Variability in pollen concentration of 20 arboreal and herbaceous taxa in Warsaw, Poland (2023)

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Abstract:
Twenty pollen taxa were characterized based on the in-situ measurements conducted with the Hirst-type pollen trap during 2023 in Warsaw, Poland: *Corylus* (hazel), *Alnus* (alder), *Populus* (poplar), *Ulmus* (elm), *Salix* (willow), *Carpinus* (hornbeam), *Acer* (maple), *Fagus* (beech), *Betula* (birch), *Fraxinus* (ash), *Taxus/Cupressaceae* (yew), *Quercus* (oak), *Pinaceae* (pine/spruce), *Poaceae* (grass), *Rumex* (sorrel), *Plantago* (plantain), *Urtica* (nettle), *Chenopodiaceae* (blite), *Artemisia* (mugwort), and *Ambrosia* (ragweed). Pollen season for each taxon was defined using the 98% method. The characteristics of each pollen season per taxon were described, including the start and end dates, the day and value of the peak concentration. An additional focus was dedicated to one of the most allergenic pollen in Poland: hazel, birch, grass, and ragweed. The number of days in 2023, when the susceptible population could experience the first symptoms of the allergy, were evaluated based on the concentration thresholds for the given taxa. The obtained results indicate that during the respective pollen season, people allergic to birch, grass, hazel and ragweed, were indeed exposed to concentrations above the threshold capable of triggering the first symptoms of rhinitis on approximately 80%, 38%, 13%, and 8% of the days, respectively.

Key words: allergenic pollen, volumetric method, pollen grains count, thresholds pollen count, pollen season

Introduction

Pollen produced by the flowers of spermatophytes plays a significant role in airborne allergen exposure. For many individuals, the immune response triggered by allergens may lead to serious health issues over time, like asthma [1, 2]. Allergens are located on the surface within the cytoplasm of individual pollen grains and are present on fine (<2 μm) pollen fragments released into the atmosphere [3]. The many factors that influence how pollen affects health have made it difficult to establish a clear link between pollen exposure and symptoms intensity. Pollen grain release is strongly influenced by meteorological conditions that impact plants.

Overall, the value of daily pollen concentration has a positive correlation with atmospheric temperature, average to maximum wind speed, and duration of sunshine hours. This relationship is particularly notable in the case of hazelnut (*Corylus*) and alder (*Alnus*), where sunshine hours influence pollen concentration not only immediately before the season but also well in advance. These species are among the first to release pollen after the Polish winter, which makes them sensitive to climatic conditions during the preceding months [4, 5]. Atmospheric circulation, the type and direction of the air masses, and the local topography all influence the distribution and transport of pollen [4–6].

Monitoring pollen concentration and its temporal distribution can help track environmental changes, reveal the effects of climate change, and provide insights into shifts in plant species composition and distribution range/area. It plays a vital role in public health by helping to predict and manage the impacts of pollen exposure on individuals with allergies, thereby sup-

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porting preventive healthcare measures and improving the quality of life for vulnerable populations.

In recent decades, the incidence of allergic rhinitis has been increasing in European countries [7]. In seasonal allergic rhinitis, symptoms occur during shorter pollen seasons, whereas in perennial allergic rhinitis, symptoms persist year-round due to exposure to house-dust allergens and to pollen from species with longer pollen seasons, such as grass and mugwort [7]. The symptoms of allergic rhinitis include nasal congestion, an itchy and runny nose, and itchy, watery eyes, often accompanied by fatigue and headache [8]. Symptom severity is closely dependent on the degree of exposure to an allergen and its concentration in the environment [9].

Due to their allergenicity and common distribution, the most important pollen types to monitor in Poland are hazelnut (*Corylus*), birch (*Betula*), grasses (*Poaceae*), and ragweed (*Ambrosia*), due to their allergenicity, and common distribution [8]. Recent studies show that approximately 25% of the Polish population suffers from allergic rhinitis, with higher prevalence observed in urban areas, e.g. in Warsaw [10]. The aim of our study is to analyze the pollen seasons in Warsaw during 2023 by identifying and characterizing 20 distinct pollen taxa based on 297 days of in-situ measurements. The aforementioned 4 main allergenic species in Poland are discussed in greater detail.

Material and methods

Site description and meteorological conditions in 2023

Warsaw, the capital of Poland, is the largest (517,2 km² surface [11]) and the most populated (over 1,8 million [12]) city in the country. Therefore, Warsaw is a natural location for conducting observations within the European Aerosol, Cloud and Trace-gases Research Infrastructure (ACTRIS-ERIC). We co-located the pollen sensor with the Warsaw ACTRIS National Facility established and run at the Remote Sensing Laboratory of the Warsaw Observatory Station at the Institute of Geophysics of the Faculty of Physics of the University of Warsaw (further referred to as WOS), located 52° 12’ 39.6” N, 20° 58’ 57.4” E, 112 m a.s.l. This site is also a core station of the Poland-AOD research network.

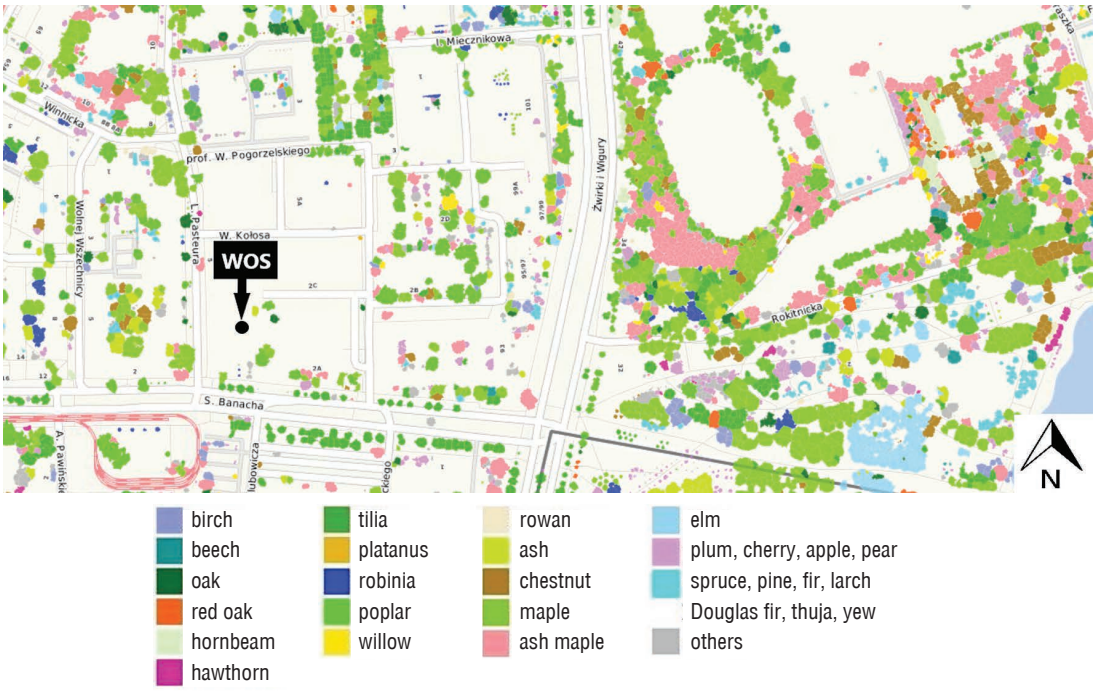
The WOS is surrounded by a medium-density distribution of buildings of a similar height. The average height of the building canopy near the pollen measurement location is 12 m; derived from the Copernicus data [13] based on the 1 km by 1 km grid centered on the WOS. The pollen sensor was installed well above building canopy on the roof-platform of WOS at a height of 21 m to assure large footprint covering 8–10 km radius. Figure 1 illustrates the area of tree distribution in close vicinity to the measurement point (marked with a black arrow). The trees maple, ash, poplar, linden, chestnut, and spruce grow nearest to the WOS. There are two parks in the close neighborhood: Park of Maria Skłodowska-Curie in the distance of ~250 m in the north direction and Pole Mokotowskie in the distance of ~400 m in the east direction. Plant species and families such as maple, linden, ash, elm, red oak, poplar, and birch, with expansive grass meadows occur in both parks. At approximately 500 m in the southeast direction, there is the garden allotment “Rakowiec” (not shown) with dominant pine/spruce and fruit trees (cherry, apple) [14].

The meteorological situation in 2023 was assessed based on the routine Poland-AOD [15] observations at the WOS (Warsaw, Ochota). The average temperature, wind speed and dominant wind direction were calculated from the WXT510 Vaisala meteorological station and Young 8100 Ultrasonic anemometer. The obtained average values are consistent with those calculated for the IMGW-BIP station #2491090890 (Warsaw, Bielany). Temperature is considered one of the most critical meteorological factors influencing pollination because it directly affects pollen production, viability and germination, and activity of pollinators. The average air temperature in 2023 was 2.5 (±4.9)°C in winter, 10.4 (±6.5)°C in spring, 18.4 (±5.0)°C in summer, and 7.2 (±6.5)°C in autumn. Wind is also a major factor but its role is different – it controls pollen transport and dispersal. In 2023, wind direction prevailed in the South-Southwest direction with an average speed of: 2,6 m/s in winter, 1.8 (±1.3) m/s in spring, 1.4 (±1.0) m/s in summer, and 2.2 (±1.6) m/s in autumn. Humidity is also an important factor in aerobiology. It mainly affects pollen release, pollen rupture, and pollen viability, rather than production or longdistance transport. At WOS station the mean relative humidity was 85 (±6)% in winter, 71 (± 14)% in spring, 65 (±8)% in summer, and 80 (±10)% in autumn.

Sampling method and microscopic analysis

Various research techniques [16–18] are used in aerobiological studies for pollen measurements. In our case, the containment of sporomorphs (in the unit of air) was measured by a Hirst-type pollen trap: the Volumetric Pollen and Particle Sampler 2010 (VPPS, 2000, Lanzoni S.r.l., Bologna, Italy). Instrument was collect-

Figure 1. *Distribution of trees and bushes in close vicinity from pollen in situ measurement site at Warsaw Observatory Station (WOS), Faculty of Physics, University of Warsaw, Poland (black arrow); source [14].*



ing data continuously, except in January and December, which were considered as a dead-period, irrelevant for plant pollen. The effective measurement period of pollen concentration spanned from 21 February to 13 November 2023, ending after no pollen taxa of interest were detected in the samples for a longer period (here 8 consecutive days). Note that analysis of fungi spores is not in scope of this paper, although obviously they were detected during the entire period.

For the entire investigated period, the volumetric method was used with a constant air suction rate of 10 L/min. In 24 h, a slow-motion rotor collected 48 mm of tape with deposited material. After 7 days of measurements, the tape on the rotor was replaced with a new one. The old tape was cut into 7 pieces, each equal to 48 mm, representing a consecutive day in a week. The quantitative analysis of samples was done using a classical method of manual pollen counting under an optical microscope. The pollen grains within each sample were identified and counted to obtain a daily concentration for each taxon.

Classification of pollen was done visually under the microscope based on the pollen grain morphology. To obtain the daily pollen concentration per 1 m^3 of air (unit: grains/m^3), a microscope-specific conversion factor must be calculated; the number of detected pollen grains is then multiplied by this factor to yield the final value. We used two microscopes. Therefore, the conversion factor of 1.01was applied to samples analyzed before 06 September 2023, and a factor of 0.46 was applied for the samples analyzed after that date. Eight days were randomly selected from the full measurement period, and samples with varying total pollen concentrations were analyzed using both microscopes for comparison. For these data points, the relationship between microscopes was linear with a slope of 0.934 and an intercept of 0.865, indicating good consistency between their measurements.

The primary variables of interest in our study are: the start and the end dates of the pollen season for each taxon, the annual pollen sum for each taxon within its respective season, and the peak concentration, defined as the maximum daily value recorded during that season (tab. 1).

Pollen taxa classification and pollen season definition

Pollen taxa classification was done in two ways: (i) the pollen season calendar, and (ii) the grain morphology.

Pollen season calendars are based on the average pollen concentration in a given city, calculated over several years of measurements [19]. They showcase the general occurrence of pollen taxa within the whole year [20]. Regarding the timing of occurrence, each pollen taxon is usually expected to appear in the air at similar times each year, reflecting the seasonal phenology of the corresponding plant species [21]. Pollination occurs

in a rather consistent timeline, related to genetically conditioned biorhythm. Pollen emission and dispersion can be modified by environmental conditions, specifically temperature, sunshine hours, rainfall, wind speed and direction, and relative humidity [6].

Pollen morphology encompasses features such as shape, size, surface sculpture, exine and intine structure, pores, furrows, cytoplasm, and surface characteristics [19]. Each taxon exhibits a characteristic set of these features, enabling pollen identification.

In aerobiological studies, determining the pollen season based on concentration of sporomorphs for different taxa is a fundamental task. To define the pollen season for specific plants in Warsaw in 2023 an analysis was carried out using the 98 percent method [19]. In this approach, the start and the end dates of the season are determined by reaching 1% and 99% of the annual pollen concentration. In our study, the concentrations of 20 types of pollen were analyzed in Warsaw during the observation period in 2023, including *Corylus* (hazel), *Alnus* (alder), *Populus* (poplar), *Ulmus* (elm), *Salix* (willow), *Carpinus* (hornbeam), *Acer* (maple), *Fagus* (beech), *Betula* (birch), *Fraxinus* (ash), *Taxus/Cupressaceae* (yew), *Quercus* (oak), *Pinaceae* (pine/spruce), *Poaceae* (grass), *Rumex* (sorrel), *Plantago* (plantain), *Urtica* (nettle), *Chenopodiaceae* (blite), *Artemisia* (mugwort), and *Ambrosia* (ragweed). Particular attention was given to the most allergenic pollen types, specifically *Corylus* (hazel), *Betula* (birch), *Poaceae* (grasses), and *Ambrosia* (ragweed).

Threshold concentrations triggering first allergy symptoms

Despite the characteristic release patterns observed at the taxon level, individual plants vary in pollen emission intensity, making it necessary to evaluate plantlevel thresholds when assessing the potential for triggering allergic symptoms. Based on the examination of the population in Warsaw during the years 2003, 2004, and 2005, the threshold values for evoking the first allergy symptoms (a watery nasal discharge, sneezing, as well as itching, redness, and tearing of the eyes) were identified for 4 types of taxa [8]. Such results provide a broader perspective on the theoretical impact of measured pollen concentration on vulnerable populations for each plant taxon.

In our study, threshold values were incorporated into the detailed analysis of *Betula*, *Corylus*, *Poaceae*, and *Ambrosia* [22, 23], providing insight into the number of days in 2023 when concentrations exceeded symptom-related thresholds within the vulnerable part of the Warsaw population.

Limitations

The limitations of our study are due to several factors: the incomplete measurement period in 2023 (no data before 21 February and after 13 November 2023), the change of microscope used for the analyses (on 06 September 2023), the possibility of underestimating the season start for early-flowering taxa, the used pollen concentration thresholds causing allergy symptoms (based on existing literature), the single year nature of the analysis, and the need for caution when interpreting symptom thresholds without clinical data.

The pollen monitoring start on 21 February 2023 was determined by instrument availability. Consequently, *Corylus* and *Alnus* concentrations may be undervalued as their pollination could have begun earlier (compere with the pollen calendar [20]).

We used two microscopes**.** The linear relation was applied to scale the data from the second microscope to assure consistency. However, data collected after 06 September 2023 should be interpreted with caution (herbaceous taxa).

The analysis is constrained for a single year measurements. Using only one year of pollen monitoring data is insufficient for long-term health or environmental assessments because it cannot account for significant interannual variability, track trends, and account for shifting seasons. Climate change impacts cannot be addressed, as a single year cannot show if pollen seasons are starting earlier, lasting longer or becoming more intense, which are common trends driven by rising temperatures, etc. One year of data might miss a "shift" in the start or end dates of a season, making it impossible to predict when patients should begin medication in future years. Thus our results need to be interpreted in the context of pollen calendar [20].

Single year data has high statistical uncertainty, if one would like to treat our results as general. Interannual variability is not captured. Pollen release patterns vary considerably year-to-year due to fluctuating weather (e.g. temperature, rain, wind). The year can be abnormal, an "outlier" (e.g. a drought year decreasing concentration or a storm year causing local bursts), leading to skewed values. Some trees can have mast years where they produce significantly more pollen than usual, followed by years of very low production. This cannot be assessed from only a single year data that we analyzed.

The use of our data for the forecasting also has limitations. Single year is not sufficient. It reduces forecasting accuracy and has baseline gaps. Reliable forecasting models generally require multiple years of historical data to develop accurate pollen calendars for

predicting future risks. Also there is lack of validation. Data from just one year cannot be used to validate if a forecast is generally good or just happened to match the specific weather of that year.

Our data have obvious limited clinical utility. Obtaining personal pollen-symptom thresholds (the level at which symptoms start) requires observing patients' reactions across several different types of seasons/years. Our interpretation of the results in terms of the symptom thresholds without clinical data has its limitations. The pollen concentration thresholds causing allergy symptoms were adopted from [8]. Due to differences in population sensitivity, the true thresholds may vary. We did not took this into account.

Finally, research limitations, especially for clinical trials for new allergy treatments, usually require a high, continuous exposure baseline that a single year of data cannot provide.

Results and discussion

Pollen seasons for 13 arboreal and 7 herbaceous taxa

Plant pollination is characterized by its seasonality. Due to plants vulnerability to external factors, the start and end dates of pollen season can be anticipated at similar times, but they are rarely exact every year. The obtained pollen season periods are shown in figure 2, depicting the 20 identified types of taxa in Warsaw during 2023 [24]. The clear difference between the pollen seasons of trees (occurring earlier, during shorter, well-defined periods) and herbaceous plants (occurring later in the year and span over longer periods) are well captured.

The trees species hazel, alder, poplar, and yew were present in the air from the very start of measurements. Hazel and alder stopped appearing in the first days of April. Their annual sum of the pollen concentration in the pollen season reached 502 and 1842 grains/m^3, respectively. The maximum concentration (see peak values in table 1) for hazel was 98 grains/m^3 on 18 March and for alder was 391 grains/m^3 on 10 March. Both hazel and alder might have been present in the air (in low concentrations) before monitoring began, meaning that the actual start dates of their seasons may differ slightly from those reported here. The beginning of the poplar pollen season set on 28 February 2023, lasted for 50 days, ended on 19 April 2023, with a peak concentration of 82 grains/m^3 on 24 March. Yew pollen season lasted until the end of May with concentration peak of 423 grains/m^3 on 18 of March.

In the last week of March 2023, pollination of elm, willow, and hornbeam trees started to appear. Their annual sum of the pollen concentration reached, respectively: 286, 368, and 327 grains/m^3 with peak of 57 (15 April), 33 (18 April), and 49 (13 April) grains/m^3 (tab. 1). Although elm pollen season began (24 March), almost a month later than the poplar pollen season (28 February), both ended very close in time (in both cases, a few individual grains were identified before the calculated season start dates).

Figure 2. *Pollen taxa appearance in Warsaw in 2023 based on the daily concentration of pollen taxa per 1 m^3 (mind different scale on y-axis; arboreal taxa in violet-blue colors, Herbaceous taxa in green-yellow color).*

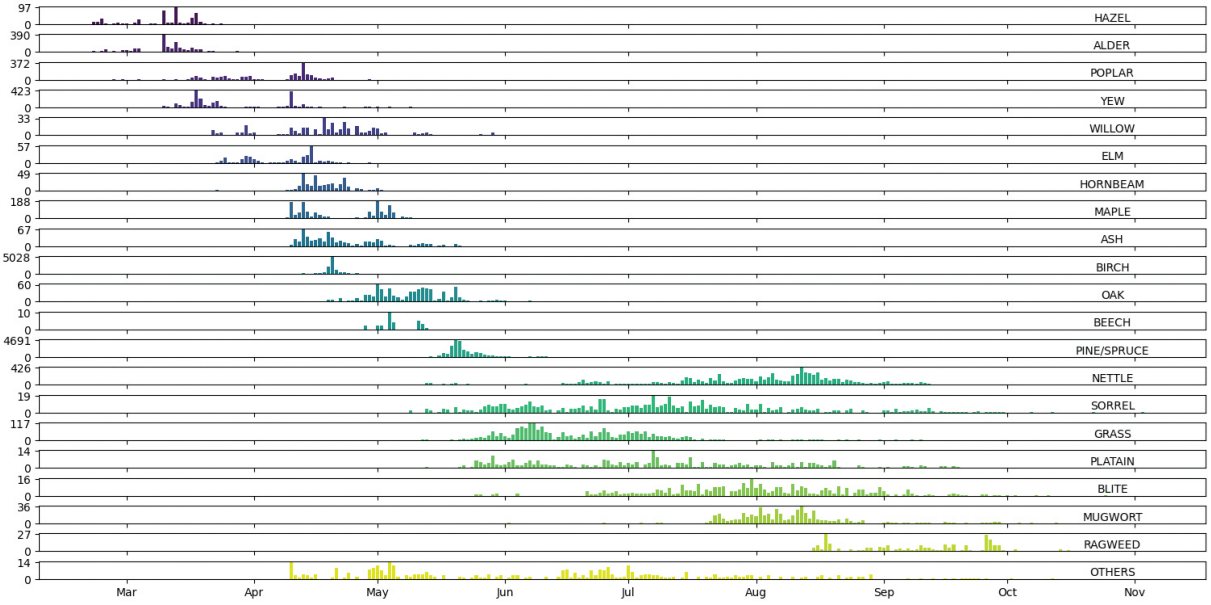


Table 1. *The characterization of pollen seasons in Warsaw in the investigated period of 2023. The start and the end dates of pollen season for each identified taxon is listed along with the highest measured daily concentrations (peak) and the annual sum of the pollen concentration for the pollen season periods. Pollen taxa in bold are the main focus of our study.*

Species	Pollen season 2023		Peak concentration [grains/m^3] (date)	Annual sum [grains/m^3]
	start	end		
Arboreal taxa (in figure 2 violet-blue colors)				
***Betula* (birch)**	13.04	13.05	5029 (20.04)	11,701
***Corylus* (hazel)**	21.02	25.03	98 (18.03)	502
Alnus (alder)	21.02	02.04	391 (10.03)	1842
Populus (poplar)	28.02	20.04	82 (24.03)	1812
Taxus/Cupressaceae (yew)	10.03	27.05	423 (18.03)	2558
Salix (willow)	22.03	29.05	33 (18.04)	368
Ulmus (elm)	24.03	22.04	57 (15.04)	286
Carpinus (hornbeam)	09.04	05.05	49 (13.04)	327
Acer (maple)	09.04	08.05	189 (01.05)	1458
Fraxinus (ash)	11.04	20.05	68 (13.04)	581
Quercus (oak)	19.04	02.06	61 (01.05)	795
Fagus (beech)	28.04	12.05	10 (04.05)	29
Pinaceae (pine/spruce)	14.05	27.06	4691 (20.05)	25,601
Herbaceous taxa (in figure 2 green-yellow colors)				
***Poaceae* (grass)**	21.05	09.09	117 (08.06)	2490
***Ambrosia* (ragweed)**	05.08	16.10	27 (18.08)	272
Urtica (nettle)	14.05	12.09	426 (12.08)	9319
Rumex (sorrel)	14.05	23.09	19 (07.07)	578
Plantago (plantain)	22.05	19.09	14 (07.07)	310
Chenopodiaceae (blite)	30.05	25.09	16 (31.07)	381
Artemisia (mugwort)	20.07	03.10	37 (12.08)	563

April was the time when maple, ash, and oak pollen were present simultaneously. It was challenging to distinguish between them due to their visual similarities. They show peaks of 189, 68, and 61 grains/m^3, respectively.

Pine/spruce and birch outnumbered all pollen taxa reaching the annual sum of the pollen concentration of 25,601 and 11,701 grains/m^3, respectively. Birch had the highest peak concentration (over 5000 grains/m^3 in the second half of April). A month later, the massive peak concentration of pine/spruce occurred (close to 4700 grains/m^3). No other taxa were even close to these numbers.

The yew, poplar, and willow pollen seasons had a significantly longer duration (51–68 days) in 2023, which was distinguishing them from all other trees species (trees seasons usually last around one month).

In the second half of May, the occurrence of pollen from herbaceous plants began, e.g. nettle, sorrel, grass, plantain, and blite, joined by mugwort and ragweed between July and August. Herbaceous plants have substantially longer pollination seasons (ranging from 63 days for ragweed to 132 days for sorrel) than any tree taxa, with the exception of willow (68 days). As expected, the annual sum of the pollen concentration for nettle was the highest (9319 grains/m^3), followed by grass (2490 grains/m^3). The pollination ended with the end of October with low abundances of latest taxa of mugwort and ragweed.

Four most allergenic pollen taxa in Warsaw

Among the four most allergenic pollen taxa – hazel and birch trees, and the herbaceous taxa grass and ragweed (tab. 2) – the longest pollen seasons were recorded for grass (117 days) and ragweed (72 days), as expected.

Birch and grass pollen seasons aligned with the typical phenological differences expected between tree and herbaceous taxa (fig. 3). For birch, the pollen season was characterized by a very short duration (30 days) with a Gaussian-like, single peak concentration. The concentration distribution of grass was scattered more evenly, throughout more than 3 times longer period, and without distinctive peak concentration [19].

Hazel and ragweed were less typical (fig. 3). Hazel was as compact as birch but showed 2 strong peaks relatively close in time. Ragweed was the least abundant of the 4 taxa. Its season was relatively long and showed an unexpected bimodal pattern with peaks near the beginning and end of the pollination period.

Table 2. *The pollen seasons characteristic of the most allergenic pollen taxa in Warsaw in 2023. Note: The annual sum of the pollen concentration in each taxon season and respective peak concentration are given in table 1.*

	HAZEL*	BIRCH	GRASS	RAGWEED
Threshold pollen concentration evoking first symptoms of allergy [grains/m^3] (values as in [8])	35	20	20	10
Duration of the pollen season for each taxon (days)	32	30	117	72
Obtained number of days above the threshold for each pollen taxon season	4 (13%)	24 (80%)	44 (38%)	6 (8%)

** delayed start date (measurements from 21.02).*

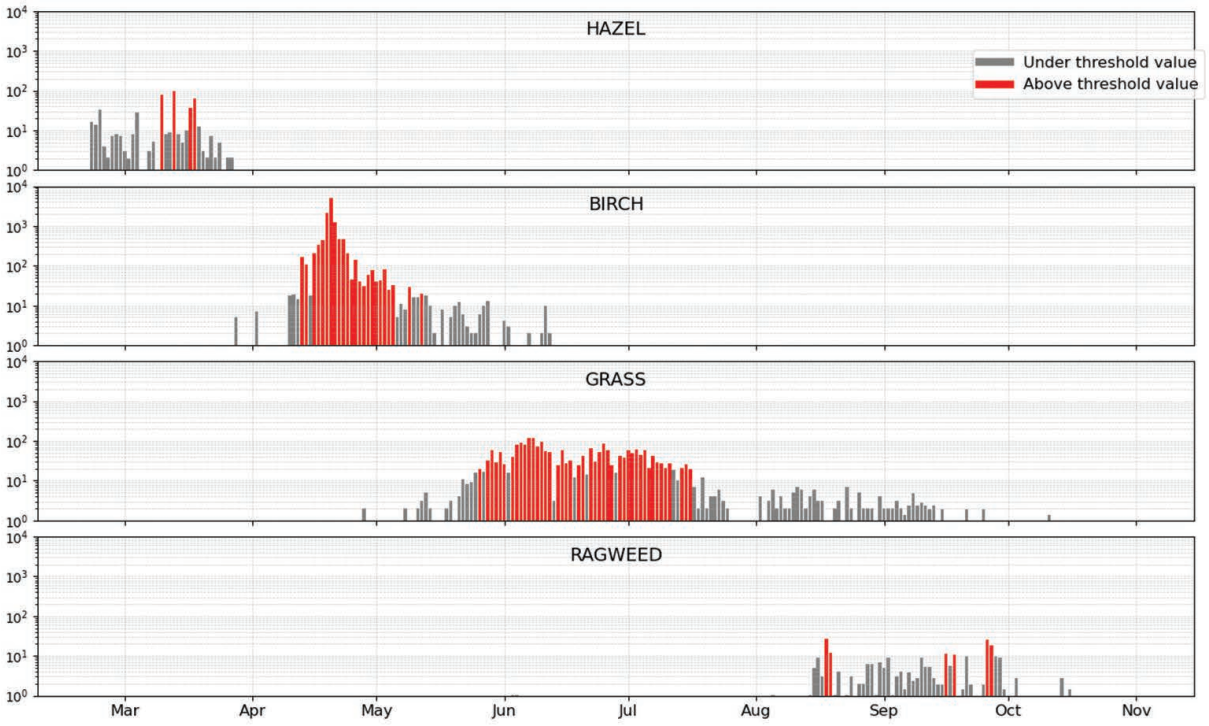
Hazel trees and ragweed do not grow in the immediate vicinity (<500 m) of the WOS measurement site but are present in more distant areas. Their presence in the samples therefore indicates transport from remote locations (i.e. our footprint is indeed large).

During 2023, the threshold capable of triggering the first symptoms among the population allergic to birch pollen was exceeded on 80% of its season days (24 days) span over short period (see: table 2 and figure 3). On the other hand, people allergic to grass pollen were exposed to concentrations above the threshold on about 38% of its season days (44 days) but span over more than twice longer period.

During the ragweed pollen season, only 6 days (8%) had sufficient concentrations to trigger the first symptoms of allergy-prone individuals, notably these days were separated by longer period with values below ragweed pollen threshold. As for hazel pollen, only 4 days during the 32-day season had concentrations that exceeded the threshold. Thus for the latter taxa (ragweed and hazel) our results are indicating a limited risk for the exposed Warsaw population in 2023.

Our results reveal significant variations in the duration and intensity of pollen seasons among different taxa. While grass pollen exhibits the longest season and substantial exposure for allergic individuals, ragweed and hazel pollen showed a more limited presence, with fewer days exceeding critical thresholds. Although it is commonly understood that the exceedances above the threshold of pollen concentration can trigger allergy symptoms, an individual suscepti-

Figure 3. *Daily concentration (grains/m^3) in Warsaw (21.02–13.11.23) for trees: hazel and birch and grass, ragweed pollen seasons. In red we denote the values exceeding the critical concentration thresholds per taxon that can trigger first allergic symptoms. Thresholds are given in table 2.*



bility can play a significant role due to the neuronal and immune mechanisms of individuals [25], i.e. the same allergen concentration might trigger different levels of response for each person. The long periods with pollen concentrations above the threshold for birch and grass underscores the need for continuous monitoring to protect vulnerable individuals throughout prolonged episodes of threshold exceedance across different pollen seasons.

Conclusion

The obtained and characterized pollen seasons covering 20 pollen taxa in Warsaw in 2023 show wide variations in duration and intensity. On 78 days pollen concentrations were high enough (above respective thresholds) to trigger allergic symptoms. The results revealed distinct patterns among the analyzed taxa.

In general, for trees the pollination seasons were shorter, with a clear single peak in pollen concentration (model example of birch). For herbaceous taxa the pollination seasons were 2–3 times longer, with more evenly distributed pollen concentrations. The compact pollination season was characteristic for most of the tree taxa (excluding poplar, willow, and yew), whereas longer seasons were typical for all herbaceous plants (especially nettle or grass). Pollen seasons were ranging from extremely short duration, as in the case of beech (14 days) to extremely long durations, such as that of sorrel (132 days).

The dynamics in occurrence of taxa with highest allergenic capability: hazel, birch, grass, and ragweed, was of special interest due to their health implications. As expected, grass and ragweed pollen exhibited long season duration (111 and 72 days), whereas hazel and birch pollen seasons were significantly shorter (32 and 30 days). The highest peak concentration was reached by birch pollen with 5029 grains/m^3 (20 April). Moreover, the birch had the highest annual sum (11,701 grains/m^3) in the shortest period (30 days). During the pollen seasons of grass, hazel, and ragweed, on respectively 38%, 13%, and 8% of the days we obtained concentrations exceeding the thresholds reported to trigger first rhinitis symptoms in individuals allergic to those pollen types. Notably, birch stood out: 80% of the days in its season exceeded the critical allergy threshold, representing the highest exposure among the taxa analyzed, despite its shortest season.

Trends of longer duration or higher concentration in some pollen taxa seasons may impact on public health conditions, which highlights the significance of continuous pollen monitoring. Particularly in the reality of increasing occurrence of allergy among people, where the prevalence of allergic rhinitis continues to increase across European countries, including Poland [12].

A justification for continuous pollen monitoring is supported by our results that indicate variations in pollen season duration and concentration above the threshold of concern for public health. Regardless of the publication date, our findings reinforce the need for long-term pollen monitoring. It is a challenging task to which all additional contribution from researchers at institutions that are not involved in network-based monitoring are of high interest to the community and development of worldwide aerobiology. More on Polish contribution into this research field can be found in excellent overview by [26].

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in 2022 "Pollen Observations with Lidar - Laser Exploring in Non-invasive Atmospheric Techniques" (TNA POLLENAT).
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Data availability

The data is available to the end users free of charge via Repository for Open Data (RepOD) run by the Open Science Platform team at the Interdisciplinary Centre for Mathematical and Computational Modelling, University of Warsaw. Data citation: Rykowska, Zuzanna; Tomczak, Artur; Stachlewska, Iwona, 2024, "Daily pollen concentration of 20 types of plants in Warsaw: pollination season 2023", https://doi.org/10.18150/6YMQNO, RepOD, V1.

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