ambrosia* pollen counts is an important area of pollen research, due to its immediate association with public health. Our study can be considered specific, since the subject of the paper has not been found in the international literature; hence, *Ambrosia* pollen has apparently not been studied from this point of view either. 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 the 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). The reason of this relationship can be as follows. Due to a rainfall on the preceding day, the water balance of the taxon may improve substantially, facilitating a higher pollen release on the given day (positive effect). However a rainfall on the given day, depending on its intensity, may substantially reduce airborne pollen counts (negative effect). As a result, since summer rainfalls are generally short showers early in the afternoon, a more intensive however short rainfall may involve higher pollen counts adding a higher weight to the given-day-related pollen count increase associated with the preceding-day rainfall compared to the given-day-related decrease in pollen counts induced by the rainfall on the given day (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. This association can be explained (1) by the well-known wash-out effect: after rainfall the pollen content of the air reduces sharply (Déchamp and Penel 2002, Kasprzyk 2008, Hernández-Ceballos et al. 2011); (2) another reason of the 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 2010) (Table 1, Table 3). 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 *Ambrosia* pollen grains were negatively correlated with rainfall (Barnes et al. 2001, Déchamp and Penel 2002, Peternel et al. 2005, Peternel et al. 2006, Kasprzyk 2008) at the same time, Bartkova-Scevkova (2003) did not find any statistically significant association.

The 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. These relationships can be explained as follows. In the case of adequate humidity conditions an increase in the mean temperature ($T_{mean}$), can accelerate vegetative and hence generative functions, if it is not too far from its optimum value. Accordingly, it involves an increase in pollen concentrations, indicating a proportional association [Table 1, category (a)] (confirmed by Bartkova-Scevkova 2003, Gioulekas et al. 2004, Kasprzyk 2008). At the same time, when there is a lack of available water, an excessive increase in mean temperature ($T_{mean}$) can mean a barrier for the pollination of *Ambrosia*, as the plant concentrates on preserving water and maintaining its vegetative life functions in contrast to the generative functions (Deák 2010). Hence, in this case mean temperature ($T_{mean}$) shows an inverse association with the daily ratios of *Ambrosia* pollen counts [Table 2, categories (a) and (d)].

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. The inverse relationship can be explained with the following. If the preceding day is rainy, the cooling effect of rainfall can cause a low temperature early in the morning; however, the 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 the low minimum temperature on the given day (Table 2). 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 *Ambrosia* slower (Table 3).

Maximum temperature ($T_{max}$) is an important variable representing a proportional association with the daily pollen ratios for category (a) in the total data set (Table 1); at the same time 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. The proportional relationship may be explained as follows. The dehiscence of anthers and release of pollen result from the dehydration of the walls of anther sacs (Kozlowski and Pallardy 2002), that is facilitated by higher maximum temperatures. Accordingly, higher values of this explanatory variable contribute to higher pollen release. At the same time this association may not be valid for a non-rainy day, preceded by a non-rainy day [category (d) in the data set for which $A \leq 1.00$; Table 2]. In summer time, extremely 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.

Temperature range ($\Delta T$) is in a significant positive relationship with the 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 show 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 ($\Delta T$) 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 cause 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. Accordingly, an increase in temperature range ($\Delta T$) is inversely associated with daily ratios of *Ambrosia* pollen counts. However, if the increase in temperature range ($\Delta T$) remains within a limit, it may show a proportional relationship with daily pollen ratios.

Irradiance (I) shows a proportional and an inverse association with daily ratios of *Ambrosia* pollen counts for category (c) in the data sets for which A ≤ 1.00 (Table 2) and for which A > 1.00 (Table 3). 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 extremely high irradiance (I) related excessive increase in mean temperature ($T_{mean}$), when the plant concentrates on preserving water and maintaining its vegetative life functions and is pressed to restrict its generative functions (Deák 2010).

Relative humidity (RH) is inversely associated with daily pollen ratios for category (c) in all three data sets (Tables 1-3). In general, pollen shedding is associated with the shrinkage and rupture of anther walls by low relative humidity (Kozlowski and Pallardy 2002). Hence, relative humidity is inversely associated with pollen release (Bartkova-Scevkova 2003, Gioulekas et al. 2004). Furthermore, humid air promotes the sticking of pollen grains, which also contributes to an inverse association (affirmed by 23).

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 ≤ 1.00 (Table 2). At the same time, this association is proportional for categories (a), (b) and (d) in the data set for which A ≤ 1.00 (Table 2). When analysing the role of wind speed a (1) physical (Deák 2010), a (2) physiological (Deák 2010) and a (3) transport factor (Makra et al. 2010) should be considered. (1) Wind speed can hinder the sticking of pollen grains (Makra et al. 2010); at the same time, (2) a higher wind speed increases evapotranspiration leading to a loss of water in the plant and the soil. This can indirectly be a limiting factor for pollination, since the plant is forced to preserve water that is more important for its life functions than producing pollen grains (negative effect). Furthermore, (3) long-range pollen transport may also have a substantial effect on local pollen counts (Makra et al. 2010). As a proportional association, slow life functions of the taxon, related to low mean temperature 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 ($T_{max}$) is around its optimum for *Ambrosia*, it facilitates to produce a substantial amount of pollen. Then, wind transports the locally produced pollen and a smaller amount of pollen is transported from other sites to the local environment instead. 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 remote places may have a higher weight in the total pollen amount than locally produced pollen.

## 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 the 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 phyto-physiological processes, while the category of $A > 1.00$ is involved with high and extreme high temperatures modifying life functions and, hence, the interrelationships of the meteorological and pollen variables (Tables 1-3).

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