

Pollution by Urticaceae pollen—influence of selected air pollutants and meteorological parameters

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Abstract The goal of this study was to analyze the influence of pollutants (concentrations of NO₂, SO₂, and soot in the air) and meteorological parameters (air temperature, humidity, wind speed, air pressure, cloud index) on Urticaceae pollen type emission measured in the region of Subotica, Serbia. The concentrations of the air pollutants, Urticaceae pollen, and meteorological parameters were measured over a 5-year period (2009–2013), followed by a statistical analysis of the values obtained. For most of the years examined, the concentration of NO₂ correlates significantly with the concentration of Urticaceae pollen type. It was also established that air temperature, humidity, wind speed, atmospheric pressure, and cloud index have an influence on Urticaceae pollen type emission, while SO₂ and soot do not contribute.

Keywords Pollutants · NO₂ · SO₂ · Soot · Meteorological parameters · Urticaceae pollen type

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Introduction

In Serbia, the genus *Urtica* is represented by two widely distributed ruderal species, *Urtica dioica* L. and *Urtica urens* L. (Blečić 1972). Plants from the family Urticaceae are very common in nitrogen-rich soils, so they grow on roadsides and on cultivated regions close to human habitations (D'Amato et al. 1991; Bisht et al. 2012). Since pollen grains of species of this family are very difficult to differentiate under light microscopy, they are usually described as Urticaceae pollen type. It has a tri-zonoporate pollen grain, with a pollen size (diameter of approximately 13–20 µm) that is smaller than most other types of anemophilous species of weeds (Erdtman 1952; Rodríguez-Damián et al. 2003).

In Central and Southern Europe, including the region of Subotica, Northern Serbia, one of the largest multi-annual average values of weed pollen index was recorded for the Urticaceae pollen type. The share of airborne pollen of Urticaceae type, relative to the total airborne pollen load during the entire sampling period (from mid-April until the first decade of October) was 17.4 % (Čamprag Sabo et al. 2015).

Pollen from species belonging to genus *Urtica* has very little allergenicity but can induce urticaria and dermatitis (Vega-Maray et al. 2006).

Urticaceae pollen persists long-term in the air of the investigated region of Subotica, due to the large population of this family, resulting from the conditions that are suitable for their development (Mitrović 2013). The release of Urticaceae pollen grains requires suitable conditions of temperature and humidity (González et al. 1997). Temperature has its most important influence on pollen concentrations during spring (Ivanović et al. 2012), while humidity has a predominant role in autumn (Galan et al. 2000). Further, the same authors concluded that there is a significant positive correlation between humidity, caused by light rainfall, and concentration of pollen,

while the level of significance drops and the correlation even becomes negative in conditions of heavy rainfall. Emberlin and Norris-Hill (1991) measured Urticaceae pollen concentrations in areas of central London and found that the annual differences in cumulative concentration were due primarily to weather conditions in the period of pollen formation; weather conditions in the pollen release season are less significant. Increase of temperature has a negative impact on the concentration of Urticaceae pollen during a dry, low-rain season.

Relative humidity was found to have adverse effect on the content of pollen in the atmosphere, while temperature and wind speed in the dry season were associated with increased pollen indexes in a study where statistical Spearman's rank-order correlations with meteorological parameters were performed (Moreno-Sarmiento et al. 2015).

It is well-known that some pollutants such as NO₂ (Zhao et al. 2016; Cuinica et al. 2014; Sousa et al. 2012) and SO₂ (Ouyang et al. 2016; Cuinica et al. 2013), may have the influence on different factors connected with concentrations of the certain types of pollen in the air.

The goal of this study was to establish previously non-investigated influence of certain chemical (NO₂, SO₂ and soot), and meteorological (air temperature and humidity, wind speed, air pressure, cloud index) parameters on pollen emission of Urticaceae.

Materials and methods

The research was conducted in Subotica, a city located in the Pannonian Basin, Northern Serbia. Inhabited by a population of nearly 120,000, Subotica could be considered as semi-rural environment, since most of the inhabitants live in family houses surrounded by a plenty of green areas and agriculture fields.

Suspended particulate matter (pollen type Urticaceae and soot), gaseous air pollutants (sulfur dioxide and nitrogen dioxide) and meteorological parameters (air temperature, humidity, wind speed, air pressure, and cloud index) were measured at a site in the urban area of Subotica (46°10'47" N, 19°66'80" E). Regular daily measurements were made and samples taken from February to November for the period 2009–2013.

Gaseous air pollutants (sulfur dioxide and nitrogen dioxide) were absorbed from a given volume of air by a suitable absorbing solution by air sampling appliance. Soot samples were obtained by filtering a given volume of air through the Whatman filter paper grade No 1. Samples of suspended particles were taken by an ambient air sampler (Sven Leckel LSV 3). Pollen samples were collected by the Hirst volumetric method (Hirst 1952) using a Burkard 7-day-recording volumetric pollen trap sampler.

The samples were analyzed in accordance with ISO standard methods (ISO 6767:1990; ISO 9835:1993; ISO 6768:1998). Air samples of pollen were analyzed in accordance with the method for sampling and counting airborne pollen and fungal spores (Mandrioli 2000).

Software Statistica 8.0 was used for statistical analysis. Minimum, maximum, and mean values together with standard deviation and variation coefficient of pollutants and meteorological variables in this study were used to investigate the relation with Urticaceae pollen counts. Data were treated using the Spearman rank order correlation test, since the variables are not normally distributed. The *F* test, factor analysis (factor loading and factor score), and modeling—day by day method were also used.

Results

Minimum, maximum, mean, standard deviation, and variation coefficient of the concentrations of Urticaceae pollen as well as air pollutants (sulfur dioxide, soot and nitrogen dioxide) and meteorological parameters (air temperature, humidity, wind speed, air pressure, and cloud index) were obtained for the period 2009–2013 in Table 1. The results show that the levels of pollutants vary greatly from year to year (the average coefficient of variation for SO₂ is 144 %, for NO₂, 41 %, and for soot 75 %), and, as expected, meteorological values are more stable (average coefficients of variation are 20 % for air temperature, 21 % for humidity, 0.4 % for air pressure, 38 % for wind speed, and 73 % for cloud index).

Since the series of pollen counts is not normally distributed, the Spearman rank order correlation was analyzed instead of the Pearson product-moment correlation. Spearman correlations between concentrations of Urticaceae pollen grain and concentrations of air pollutants factors and values of meteorological factors were derived (Table 2) together with results of factor analysis – factor loadings with factor score coefficients for pollutants (Table 3) and factor loadings with factor score coefficients for pollutants for meteorological parameters (Table 4). Elements of the correlation matrix constituted initial values for factor analysis. Principal components analysis was applied, and normalized varimax rotation used for the series of data pooled over of 5 years (632 data). There are several different procedures for determining the number of factors. Since over-factoring has less negative properties than under-factoring, Cattell's method, (Cattell 1966), although subjective, was applied instead of the simple eigenvalue over 1 rule (Kaiser 1960), so the eigenvalue preceding the last substantial drop was retained. Two factors were determined for three variables, sulfur dioxide, nitrogen dioxide, and soot (Table 3). Variables SO₂ and soot form the first cluster and are represented by factor 1, with the same signs of factor loadings showing the

Table 1 Descriptive statistics for the period 2009–2013

Variable	Year	Min	Max	Mean	Standard deviation	Variation coefficient (%)
Urticaceae pollen grains (pg/m ³)	2009	0	116	35.9	29.9	83
	2010	0	205	58.4	53.0	91
	2011	0	86	26.3	19.4	73
	2012	0	181	46.6	45.3	97
	2013	0	408	80.0	92.5	116
	2009–2013	0	408	51.3	59.2	115
Pollutants						
SO ₂ (µg/m ³)	2009	0.6	24	9.1	4.8	52
	2010	0	12	32.5	17.1	79
	2011	0	6	1.2	1.3	107
	2012	0	12	1.3	2.1	155
	2013	0	1	0.02	0.1	678
	2009–2013	0	24	2.8	4.1	144
NO ₂ (µg/m ³)	2009	15.5	61	35.3	8.7	24
	2010	0.9	59	20.2	4.5	37
	2011	1	52	25.3	10.6	42
	2012	0	88	33.8	13.9	41
	2013	2	90	32.7	15.9	48
	2009–2013	0	90	31.9	13.0	41
Soot (µg/m ³)	2009	0	85	34.2	16.6	48
	2010	0	78	73.6	12.1	53
	2011	3	120	29.2	19.8	68
	2012	0	94	17.9	17.1	95
	2013	0	50	12.2	11.2	91
	2009–2013	0	120	24.8	18.6	75
Meteorological factors						
Air temperature (°C)	2009	12.0	28.1	21.6	3.6	17
	2010	8.4	28.4	20.2	4.5	22
	2011	14.7	30.0	22.0	3.3	15
	2012	9.8	30.3	22.2	4.4	20
	2013	11.0	29.5	20.6	4.5	22
	2009–2013	8.4	30.3	21.3	4.2	20
Humidity (%)	2009	43	95	61.9	12.1	20
	2010	50	99	73.6	12.1	16
	2011	42	94	65.7	11.3	17
	2012	36	98	57.0	13.6	24
	2013	42	96	64.9	13.9	21
	2009–2013	36	99	64.8	13.9	21
Air pressure (mbar)	2009	994.8	1011.6	1003.7	4.1	0.4
	2010	982.3	1011.7	1000.9	4.9	0.5
	2011	990.1	1009.3	1001.9	4.1	0.4
	2012	993.3	1012.7	1002.6	4.0	0.4
	2013	989.8	1011.0	1002.9	4.2	0.4
	2009–2013	982.3	1012.7	1002.4	4.4	0.4
Wind speed (m/s)	2009	1.7	5.5	3.3	0.8	24
	2010	2.0	7.2	3.4	1.0	30
	2011	0.8	5.1	2.4	0.9	40
	2012	0.7	9.0	2.5	1.0	41
	2013	0.8	4.9	2.2	0.8	37

Table 1 (continued)

Variable	Year	Min	Max	Mean	Standard deviation	Variation coefficient (%)
Cloud index	2009–2013	0.7	9.0	2.8	1.1	38
	2009	0	8	2.9	1.9	65 %
	2010	0	8	3.8	2.4	64
	2011	0	7.9	3.0	2.2	75
	2012	0	8	2.5	2.1	85
	2013	0	8	3.2	2.3	74
	2009–2013	0	8	3.1	2.3	73

same direction of effects. Factor 2 is highly correlated to variable NO₂.

Daily changes in values of the pollen concentrations with changes of explanatory meteorological and chemical parameters are shown in Table 5. One of the preconditions of dependence between explanatory variables and Urticaceae pollen grain concentrations is that any change in the regressor will contribute to change of the dependent variable. Consecutive correlation coefficients were calculated between Urticaceae pollen grain concentrations and every separate regressor for daily measurements, and then compared to the one obtained on the previous day. When the direction of changes of the two variables is the same, then $r = 1$ and, if the changes are opposite, then $r = -1$. Days with no changes were not considered. The relation between the sum of the positive and negative variables shows the prevailing sign of connection between the independent and the dependent variables. In the case of there being no influence, the proportion of signs is 0.5:0.5. One sample t test was performed for significance of the difference between the proportion with higher value (out of two proportions) and the given hypothesized proportion of balanced changes (0.5).

Discussion

The period of appearance of Urticaceae pollen in the air varies from year to year, depending on metrological conditions. It starts between mid-April and mid-May and ends between the end of September and the middle of October. The start and end of Urticaceae pollen seasons in examined region of Subotica are characterized by a very low pollen count that does not reflect the general conditions of the factors that are influencing. For a better insight into possible interdependencies, the tails of the yearly periods were cut out by determining the main season using the modified Thompson Tau Test, a statistical method for deciding whether to discard suspected outliers in a sample of a single variable. Minimal values that are still not outliers were determined for every year and the minimum

of those values, Y_0 , was chosen as a general lower bound for every year. The season was defined as lasting from the first appearance of a value equal or greater than Y_0 through the day before the last value less than Y_0 appeared. The lower bound for Urticaceae was found to be 17 grains per m³ ($=Y_0$).

A Spearman rank order correlation shows that, unlike in cases of some other pollen—*Acer negundo*, (Sousa et al. 2012), *Betula pendula* (Cuinica et al. 2013), *Ostrya carpinifolia* and *Carpinus betulus* (Cuinica et al. 2014), there was no effect of either SO₂ or soot on Urticaceae pollen count over the observed individual years, which is confirmed by average data for all years. On the other hand, as it may be expected from investigation of other pollen, e.g., *Ambrosia* (Zhao et al. 2016), *Quercus* (Ouyang et al. 2016), and opposite to some other research of *Betula*, *Ostrya carpinifolia*, and *Carpinus betulus* pollen (Cuinica et al. 2014); the count is strongly positively affected by NO₂ in 2009, 2010, 2012, and 2013 (correlation diagram for 2009–2013 was shown in Fig. 1) and this also applies to pooled data. The correlation equations expressing the relation between concentrations of NO₂ and show that, in theory, if the concentration of NO₂ in the air were equal to zero, the Urticaceae pollen grains concentrations would be between 3.5 pg/m³ and 24.9 pg/m³, far from maximal concentrations, thus proving significant influence concentration of NO₂ has on the concentration of the Urticaceae pollen in the air.

Of the five meteorological variables analyzed, air temperature has a highly significant positive impact on pollen count in every year (correlation diagram for 2009–2013 was shown in Fig. 2), and accordingly, on average, for pooled data also, as shown by Spearman correlations. According to correlation equations in 2009, 2010, 2012, and 2013, at the temperatures between approximately 11 and 14 °C, the concentration of the observed pollen would be equal to zero, on the assumption that, at the lower temperatures, pollination does not occur. Unlike in the other examined years, temperature corresponding to a pollen concentration of zero is much lower, less than 8.8 °C, taking into consideration the possibility that pollination starts at lower temperatures than in 2009–2010 and 2012–2013.

Table 2 Spearman rank order correlations between the concentration of Urticaceae pollen grains and pollutants

Pollutants	Year	Spearman <i>R</i>	<i>p</i> level
SO ₂ (µg/m ³)	2009	0.1603	0.0857
	2010	−0.0475	0.5775
	2011	0.1636	0.0955
	2012	−0.0730	0.4071
	2013	−0.1605	0.0566
	2009–2013	−0.0620	0.1193
NO ₂ (µg/m ³)	2009	0.2935	0.0014
	2010	0.4869	0.0000
	2011	0.0638	0.5178
	2012	0.3341	0.0001
	2013	0.3079	0.0002
	2009–13	0.3237	0.0000
Soot (µg/m ³)	2009	−0.0524	0.5764
	2010	−0.0350	0.6813
	2011	−0.0190	0.8509
	2012	0.1904	0.0394
	2013	−0.0861	0.3118
	2009–2013	−0.0458	0.2498
...meteorological factors			
Air temperature (°C)	2009	0.4818	0.0000
	2010	0.7358	0.0000
	2011	0.4087	0.0000
	2012	0.5056	0.0000
	2013	0.4125	0.0000
	2009–2013	0.5615	0.0000
Humidity (%)	2009	−0.2926	0.0014
	2010	−0.5749	0.0000
	2011	−0.3990	0.0000
	2012	−0.3426	0.0001
	2013	−0.5883	0.0000
	2009–2013	−0.3780	0.0000
Air pressure (mbar)	2009	0.0565	0.5471
	2010	0.3736	0.0000
	2011	0.2333	0.0166
	2012	0.1664	0.0575
	2013	0.2724	0.0011
	2009–2013	0.2125	0.0000
Wind speed (m/s)	2009	0.0013	0.9893
	2010	−0.3190	0.0001
	2011	−0.1660	0.0909
	2012	−0.1019	0.2467
	2013	−0.2880	0.0006
	2009–13	−0.1468	0.0002
Cloud index	2009	−0.3428	0.0002
	2010	−0.6753	0.0000
	2011	−0.4750	0.0000
	2012	−0.3660	0.0000
	2013	−0.5625	0.0000
	2009–2013	−0.4710	0.0000

Table 3 Factor loadings and factor score coefficients for pollutants

	Variable	Factor 1	Factor 2
Factor loadings	SO ₂	0.882	0.017
Factor score coefficients		0.708	0.242
Factor loadings	NO ₂	0.121	−0.974
Factor score coefficients		−0.152	−0.983
Factor loadings	Soot	0.754	−0.305
Factor score coefficients		0.524	−0.125
	Eigenvalues	1.570	0.832
	% of total variance	52.33	27.74

Loadings > 0.7 are italicized

Positive impact is evident for air pressure in the three years but significant only for the pooled data. The average impacts of air temperature and pressure are significant, their higher values contributing to higher pollen counts.

Humidity and cloud index are significantly inversely connected to pollen count in each year. Over the 5 years analyzed, significant impact of wind speed on pollen count is shown in 2 years, 2010 and 2013.

On the basis of factor score coefficients, the factor scores (FS) represent explanatory variables in the estimated multiple regression by which concentrations of Urticaceae pollen grains constitute the dependent variable calculated for the first factor (FS1) and the second factor (FS2). The effect of each factor on the dependent variable represents the common influence of variables encompassed by the respective factor, and can be described as:

$$Y = 51.285 - 9.465 \cdot \text{FS1} - 18.416 \cdot \text{FS2}$$

$$p : 0.000 \quad 0.0000.000$$

$$R^2 = 0.1225, F = 43.92, p < 1\%$$

F test shows the high significance of the determination coefficient and also that of the explanation of changes in Urticaceae pollen grains concentration by the common influence of F1 and F2. Factor F1 is positively correlated to both SO₂ and soot while the sign of the corresponding parameter is negative, meaning that higher levels of SO₂ and soot combined contribute to a lower value of the dependent variable. The abundant presence of Urticaceae pollen at the lowest SO₂ concentrations has been reported in Poland (Puc and Bosiacka 2011).

The factor loading of F2 is negative and, since the sign of the respective parameter in the regression equation is also negative, the influence of the encompassed variable (NO₂) is positive towards Urticaceae pollen grains concentrations. These findings are in accord with the direction of influence presented by the correlation matrix.

Three factors were determined for the five variables, air temperature, air humidity, wind speed, air pressure, and cloud index (Table 4). Factor 1 is highly correlated to air temperature,

Table 4 Factor loadings with factor score coefficients for meteorological factors

	Variable	Factor 1	Factor 2	Factor 3
Factor loadings	Air temperature	<i>0.881</i>	0.163	−0.185
Factor score coefficients		−0.166	−0.000	−0.967
Factor loadings	Humidity	−0.835	0.358	−0.035
Factor score coefficients		0.149	0.967	0.015
Factor loadings	Air pressure	0.150	−0.945	−0.140
Factor score coefficients		0.410	−0.203	0.373
Factor loadings	Wind speed	−0.133	0.133	<i>0.976</i>
Factor score coefficients		0.149	0.967	0.015
Factor loadings	Cloud index	−0.810	0.352	0.170
Factor score coefficients		−0.421	−0.058	0.050
	Eigenvalues	2.615	0.961	0.821
	% of total variance	52.30	19.21	16.41

Loadings > 0.7 are italicized

humidity, and cloud index, which thus form the first cluster. Equal signs of factor loadings for air humidity and cloud index show the same direction of their common effects which is, at the same time, opposite to the effect of air temperature. Factor 2 is highly correlated to variable air pressure and factor 3 to wind speed. On the basis of factor score coefficients the factor scores (FS) are calculated for the first (FS1), the second (FS2), and the

third (FS3) factors and the next regression equation was defined as:

$$Y = 51.284 + 23.957 \cdot \text{FS1} - 5.049 \cdot \text{FS2} - 8.505 \cdot \text{FS3}$$

$$p: 0.000 \quad 0.000 \quad 0.000 \quad 0.000$$

$$R^2 = 0.1920, F = 49.74, p < 1\%$$

Table 5 Daily changes in values of the dependent variable *Y* with changes of explanatory variables: increasing (↗) and decreasing tendency (↘)

Variable	SO ₂	NO ₂	Soot	Air temperature	Humidity	Air pressure	Wind speed	Cloud index
No changes in one direction (+1)	191	330	297	333	231	303	256	262
No changes in the opposite direction(-1)	167	254	282	255	341	291	314	320
No changes in one of the variables (0)	269	42	47	38	54	32	56	44
Proportion of changes in the same direction	0.534	0.565	0.513	0.566	0.404	0.510	0.449	0.450
Proportion of changes in opposite directions	0.466	0.435	0.487	0.434	0.596	0.490	0.551	0.550
p	0.1023	0.0008	0.2665	0.0006	0.0000	0.3112	0.0076	0.0081
Significance	NO	YES	NO	YES	YES	NO	YES	YES
Value of the explanatory variable increases on any one day compared to the previous day		↗		↗	↗		↗	↗
Changes in Y are significantly more frequent in the presented direction		↗		↗	↘		↘	↘
Value of the explanatory variable decreases on any one day compared to the previous day		↘		↘	↘		↘	↘
Changes in Y are significantly more frequent in the presented direction		↘		↘	↗		↗	↗

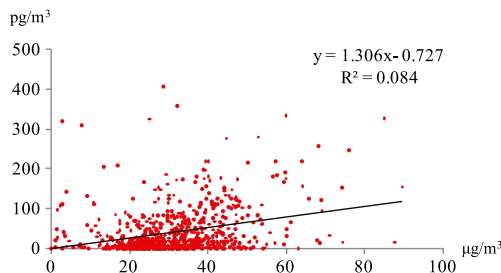


Fig. 1 Scatter diagram for Urticaceae pollen grains (vertical axis) and NO₂ for the period 2009–2013

F test shows the high significance of the determination coefficient and the explanation of changes in Urticaceae pollen grain concentrations under the common influence of F1, F2, and F3. F1 is positively correlated to air temperature and negatively to air humidity and cloud index, while the sign of the respective parameter is positive, meaning that higher levels of air temperature, combined with lower levels of air humidity and cloud index, contribute to higher values of the dependent variable. Factor loading of F2 is negative and since the sign of the respective parameter in the regression equation, meaning that the influence of the encompassed variable (air pressure) is positive on the concentration of Urticaceae pollen grains, i.e., that higher air pressure is followed by higher concentrations of Urticaceae pollen grains. F3 is positively correlated to wind speed and the sign of the respective parameter in the estimated regression equation is negative, meaning that the influence of wind speed, shown through F3, is negative towards the concentration of Urticaceae pollen grains, higher wind speed contributing to lower levels of the dependent variable. These findings are in accordance with the direction of influence presented by the correlation matrix.

Conclusion

The influence of some chemical (concentrations of NO₂, SO₂, and soot in the air) and meteorological (air temperature, humidity, wind speed, air pressure, cloud index) parameters over a 5-year period (2009–2013) on Urticaceae pollination measured in the region of Subotica, Serbia, has been analyzed.

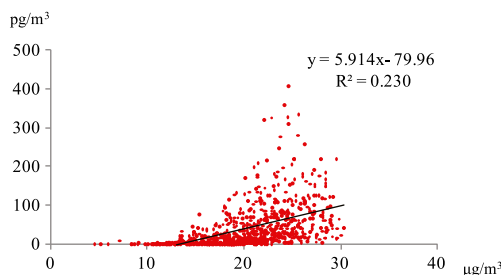


Fig. 2 Scatter diagram for Urticaceae pollen grains (vertical axis) and air temperature for the period 2009–2013

The influence of concentrations of NO₂, a relevant air pollutant, on pollination process has been revealed for the first time. Pollen concentrations in the air have been shown to increase with increased NO₂ content in 4 of the 5 years examined. The only year with no significant correlation between concentrations of NO₂ and Urticaceae pollen grain was 2011, having the highest minimal air temperature during the pollination period in the investigated years, thus supporting the speculation that pollination in years with high minimal temperatures occurs by a different mechanism, one that is not influenced by NO₂ concentrations in the air. Unlike NO₂, soot, and SO₂ concentrations do not exhibit statistically visible and significant influences on the concentration of Urticaceae pollen grains.

Concerning the investigated meteorological parameters, it was once again confirmed that air temperature is, among those examined, the most important factor influencing the rise of the Urticaceae pollen index. High concentrations of Urticaceae pollen grain in the air also coincide with high air pressure, absence of wind, low cloud index and low air humidity conditions.

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Compliance with ethical standards None of the research described in this paper was done with the involvement of human participants and/or animals.

The authors declare that they have no competing interests.

References

- Bisht S, Bhandari S, Bisht NS (2012) *Urtica dioica* (L): an undervalued, economically important plant. *Agric Sci Res J* 2:250–252, ISSN-L: 2026–6073
- Blečić V (1972) *Flora of SR Serbia*. SANU, Belgrade
- Čamprag Sabo N, Popović A, Đorđević D (2015) Air pollution by pollen grains of Anemophilous Species: influence of chemical and meteorological parameters. *Water Air Soil Pollut*. 226–292. doi:10.1007/s11270-015-2549-5
- Cattell RB (1966) The data box: Its ordering of total resources in terms of possible relational systems. In: Cattell RB (ed) *Handbook of multivariate experimental psychology*. Rand-McNally, Chicago, pp 67–128
- Cuínica LG, Abreu I, Esteves da Silva J (2014) Effect of air pollutant NO₂ on *Betula pendula*, *Ostrya carpinifolia* and *Carpinus betulus* pollen fertility and human allergenicity. *Env Pollut* 186:50–55
- Cuínica LG, Abreu I, Rocha Gomes C, Esteves da Silva JCG (2013) Exposure of *Betula pendula* Roth pollen to atmospheric pollutants CO, O₃ and SO₂. *Grana* 52:299–304
- D'Amato G, Ruffilli A, Ortolani C (1991) Allergenic significance of *Parietaria* (Pellitory of the wall) pollen. In: D'Amato G, Spiekma FTM, Bonini S (eds) *Allergenic Pollen and Pollinosis in Europe*. Blackwell Scientific Publishers, Oxford, pp 113–118

- Emberlin J, Norris-Hill J (1991) Annual, daily and diurnal variation of Urticaceae pollen in North-central London. *Aerobiologia* 7:49–57. doi:10.1007/BF02450017
- Erdtman G (1952) Pollen morphology and plant taxonomy. In Almquist & Wiksells (ed) *Angiosperms*, Sweden, pp 445–446
- Galan C, Alcazar P, Carinanos P, Garcia H, Dominguez-Vilches E (2000) Meteorological factors affecting daily Urticaceae pollen counts in southwest Spain. *Int J Biometeorol* 43:191–195. doi:10.1007/s004840050008
- González MFJ, Candau P, Tomás P, Morales J (1997) Variación anual y estacional del polen de Urticaceae en el aire de Sevilla y su relación con los factores meteorológicos. *Polen* 8:69–78
- Hirst JM (1952) An automatic volumetric spore trap.—*Ann. Appl Biol* 39:257–265. doi:10.1111/j.1744-7348.1952.tb00904.x
- Ianovici N, Panaitescu CB, Brudiu I (2012) Analysis of airborne allergenic pollen spectrum for 2009 in Timișoara, Romania. *Aerobiologia* 29:95–111. doi:10.1007/s10453-012-9266-y
- ISO 6767:1990 Ambient air. Determination of the mass concentration of sulfur dioxide. Tetrachloromercurate (TCM)/pararosaniline method
- ISO 6768:1998 Ambient air. Determination of mass concentration of nitrogen-dioxide. Modified Griess-Saltzman method
- ISO 9835:1993 Ambient air. Determination of a soot index
- Kaiser HF (1960) The application of electronic computers to factor analysis. *Educ Psychol Meas* 20:141–151. doi:10.1177/001316446002000116
- Mandrioli P (2000) Method for sampling and counting of airborne pollen and fungal spores. Institute of Atmospheric and Oceanic Sciences. National Research Council, Bologna
- Mitrović S (2013) The environment quality of Northern Backa district in 2012. Open University, Subotica
- Moreno-Sarmiento M et al. (2015) Urban airborne pollen in a semiarid environment. *Aerobiologia*:1–8. *Brief Commun.* doi:10.1007/s10453-015-9401-7
- Ouyang Y et al. (in press) Effect of nitrogen dioxide and sulfur dioxide on viability and morphology of oak pollen. *Int Forum Allergy Rhinol.* doi:10.1002/alr.21632
- Puc M, Bosiacka B (2011) Effects of meteorological factors and air pollution on urban pollen concentration. *Polish J Environ Stud* 20:611–618
- Rodríguez-Damián M, Cemadas E, Formella A, Gonzáles A (2003) Automatic identification and classification of pollen of the Urticaceae family. *Proceedings of Acivs (Advanced Concepts for Intelligent Vision Systems)*, Ghent, Belgium
- Sousa R et al (2012) In vitro exposure of *Acer negundo* pollen to atmospheric levels of SO₂ and NO₂: effects on allergenicity and germination. *Environ Sci Technol* 46:2406–2412. doi:10.1021/es2034685
- Vega-Maray A et al (2006) Allergenic proteins in *Urtica dioica*, a member of the Urticaceae allergenic family, *Ann. Allergy Asthma Immunol* 97:343–349
- Zhao F et al. (in press) Common ragweed (*Ambrosia artemisiifolia* L.): allergenicity and molecular characterization of pollen after plant exposure to elevated NO₂. *Plant Cell Envir.* doi:10.1111/pce.12601