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Airborne pollen from allergenic herbaceous plants in urban and rural areas of Western Pomerania, NW Poland

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Abstract

This paper presents the course of the pollen season of selected allergenic taxa (*Rumex* spp., *Plantago* spp., *Urtica* spp. and Chenopodiaceae) in two towns with different degrees of urbanisation (urban, the city Szczecin, and rural, the village Gudowo in Western Pomerania, northwest Poland). The study was conducted in the years 2012–2014 with the volumetric method. The pollen of allergenic herbaceous plants was present in the air from early May until the end of September. From among the taxa studied, the genus *Rumex* is characterised by the longest pollination period, while the genus *Urtica* by the shortest. The highest percentage contribution of pollen grains to the total pollen count in the air reaching over 90% is from nettle. The pollen seasons determined for the majority of taxa are longer in the city, however the mean pollen grain counts in the air are higher for the rural area.

Keywords: allergens, airborne pollen concentrations, sorrel, plantain, nettle, white goosefoot

Allergy is the body's abnormal hypersensitivity reaction following exposure to a variety of environmental agents (allergens), which are otherwise harmless to the majority of people (Hofman & Michalik 1998). Allergic diseases have become an important social problem, which affects nearly 20% of the population in Poland (Hofman & Michalik 1998). Allergic rhinitis, manifesting as itchy nose, sneezing, watery nasal discharge and the sensation of stuffy nose, is caused by house dust mites, animal epidermal allergens and plant pollen allergens (Rapiejko 2006). A distinguishing feature of allergic conditions triggered by plant pollen allergens is the seasonality of symptoms. An increase in disease symptoms in individuals who are allergic to plant pollen is strictly correlated with the aeroallergen count in the air. A rising aeroallergen count is accompanied by an increase in the severity of pathological symptoms (Rapiejko 2004). The diagnosis, prevention and efficacy assessment of pollen allergy treatment rely on aeropalynological test results (Obtułowicz et al. 1990; Obtułowicz &

Myszkowska 1996; Rapiejko 1997; Ouyang et al. 2012). Airborne pollen concentrations for herb species tend to be representative only of a local area, while tree airborne pollen concentrations provide information about a wider area, and even at the regional level (Hicks 1992).

Common plant species of the genus *Rumex* in Poland include *R. acetosa* L. (common sorrel) and *R. crispus* L. (curly dock). *Rumex crispus* is a ruderal plant and a cereal weed. It grows in shoreline communities and meadows. It is a tall perennial with an erect, rigid stem reaching up to 150 cm in height. The leaves of the plant are petiolate, elliptic or linear-lanceolate in shape, with undulate margins. The flowers are greenish or reddish in colour, arranged in a panicle (Szwejkowski & Szwejkowska 1993). *Rumex acetosa* is an edible perennial, a culinary herb and a medicinal plant. It is commonly found in meadow plant communities, near ditches and in shrubberies. The stalk is tall, growing to 100 cm high. The leaves have hastate bases and long

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petioles. The flowers are greenish/reddish in colour, arranged in panicles at the apices of branched stems (Szwejkowski & Szwejkowska 1993).

The most commonly represented species of the genus *Plantago* in Poland are *P. major* L. (broad-leaf plantain), *P. lanceolata* L. (narrowleaf plantain) and *P. minor* L. (hoary plantain). Other *Plantago* species found in Poland include *P. intermedia* Gili. (many-seeded plantain), *P. montana* Lam. (mountain plantain), *P. serpentina* All. (snake plantain) and, rarely, *P. maritima* L. (sea plantain), *P. coronopus* L. (buckshorn plantain) and *P. indica* L. (whorled plantain) (Zajac & Zajac 2001; Rutkowski 2004). *Plantago major* is a ruderal weed. It has broad-ovate leaves clustered in a rosette at the base of the plant. The leafless erect stem ends with a lance-shaped spike, up to 15 cm in length. *Plantago* flowers are small, usually hermaphroditic and wind-pollinated. *Plantago* fruits have the form of a capsule or an indehiscent nut. *Plantago* herbs are used for medicinal purposes (Szwejkowski & Szwejkowska 1993). A single *Plantago* inflorescence produces up to 2010000 pollen grains (Rapiejko 2008).

The genus *Urtica* is commonly represented in Poland by the two species *U. dioica* L. (common nettle) and *U. urens* L. (dwarf nettle) (Szwejkowski & Szwejkowska 1993). *Urtica dioica* is a nitrophilous plant dispersed by ants, growing in primary and ruderal habitats. It is a dioecious perennial covered with stinging hairs. It has a four-angled stem growing to a height of 150 cm. The leaves are ovate with serrate margins. The wind-pollinated flowers are small, greenish in colour, arranged in clusters in leaf axils near the stem. *Urtica dioica* is a medicinal plant. *Urtica urens* is a monoecious annual plant reaching up to 60 cm in height. As opposed to *U. dioica*, *U. urens* develops inflorescences, which are shorter than the petioles (Szwejkowski & Szwejkowska 1993).

Chenopodiaceae is a family of cosmopolitan weeds and ruderal plants. A common representative of the family in Poland is *Chenopodium album* L. (white goosefoot). It is an annual plant growing to 150 cm. The entire plant is covered with a mealy coating. The leaves are oblong-ovate or lanceolate, with serrate margins and a wedge base. The flowers are small, greenish and clustered in panicles. The plant produces fruits in the form of dry indehiscent nuts (Szwejkowski & Szwejkowska 1993).

Pollen released by *Rumex*, *Plantago*, *Urtica* and Chenopodiaceae rarely triggers disease symptoms; however, it acquires importance in severe pollinosis (Rapiejko 1997; Weryszko-Chmielewska & Piotrowska 2004; Myszkowska et al. 2007). Organic and inorganic chemical compounds that are present in the air are deposited on the surface of pollen grains

and they are inhaled with them. In recent decades, it is one of the reasons for the increased incidence of pollinosis in industrialised areas (Obtułowicz 2001). In addition, the pollen grains can be carriers of bacteria, microscopic fungi and bacterial and fungal toxins (Śpiewak et al. 1996). The adjuvanticity impact of air pollutants strengthens or enhances the appearance of an immune response after exposure to a pollen allergen. Pollutant emissions (suspended particles, ozone, sulphur oxides and carbon oxides) into the environment causes therein permanently or difficult to reverse changes. PM₁₀ dust particles (respirable suspended particle [RSP], which are particles with a diameter of 10 µm or less) are generated in combustion processes and can easily penetrate into the lungs causing an increase in the number of respiratory tract infections and severity of the symptoms of pollinosis. Ozone is formed extensively during the summer, in large urban areas, a few hours after the peak of car traffic, as a result of complex photochemical reactions between volatile organic substances, nitrogen oxides and sunlight. Ozone irritates the mucous membrane of the respiratory tract. Sulphur dioxide is produced by burning high-sulphur black coal and it damages the mucosa of the respiratory tract, increasing the viscosity of mucus (Rogerieux et al. 2007).

Urbanisation, high levels of vehicle emissions and a westernised lifestyle are correlated with the increasing frequency of pollen-induced respiratory allergy. People living in urban areas tend to be more affected by pollen-induced respiratory allergy than those from rural areas (D'Amato et al. 2001). The effects of carbon dioxide, as well as increased temperatures from climate change, increase pollen production and the allergen content of pollen grains (Reid & Gamble 2009).

Amjad and Shafighi (2012) studied the effect of air pollution on structure and pollen grain development in *Chenopodium album*. When pollen grains were exposed to polluted air, they became abnormal in form and were covered with large amounts of pollutants. Pollen abnormalities were seen as irregularities, shrinkage, thinning and breakage of the exine. Cellular material release was also induced. Prolonged exposures of plants to air pollution may cause different biological effects at the cellular tissue and organ levels.

The aim of the present study was to examine airborne pollen concentrations for selected taxa of herbaceous plants in two locations differing in the degree of urban development: the city of Szczecin and the village of Gudowo (Western Pomerania), and to evaluate the risk of exposure to pollen allergens in patients suffering from pollinosis (pollen calendars). Before the current study, there had not been any analyses comparing the risk of exposure to

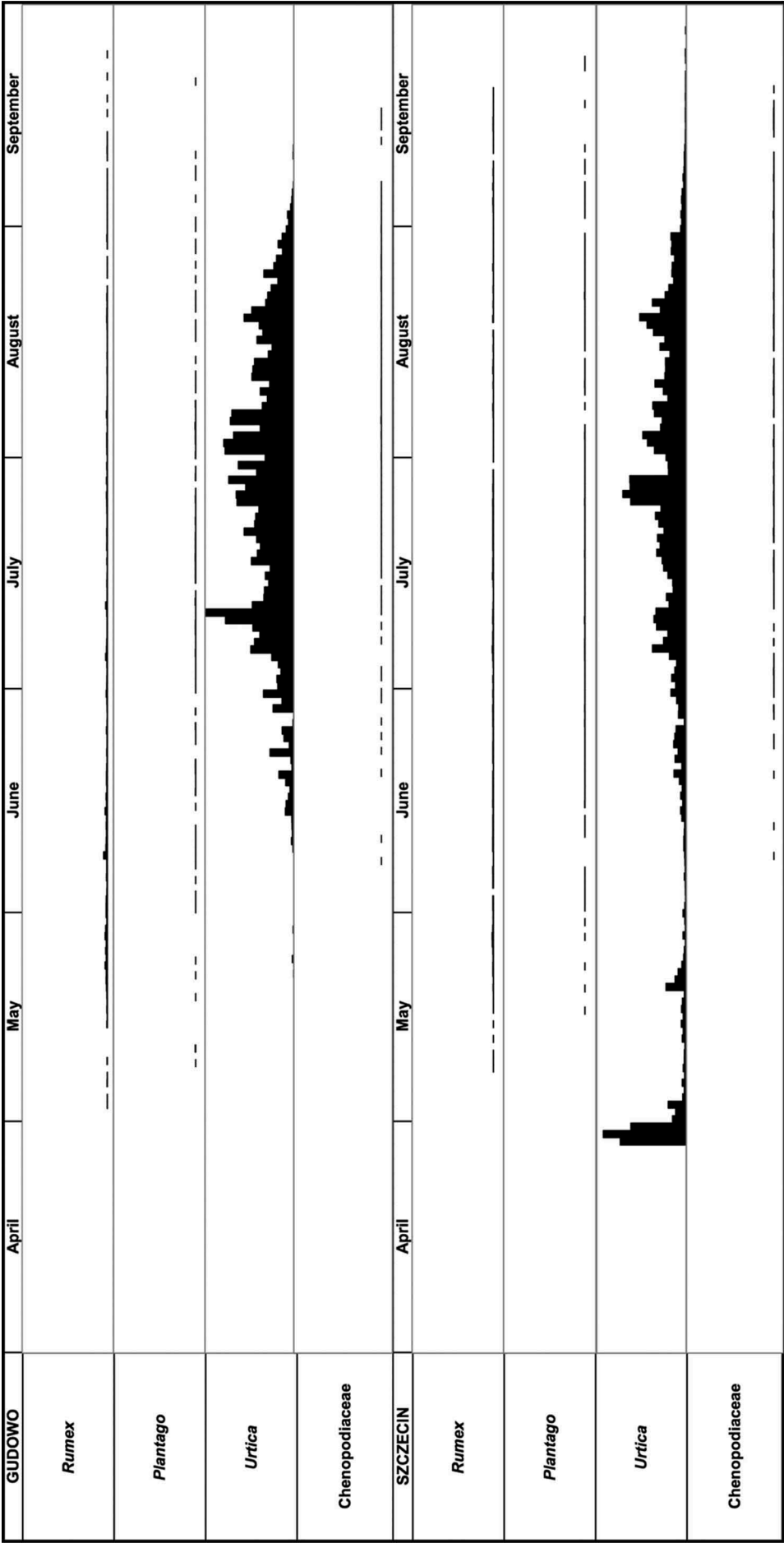


Figure 1. Pollen calendars for Gudowo and Szczecin 2012–2014.

Table I. Characteristics of pollen seasons of herbaceous plants in Szczecin (S) and Gudowo (G) in the years 2012–2014.

Taxon	Year	Start		End		Length/days		Maximum		Date of maximum		SPI		Month with maximum sum	
		S	G	S	G	S	G	S	G	S	G	S	G	S	G
<i>Rumex</i>	2012	13 V	15 V	14 IX	2 IX	125	111	13	36	27 VII	28 V	354	867	VII	VI
	2013	18 VI	17 V	16 IX	16 IX	122	123	11	28	25 VII	13 VI	342	429	VI	VI
	2014	20 V	18 V	15 IX	5 IX	119	111	19	87	26–27 V	7 VI	428	535	V	V
<i>Plantago</i>	2012	29 V	8 V	2 IX	20 IX	97	135	6	4	9 VII	11 V	109	69	VII	VII
	2013	31 V	18 V	11 IX	10 IX	104	116	6	5	22 VIII	4 VIII	121	77	VIII	VII
	2014	27 V	30 V	17 IX	8 IX	114	102	4	4	11 VII	11/17 VII	121	52	VII	VII
<i>Urtica</i>	2012	18 VI	11 VI	5 IX	2 IX	80	84	956	1214	19 VIII	2 VIII	13 620	23 310	VIII	VIII
	2013	21 V	11 VI	2 IX	31 VIII	105	82	813	665	26 VII	18 VII	17 115	23 772	VII	VII
	2014	29 IV	28 VI	4 IX	3 IX	129	68	707	1747	30 IV	10 VII	16 762	18 444	VII	VII
Chenopodiaceae	2012	26 VI	6 VI	19 IX	15 IX	86	102	4	3	30 VII	18 VI	82	63	VIII	VIII
	2013	7 VI	9 VI	10 IX	2 IX	96	86	6	8	9 VIII	23 VIII	75	83	VIII	VIII
	2014	11 VI	21 VI	17 IX	16 IX	99	88	4	12	21 VII; 2 VIII	18 VIII	73	73	VII	VIII

Table II. Spearman's rank correlation coefficients for weather parameters, Gudowo.

Gudowo	Temperature (°C)			Dew point (°C)			Humidity (%)			Pressure (hPa)			Wind (km/h)			Precipitation (cm)
	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Minimum	Maximum	Maximum	Average	Gust	Sum
<i>Rumex</i>	*0.52	*0.51	*0.34	*0.46	*0.44	*0.36	*0.28	*-0.12	*-0.13	-0.02	0.02	0.00	*-0.12	-0.09	-0.09	-0.09
<i>Plantago</i>	*0.38	*0.4	*0.28	*0.39	*0.38	*0.3	*0.16	0.01	-0.01	*0.15	*0.19	-0.03	*-0.14	-0.03	-0.03	-0.06
<i>Urtica</i>	*0.61	*0.68	*0.57	*0.72	*0.71	*0.62	*0.36	*0.18	*0.12	*0.21	*0.31	*-0.23	*-0.31	*-0.24	*-0.24	-0.03
Chenopodiaceae	*0.35	*0.36	*0.27	*0.38	*0.36	*0.3	*0.13	0.07	0.03	*0.15	*0.22	-0.07	*-0.14	-0.04	-0.04	-0.04

*Statistical significance $p < 0.05$.

Table III. Spearman's rank correlation coefficients for weather parameters and air pollution characteristics, Szczecin.

Szczecin	Temperature (°C)			Dew point (°C)	Humidity (%)	Pressure (hPa)	Wind (m/s)		Precipitation (mm)	Visibility (km)	SO ₂ (µg/m ³)	NO (µg/m ³)	NO ₂ (µg/m ³)	O ₃ (µg/m ³)	NO _x (µg/m ³)	PM ₁₀ (µg/m ³)	CO (µg/m ³)
	Maximum	Average	Minimum				Maximum	Average									
<i>Rumex</i>	*0.48	*0.5	*0.39	*0.37	*-0.19	*0.13	-0.06	-0.03	*-0.10	*0.17	*-0.09	*-0.11	*-0.20	*-0.11	*-0.19	0.00	-0.06
<i>Plantago</i>	*0.43	*0.47	*0.42	*0.4	*-0.11	0.06	-0.04	-0.06	-0.06	*0.10	*-0.11	-0.06	*-0.15	*0.10	*-0.14	0.02	-0.06
<i>Urtica</i>	*0.65	*0.7	*0.63	*0.66	-0.05	*0.13	*-0.15	*-0.20	0.00	0.05	*-0.18	-0.06	*-0.28	0.04	*-0.23	-0.01	0.00
Chenopodiaceae	*0.39	*0.42	*0.41	*0.42	0.02	0.07	*-0.09	-0.08	0.00	-0.02	*-0.10	0.08	-0.03	-0.01	0.00	0.08	-0.01

*Statistical significance $p < 0.05$.

pollen allergens and phenological phenomena in urban and rural areas in relation to air pollution.

Material and methods

The aerobiological studies were conducted in 2012–2014 by means of a volumetric method using VST Burkard (in Szczecin, 53° 26' 23" N, 14° 32' 53" E) and VPPS Lanzoni 2000 (in Gudowo, 53° 29' 34" N, 15° 51' 44" E) devices. Gudowo (500 inhabitants) is situated on the shore of Lake Lubie. The village is dominated by houses with adjoining farm buildings, fields and grasslands. There are numerous woodlots and forests in the area. The pollen trap was on a roof at a height of approximately 4.5 m above ground level. In Szczecin (more than 400 000 inhabitants), the pollen trap was set at the centre of the city, at a height of about 21 m above ground level, on the roof of the Faculty of Biology, University of Szczecin building. The city centre is dominated by tall buildings with flats, characteristic of the nineteenth–twentieth century. The area immediately around Szczecin consists of forests as well as some hills and water bodies.

The used devices, which are recommended by the IAA (International Association for Aerobiology), take air samples in volumes corresponding to average human respiratory parameters. The studies analysed pollen produced by the following taxa: *Rumex* spp., *Plantago* spp., *Urtica* spp. and Chenopodiaceae. Pollen grains were counted along four longitudinal transects (a method recommended by the Spanish aerobiological network (REA; Galán et al. 2007).

A number of parameters were established including the onset and end dates and durations of pollen seasons, peak airborne pollen concentrations and periods of their occurrence, and SPI (Seasonal Pollen Index) values. The duration of the pollen season was determined by the 98% method (Emberlin et al. 1993), assuming that the onset and end of the season were days with recorded 1% and 99% of the annual total of pollen grains, respectively. For the purpose of comparing the abundance of pollen produced by different taxa during the pollen season, the SPI value (sum of mean daily airborne pollen concentrations in the season) was calculated (Comtois 1998). In order to compare the dynamics of seasons (Latałowa et al. 2002), consecutive phases of the pollen seasons were determined: (1) onset of the season, corresponding to 1% of the annual pollen total; (2) 2.5–5%; (3) 5–25%; (4) 25–50%; (5) 50%; (6) 50–75%; (7) 75–95%; (8) 95–97.5%; (9) end of the season, corresponding to 99% of the annual pollen total.

The effect of weather factors (air and dew point temperatures, humidity, pressure, wind speed, precipitation and visibility) on the airborne concentration of pollen grains was assessed. Correlations

between pollen count and air pollution in Szczecin was examined. Relationships existing between the variables were analysed statistically using Spearman's rank correlation coefficient (Statistica StatSoft 2011), which is a measure of statistical dependence between random variables. The weather data were obtained from the meteorological stations in Szczecin and in Drawsko Pomorskie, which is situated 5 km from Gudowo.

Results

The pollen of the studied taxa of allergenic herbaceous plants was present in the air in both investigated locations for a period of around 140 days, from early May until the end of September. In 2012, the pollen seasons of herbaceous plants, with the exception for *Rumex*, started earlier in Gudowo and lasted longer than in Szczecin (Table I). The airborne pollen concentrations recorded for *Rumex* and *Urtica* were higher in the rural area, while for *Plantago* and Chenopodiaceae, they were higher in the city. In 2013, the pollen seasons for *Rumex* and *Plantago* occurred earlier in Gudowo and were longer than in Szczecin. In contrast, the pollen seasons for *Urtica* and Chenopodiaceae started earlier in Szczecin and lasted longer than in Gudowo. With the exception for *Plantago*, the airborne pollen concentrations were higher in the rural environment. In 2014, the pollen seasons of the studied herbaceous plant taxa, with the exception for *Rumex*, started earlier and lasted longer in Szczecin than in Gudowo. The airborne concentrations of *Rumex* and *Urtica* pollen were higher in the countryside while *Plantago* pollen was higher in the city. The Chenopodiaceae airborne pollen concentrations were similar in both locations. The percentage of *Urtica* pollen grains in relation to the SPI of the studied taxa in the atmosphere of the city and the countryside was the highest and exceeded 90%. The lowest percentages in Gudowo were recorded for Chenopodiaceae and *Plantago* pollen grains (c. 0.3% each), and for Chenopodiaceae pollen (0.4–0.5%) in Szczecin. Based on pollen calendars (Figure 1), the progression of the pollen seasons was assessed. In the period under study, *Plantago* and *Rumex* pollen grains were recorded in the air in both locations in May and Chenopodiaceae pollen grains in June. In Gudowo in 2012–2014 and in Szczecin in 2012, *Urtica* pollen grains were detected in the atmosphere from June onwards. In subsequent years, however, *Urtica* pollen appeared in the air in Szczecin earlier (2013: in May; 2014: as early as in April).

The progression of the pollen seasons of herbaceous plants (Figure 2) in both locations was characterised by the occurrence of alternating periods

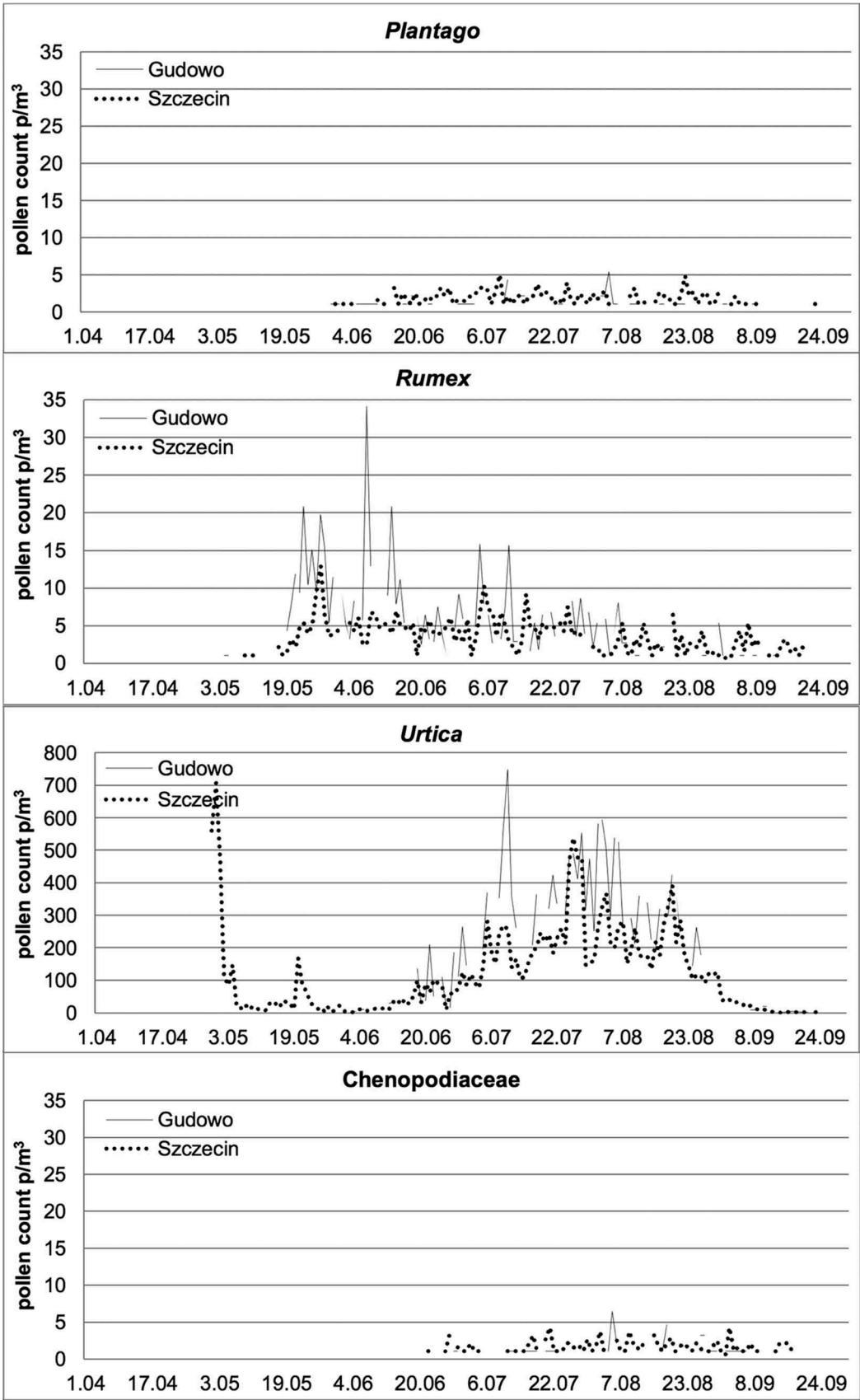


Figure 2. The progression of the pollen seasons of *Rumex* spp., *Plantago* spp., *Urtica* spp. and *Chenopodiaceae* in Gudowo and Szczecin 2012–2014.

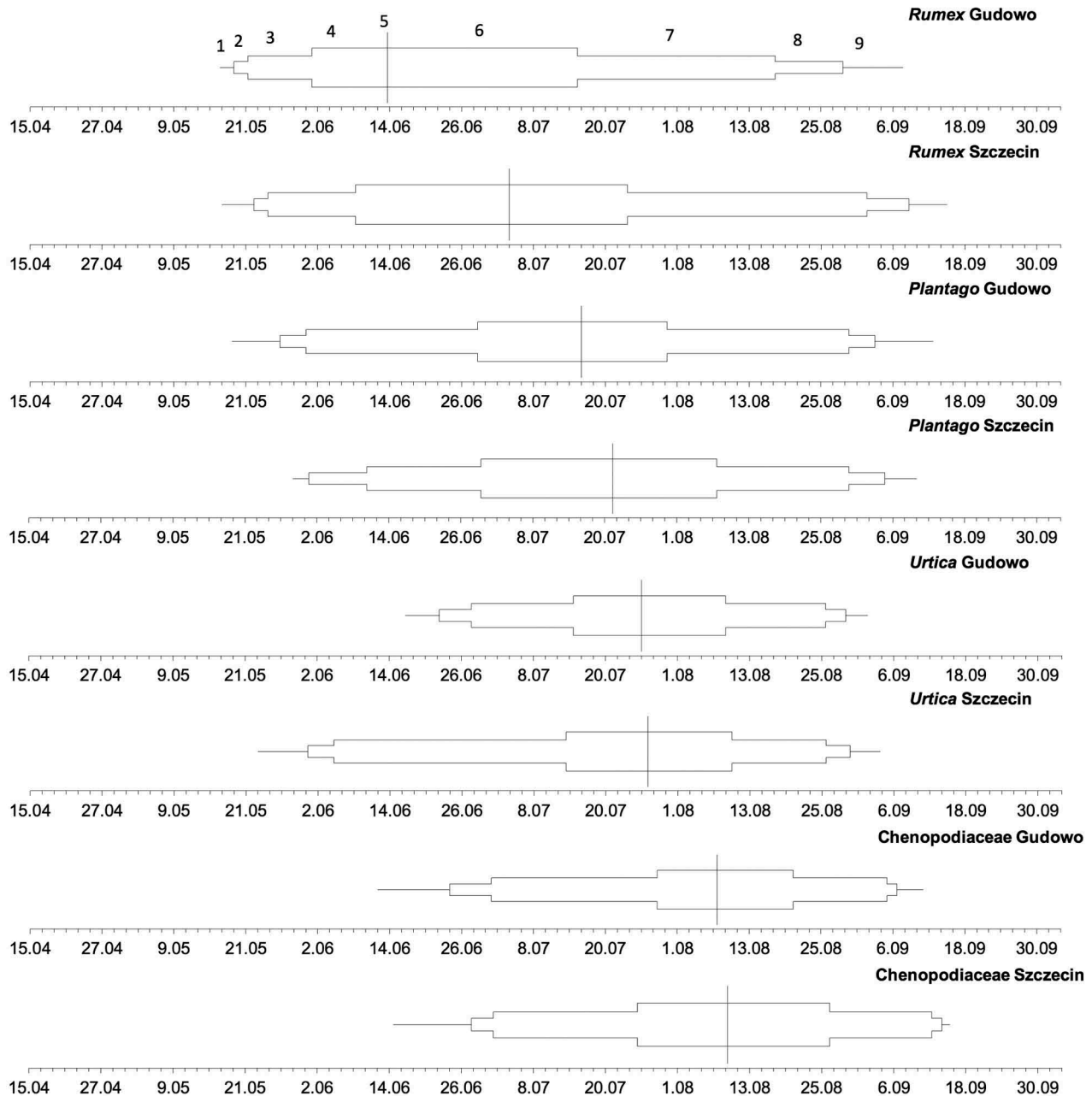


Figure 3. The dynamics of the pollen seasons of *Rumex* spp., *Plantago* spp., *Urtica* spp. and *Chenopodiaceae* in Gudowo and Szczecin 2012–2014; phases of the pollen seasons: (1) onset of the season, corresponding to 1% of the annual pollen total; (2) 2.5–5%; (3) 5–25%; (4) 25–50%; (5) 50%; (6) 50–75%; (7) 75–95%; (8) 95–97.5%; (9) end of the season, corresponding to 99% of the annual pollen total.

of increased and decreased airborne pollen concentrations. With a view to comparing the dynamics of the pollen seasons (Latałowa et al. 2002) for the taxa of allergenic herbaceous plants in Gudowo and in Szczecin (Figure 3), a total of nine pollen season phases were identified and assigned appropriate percentages of the annual pollen total. Spearman's rank correlation coefficients were then determined (Tables II, III) on the basis of plant airborne pollen concentrations

and weather parameters and, for Szczecin, air pollution characteristics.

Discussion

The presented studies encompassing a three-year period demonstrated lower airborne pollen concentrations for the majority of herbaceous plant taxa in Szczecin, where the measuring device was placed at a height of 21 m above ground level, compared to Gudowo, where

the device was located c. 4.5 m above the ground level. Differences in the airborne pollen concentrations of herbaceous plants depend on the height of measuring device installation. Measuring devices that are placed 15–25 m above ground make it possible to obtain mean results for a large area, while reducing the representation of pollen in the aeroplankton released by low plants (Lipiec et al. 2007). Similar correlations were demonstrated by Kasprzyk (2006) who, comparing the airborne content of plant pollen in rural and urban areas, showed the mean content of *Rumex* and *Urtica* pollen grains in the air to be higher in the countryside. Studies on the vertical distribution of pollen in aeroplankton, carried out at different heights, showed that the concentrations of pollen of many herbaceous plants can be several times higher near to ground level than at a height of 20 to 30 m (Käpylä 1981; Bryant et al. 1989; Rantio-Lehtimäki et al. 1991; Alcázar & Comtois 1999; Leuschner 1999; Spiessma et al. 2000). Rantio-Lehtimäki et al. (1991) found higher concentrations of Poaceae, *Urtica* and *Artemisia* pollen above ground level than at a height of 15 m. Maximum daily values of *Artemisia* pollen had previously been registered at the measuring points located near to the ground rather than traps located at a height of 10 to 20 m (Käpylä 1981). The distance of the measuring point from the emission source may affect when the pollen season start is registered, as well as the relationship to the vertical distribution of pollen. Placing the trap in Gudowo at a height of several metres above ground level, is probably one of the reasons why the mean pollen grain counts in the air are higher for the rural area than the city. Higher concentrations of herbaceous taxa pollen in the rural area compared to the urban area in other European countries, were also shown by Unger (1999), Ziska et al. (2003, 2004), Rodríguez-Rajo et al. (2010) and Bosch-Cano et al. (2011).

The progression of the pollen seasons of herbaceous plants in 2012–2014 was characterised by the occurrence of alternating periods of increased and decreased airborne pollen concentrations. Similar trends were observed by Myszkowska et al. (2007). The aerobiological study of herbaceous species tends to be more complex than that of trees due to the taxonomical composition of herb pollen types, usually involving a large number of species, genera or even families. As a result, herbaceous pollen types display more irregular pollen season curves over the year due to individual variations in timing for the various species, genera or families involved (Latałowa et al. 2005). As the study showed, *Rumex* has a relatively long pollen season of around three months, although the airborne pollen concentrations are not high.

Comparing the volumetric and gravimetric methods, Piotrowska and Weryszko-Chmielewska (2003) pointed out low values recorded for *Rumex* pollen

count and daily pollen fall. Low daily *Rumex* airborne pollen concentrations were also recorded by Silny and Czarnecka-Operacz (2001), Rapiejko (1997) and Alcázar et al. (2009). *Plantago* and Chenopodiaceae airborne pollen concentrations are not high. In spite of their long pollen seasons, the peak airborne pollen concentrations obtained for the two plants amount to several pollen grains per cubic metre of air. Rapiejko et al. (2010) showed that the airborne pollen concentrations of *Plantago* in the air have been very low for many years. Lipiec et al. (2009), in turn, pointed to the low Chenopodiaceae pollen content in the air of urban conurbation. In their study conducted for Brussels (Belgium) and spanning the period 1982–1997, Detandt and Nolard (2000) demonstrated a low mean annual total of the airborne pollen grains of *Plantago*, Chenopodiaceae and *Rumex*. Lipiec et al. (2009) specified that the airborne pollen concentrations of Chenopodiaceae in urban conurbation in Poland rarely exceed ten grains per cubic metre of air, and the exposure to these pollen allergens in cities is so low that it warrants their exclusion from the composition of products used in allergen-specific immunotherapy. However, *Plantago* pollen is an important cause of pollinosis in northern Mediterranean countries, but it is difficult to determine its incidence in allergies because *Plantago* pollen appears in the atmosphere at the same time as Poaceae pollen (González Parrado et al. 2014).

Urtica produces considerable quantities of pollen grains for a long period, and *Urtica* airborne pollen concentrations in the air achieve very high levels, as demonstrated for both studied locations. *Urtica* pollen, however, rarely causes allergy in Poland. In fact, *Urtica* pollen only acquires significance in individuals suffering from severe pollinosis because an allergy to this pollen type frequently coexists with an allergy to the pollen of grasses or weeds (Rapiejko 1997; Silny & Czarnecka-Operacz 2001). Longo et al. (2004), investigating the pollen count of Urticaceae in the atmosphere of Trieste (Italy) in 1990–1999, demonstrated a considerable variation in peak daily airborne pollen concentrations across the studied years. In the present study, this is particularly noticeable in Gudowo.

Weather factors can have a varying impact on the dynamics of distribution of bioaerosol particles, affecting the duration and severity of pollen production. Their direct impact is investigated by determining correlations between daily values of meteorological parameters and daily sporomorph concentrations in the atmosphere (Palacios et al. 2007). Relative humidity and/or air temperature are one of the most significant environmental factors determining the amount of pollen in the atmosphere during flowering (Veriankaitė et al. 2011). Humidity and temperature are associated with the release and transport of pollen grains (Pio-

trowska & Weryszko-Chmielewska 2003; Palacios et al. 2007). Drops in temperature and atmospheric precipitation reduce the airborne content of pollen grains produced by all plants (Peternel et al. 2004). A statistically significant correlation between the pollen count in the air and the maximum, minimum, mean and dew point temperatures was also identified in the present study. The influence of meteorological factors on *Urtica* spp. pollen concentrations in Spain was studied by Galán et al. (2000). Temperature was found to be the most important influence on pollen concentrations in the spring, whereas humidity was most important in autumn. Amounts of rain were not found to be significant. *Urtica* has an active pollen release mechanism which is triggered by temperature and humidity. Concentrations were found to be negatively correlated with relative humidity during periods of heavy rainfall, but positively correlated with humidity during periods of light rainfall. This study also found correlations between airborne pollen concentrations and atmospheric pollution, which are the result of the impact of weather conditions on both groups of variables (Puc 2011). Therefore, the severity of allergic reactions in patients with pollen allergy should be considered in relation to the synergism (the phenomenon of mutual reinforcement) between pollen allergens and air pollution (Puc & Puc 2012).

Conclusions

From among the taxa studied, *Rumex* is characterised by the longest pollination period, while *Urtica* by the shortest. The highest percentage contribution of pollen grains to the total pollen count in the air is for *Urtica*, reaching over 90%. The pollen seasons determined for the majority of taxa are longer in the city, however the mean pollen grain counts in the air are higher for the rural area. The most frequent correlations were found between pollen emissions and maximum, minimum and mean air temperatures and dew point temperature with a positive correlation, while there was a negative correlation with air pollution parameters. For atmospheric precipitation, the negative correlation was statistically insignificant.

Disclosure statement

No potential conflict of interest was reported by the authors.

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