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Article

On the formation of pollen assemblages of allergenic plants in the city of Ulyanovsk (Russia)

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Abstract. Phytocenoses and spore-pollen spectra of surface soil layers were analysed in the time span from 2020 to 2023 in all zones of the city of Ulyanovsk, including recreational, residential, industrial, and educational wellbeing spaces. This study identified 139 allergenic plant species, 69 of which were moderately and highly allergenic. The overwhelming majority of them are found in the recreational zone (67). Somewhat fewer were identified from the residential (44) and educational zones (38). The highest content of tree and shrub pollen in soil samples is observed in the recreational and industrial zones, while most cereals were identified in the industrial zone, and Chenopodiaceae – in the residential zone. Nettle pollen is found in all zones, while sedge and plantain – in the residential and recreational zones, and forbs – in the recreational zone. A higher rate of occurrence of pollen in relation to the pollen-producing plants is characteristic of representatives of the families Pinaceae, Brassicaceae, Amaranthaceae, Chenopodiaceae, Plantaginaceae, Betulaceae, Urticaceae, Polygonaceae, Asteraceae, as well as the genera *Salix* spp. and *Artemisia* spp. For the subrecent spectra for families Poaceae, Cyperaceae, Rosaceae, and Tiliaceae, the frequency and abundance of pollen and pollen-producing plants in phytocenoses is approximately equal. Furthermore, pollen from representatives of these families is found in spectra even outside their native habitats. Therefore, there is a significant risk of seasonal hay fever (pollinosis) throughout the snowless period. It is recommended to carefully review the species composition of plants used in urban landscaping.

Keywords: pollen rain, hay fever, pollinosis, subrecent pollen spectra

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Научная статья

Особенности формирования пыльцевых комплексов аллергенных растений г. Ульяновска

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Аннотация. В работе представлены результаты анализа фитоценозов и спорово-пыльцевых спектров поверхностных слоев почвы, проведенного в 2020–2023 гг. во всех зонах г. Ульяновска (рекреационной, селитебной, промышленной, учебно-оздоровительной). В результате выявлено 139 видов аллергенных растений, из них 69 – средне- и высокоаллергенные. Подавляющее большинство из них встречаются в рекреационной зоне (67). Несколько меньше – в селитебной (44) и в учебной зоне (38). Наибольшее содержание пыльцы древесно-кустарниковых пород в почвенных образцах наблюдается в рекреационной и промышленной зонах, злаков – в промышленной, маревых – в селитебной, пыльца крапивы встречается во всех зонах, осоковых и подорожниковых – в селитебной и рекреационной, разнотравья – в рекреационной. Большая встречаемость пыльцы по отношению к самим продуцирующим ее растениям свойственна представителям семейств Pinaceae, Brassicaceae, Amaranthaceae, Chenopodiaceae, Plantaginaceae, Betulaceae, Urticaceae, Polygonaceae, Asteraceae, а также родов *Salix* spp. и *Artemisia* spp. Для семейств Rosaceae, Cyperaceae, Rosaceae, Tiliaceae отмечена примерно равная встречаемость пыльцы в субрецентных спектрах и самих растений в фитоценозах; кроме того пыльца представителей этих семейств обнаруживается в спектрах и вне мест их произрастания. Таким образом, существует значительная опасность поллинозов в течение всего бесснежного периода. Рекомендуется особо тщательно пересмотреть видовой состав растений, используемых в озеленении территорий города.

Ключевые слова: пыльцевой дождь, поллиноз, субрецентные пыльцевые спектры

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Introduction

Despite their enormous importance for the management of hay fever, pollen assemblages of allergenic plants have been understudied in many countries, including Russia. In the Ulyanovsk Region, we have only recently begun to conduct pollen complex studies, despite hay fever being a major allergy pathology (Golodnova, 2020; Golodnova et al., 2021; Ulendeeva, 2022).

Importantly, pollen that triggers allergic reactions in humans can be present in the air even when plants are not actively pollinating. A certain portion of "pollen rain" (the increased pollen load in the air) is pollen that has settled on the soil surface and persisted in the topsoil layers for a long time (so-called "subrecent pollen"), and then, as a result of erosion processes and under certain meteorological conditions, is released and dispersed into the atmosphere.

In our opinion, determining the composition and proportions of subrecent pollen released by allergenic plant species is critical for identifying the specific allergenic agents responsible for hay fever symptoms that occur outside typical, high-volume pollen seasons. Unfortunately, only a few studies have covered this, in Mongolia (Begziin, 2004). Similar studies are lacking for European Russia.

On the other hand, topsoil pollen analysis allows us to map local vegetation and identify dominant pollen-producing species during the snow-free period and determine which pose the greatest allergy risk. It is known that spore-pollen spectra do not perfectly mirror the composition of the phytocenoses. Therefore, studying subrecent pollen and comparing it with modern vegetation is extremely important for accurate reconstructions of the formation of pollen dispersal.

There are many studies of subrecent pollen spectra in the forest and forest-steppe zones (Chepurnaya and Novenko, 2015; Golovko, 2004; Nosova et al., 2015; Rudenko and Novenko, 2015; Tupitsyn et al., 2015; Zhuikova, 2002), which includes the Ulyanovsk Region. In one of our previous studies (Blagoveshchenskaya, 2016), we analyzed the formation of subrecent pollen spectra in the north-eastern regions of the Volga Upland (which includes the territory of the city of Ulyanovsk) and compared with the results published by other authors. It has been shown that plant pollen productivity, dispersal patterns, and the degree of preservation in the fossil state are the main factors influencing the formation of subrecent spore-pollen spectra in phytocenoses. The numerous studies in this area, in our opinion, have been well reviewed and summarized by N.A. Rudaya (2010) and in our previous publications (Blagoveshchenskaya, 2016).

The purpose of this study was to investigate the contribution of subrecent spectra of allergenic plants to the formation of pollen rain.

Material and methods

We conducted studies of the spore-pollen spectra of topsoil layers in 2020–2023 in all areas of Ulyanovsk and its vicinity:

- recreational (parks, forest parks);
- residential (quarters of residential buildings);
- industrial (large enterprises over a large area and industrial zones);
- educational and wellbeing (schools, universities, preschools, hospitals).

Seventy-two sample plots (SPs) measuring 1000 m² were established using K.V. Prokhorova's (1965) method. In each SP, trees and shrubs were counted, their percentage content was calculated, and the contribution of each herbaceous layer species was determined. Two samples of the surface soil layer (10× 10cm) or the surface of a moss clump to a depth of 1 cm were taken from different locations within each SP. The samples were then mixed, and a combined sample was taken for analysis. After appropriate processing using the Erdtmann method or the alkaline method (Pyltsevoy analiz, 1950), up to 500 tree pollen grains and 300–500 grass pollen grains were counted in all the obtained samples, and their percentage content was then calculated. The obtained data were averaged for each city zone and for its entire territory, including the immediate surroundings. As a result of our research, we compiled regional subregional spectra of various zones of the city of Ulyanovsk and its environs.

Aeropalynological studies were conducted from 2019 to 2022 at 40 key sites in various urban areas (16 sites in the industrial zone, 8 in the recreational zone, 8 in the educational and wellbeing zones, and 8 in the residential zone) using gravimetric pollen traps (Golovko, 2004; Meyer-Melikyan et al. 1999; Seppä and Hicks, 2006). Pollen was processed using the Post method by boiling in 10% NaOH for 3–10 minutes, followed by centrifuging to increase the concentration of pollen grains in the sample (Pyltsevoy analiz, 1950). Pollen was identified using a microscope at 600× magnification. Pollen preparations from the authors' collection and special pollen identifiers were used as reference samples.

A total of 220 permanent and 2116 temporary pollen samples were prepared and analyzed. A quantitative and qualitative analysis of 29 320 aerial pollen samples was conducted, with pollen grain concentrations calculated per cm². For each allergenic plant species, we determined the hazard level – an Allergenicity Index ranging from 1 to 3 (Dikareva and Rumyantsev, 2015). Furthermore, the occurrence of plants in phytocenoses at the sample plots and the occurrence of their pollen in subrecent spectra of soil samples were calculated.

Results and discussion

Based on floristic and phenological observations, we previously identified 139 species of allergenic plants (Astafieva et al., 1986; Bagziin, 2004; Dikareva and Rumyantsev, 2015; Knyazhenskaya et al., 2005; Official List..., 2004; Shamgunova and Zaklyakova, 2010), which is about 11.2% of the total phytodiversity of the urban environment (Golodnova et al., 2021). The distribution of the 69 most allergenic species by functional zones of the city (highly and moderately allergenic with allergenic indices of 2 and 3) is presented in Table 1.

It is noteworthy that about 70 representatives of the following families, widely distributed in the city and its surroundings, are considered to be low-allergenic plants (allergenicity index = 1): Tiliaceae (linden *Tilia* spp.); Ulmaceae (elm *Ulmus* spp.); Fagaceae (English oak *Quercus robur* L.); Aceraceae (maple *Acer* spp.); Oleaceae (ash *Fraxinus* spp.); Asteraceae (globe thistle *Echinops* spp., daisies *Aster* spp., cocklebur *Xanthium* spp., tansy *Tanacetum* spp., dandelions *Taraxacum* spp., warty thistle *Carduus* spp., sunflowers *Helianthus* spp., etc.); Rosaceae (Manchurian apricot *Armeniaca mandshurica* (Maxim) Skvorts.), hackberry *Padus* spp., mountain-ash *Sorbus* spp., elderberry *Ambucus* spp., hawthorns *Crataegus* spp., currant *Ribes* spp., meadowsweet *Filipendula* spp., sweet woodruff *Galium* spp., cinquefoils *Potentilla* spp.); Brassicaceae (field cabbage *Brassica campestris* L., field mustard *Sinapis arvensis* L.), Fabaceae (Bird's-foot trefoil *Lotus corniculatus* L., lucerne *Medicago sativa* L., common sainfoin *Onobrychis viciifolia* Scop., sweet clover *Melilotus* spp.); Malvaceae (hollyhock *Alcea rosea* L., small mallow *Malva pusilla* Smith); Liliaceae (Turk's cap lily, *Lilium martagon* L.); Polygonaceae (dock *Rumex* spp., Tartary buckwheat *Fagopyrum tataricum* (L.) Gaertn.) and many others.

The total Allergenicity Index was 259 points, which allowed us to classify the studied region into Group 6 (the highest risk in terms of allergenic safety) (Dikareva and Rumyantsev, 2015; Golodnova et al., 2021).

An analysis of allergenic flora (Table 1) showed that most allergenic plants are found in recreational areas – places for rest, walks, and sports. A somewhat smaller number are found in residential areas. Many of the species presented grow as weeds in courtyards, vacant lots, lawns, and along roadsides. It is alarming that moderately and highly allergenic species (larch, balsam poplar, sweet poplar, laurel poplar, sweet fescue (it is sown in almost all lawns and flower beds), rose hips, and amaranth) are widely used as ornamental plants for landscaping the grounds of educational, training, and health institutions. Birch and spruce are widely used in recreation areas.

The results of the study of subrecent pollen spectra in different zones of the city are presented in Table 2. For convenience, we have grouped the families according to the classification generally accepted in medical practice (Golodnova et al., 2021):

Woody and shrubby plants (pine, birch, and willow families), which cause the first spring peak in hay fever (April–May).

Cereals – the second, spring-summer period of pollinosis (May–June–July).

Weeds (Asteraceae, Chenopodiaceae, Nettle, Amaranthaceae, Plantain, Sedge) – third summer-autumn period (July–August–September).

Mixed-herb species are conditionally allergenic or slightly allergenic (from May to August).

Evidently, the highest tree and shrub pollen content in soil samples is observed in the recreational zone, followed by the industrial zone. Therefore, the risk of hay fever from tree pollen is higher here throughout the snowless period.

Cereal pollen concentrations in the air are highest in the industrial zone (where grasses are typically not mown before flowering), and lowest in the recreational and residential areas, as cereals play a minor role in the formation of forest park phytocenoses and the greening of lawns in courtyard areas (where, in addition, several mows are made during the season). The high cereal pollen concentration in the study area, in our opinion, can be explained by its high volatility and its adventitious origin. The same ratio holds true for the subrecent spectra.

Table 1. Distribution of highly and moderately allergenic plants in the functional zones of Ulyanovsk.

Plant name (allergenic hazard level)	Zone			
	Industrial	Residential	Recreational	Educational
Family (Pinaceae)				
Siberian spruce (<i>Picea abies</i> (L.)Karst.) ¹ (2)	+	+	+	+
Siberian larch (<i>Larix sibirica</i> Ledeb.) (2)			+	
Family Salicaceae				
Goat willow (<i>Salix caprea</i> L.) (3)			+	+
Almond willow (<i>S. triandra</i> L.) (3)			+	+
White poplar(<i>Populus alba</i> L.) (3)	+	+	+	+
Black poplar (<i>P. nigra</i> L.) (2)			+	
European aspen (<i>P. tremula</i> Ledeb.) (2)			+	+
Eastern cottonwood (<i>P. deltoides</i> Marsh.) (2)			+	
Balsam poplar (<i>P. balsamifera</i> L.) (2)		+	+	+
Mongolian poplar (<i>P. suaveolens</i> Fisch.) (2)		+	+	
Laurel-leaf poplar (<i>P. laurifolia</i> Ledeb.) (2)			+	
Family Betulaceae				
Silver birch (<i>Betula pendula</i> Roth.) (2-3)	+	+	+	+
Downy birch (<i>B. pubescens</i> Ehrh.) (2)			+	
Common hazel (<i>Corylus avellana</i> L.) (2)			+	
Family Rosaceae				
Prickly wild rose (<i>Rosa acicularis</i> Lindl.) (2)	+	+	+	+
Dog-rose (<i>R. canina</i> L.) (2)		+	+	+
Cinnamon rose (<i>R. majalis</i> Herrm) (2)		+	+	
French rose (<i>R. gallica</i> L.) (2)			+	
Beach rose (<i>R. rugosa</i> Thunb.)(2)			+	
Burnet rose (<i>R. pimpinellifolia</i> L.) (2)			+	

¹ Латинские названия растений даны по С.К. Черепанову (1995).

Plant name (allergenic hazard level)	Zone			
	Industrial	Residential	Recreational	Educational
Family Poaceae				
Crested wheat grass (<i>Agropyron pectinatum</i> (Bieb.) Beauv.) (3)	+	+	+	+
Dog bent (<i>Agrostis canina</i> L.) (3)		+	+	
Wheat grass (<i>A. tenuis</i> Sibth.) (3)		+	+	+
Bluegrass (<i>Poa pratensis</i> L.) (3)	+	+	+	+
Narrow-leaf meadow-grass (<i>Poa angustifolia</i> L.) (3)	+	+	+	+
Annual bluegrass (<i>Poa annua</i> L.) (3)		+	+	
Flattened meadow-grass (<i>Poa compressa</i> L.) (3)			+	+
Wood bluegrass (<i>Poa nemoralis</i> L.) (3)			+	
Rough meadow-grass (<i>Poa trivialis</i> L.) (3)		+	+	
Purple-stem cat's-tail (<i>Phleum phleoides</i> (L.) Karst.) (3)	+	+	+	+
Timothy grass (<i>P. pratense</i> L.) (3)	+	+	+	+
Austrian brome (<i>Bromopsis inermis</i> (Leyss.) Holub.) (3)	+	+	+	+
Soft brome (<i>Bromus mollis</i> L.) (3)			+	
Rough brome (<i>Bromus squarrosus</i> L.) (3)			+	
Meadow foxtail (<i>Alopecurus pratensis</i> L.) (3)	+	+	+	+
Common couch (<i>Elytrigia repens</i> L.) (3)	+	+	+	+
Meadow fescue (<i>Festuca pratensis</i> Huds.) (3)	+	+	+	+
Foxtail barley (<i>Hordeum jubatum</i> L.) (3)	+	+		+
Family Chenopodiaceae	+	+	+	+
White goosefoot (<i>Chenopodium album</i> L.) (3)	+	+	+	+
Maple-leaved goosefoot (<i>C. hybridum</i> L.) (3)	+	+	+	+
City goosefoot (<i>C. urbicum</i> L.) (3)	+	+	+	+
Oakleaf goosefoot (<i>C. glaucum</i> L.) (3)	+	+	+	+
Seaport goosefoot (<i>C. opulifolium</i> L.) (3)			+	
Tatarian orache (<i>Atriplex tatarica</i> L.) (3)	+	+	+	+
Halberdleaf orache (<i>A. calotheca</i> (Rafn) Fries) (3)			+	
Common orache (<i>A. Patula</i> L.)	+	+	+	+
Forage kochia (<i>Kochia prostrata</i> (L.) Schrad.) (3)		+	+	
Summer cypress (<i>K. Scoparia</i> Schrab.) (3)		+	+	

Plant name (allergenic hazard level)	Zone			
	Industrial	Residential	Recreational	Educational
Family Asteraceae				
Annual ragweed (<i>Ambrosia artemisiifolia</i> L.) (3)	+		+	
Giant ragweed (<i>A. Trifida</i> L.) (3)	+			
Giant sumpweed (<i>Cyclachaena xanthiifolia</i> (Nutt.) Fresen.) (3)	+	+		
Sievers' wormwood (<i>Artemisia sieversiana</i> Wild.) (3)			+	
Tarragon (<i>A. dracunculus</i> L.) (3)			+	
Mugwort (<i>A. vulgaris</i> L.) (3)	+	+	+	+
Southernwood (<i>A. abrotanum</i> L.) (3)	+	+	+	+
Common wormwood (<i>A. absinthium</i> L.) (3)	+	+	+	+
Austrian wormwood (<i>A. austriaca</i> Jacq.) (3)			+	
Field wormwood (<i>A. campestris</i> L.) (3)			+	
Field sagewort (<i>A. marschalliana</i> Spreng.) (3)		+	+	
Redstem wormwood (<i>A. scoparia</i> Waldst. et Kit.)	+	+	+	
Sievers' wormwood (<i>A. sieversiana</i> Wild.) (3)			+	
Family Amaranthaceae				
Common tumbleweed (<i>Amaranthus albus</i> L.) (3)	+	+	+	+
Purple amaranth (<i>A. Blitum</i> L.) (3)			+	
Red-root amaranth (<i>A. Retroflexus</i> L.) (3)	+	+	+	+
Family Urticaceae				
Common nettle (<i>Urtica dioica</i> L.) (3)	+	+	+	+
Family Cyperaceae				
Sedge (<i>Carex</i> spp) (2)	+	+	+	+
Family Plantaginaceae				
Hoary plantain (<i>Plantago media</i> L.) (3)	+	+	+	+
Broadleaf plantain (<i>P. major</i> L.) (3)	+	+	+	+
Ribwort plantain (<i>P. lanceolata</i> L.) (3)	+	+	+	+
Total	34	44	67	38

The highest Chenopodiaceae pollen content is observed in residential areas, both in the pollen rain during flowering and in subrecent spectra. Even greater amounts accumulate in the soil than in the air during flowering. In this case, mowing is no longer a factor: while cereals bloom in the first half of summer, Chenopodiaceae blooms from the second half of summer until late autumn (when mowing is no longer done). High Chenopodiaceae pollen content is observed in all areas of the city, due to its high volatility and high productivity. Therefore, those with allergies to Chenopodiaceae pollen should exercise caution during the snow-free season, especially in residential areas. It is important to note that Chenopodiaceae, along with Asteraceae (primarily *Artemisia*), are the most common weeds.

Nettle pollen is found in the air and in the upper layers of soil in approximately equal quantities in all zones (somewhat more in the study zone), which means it poses a risk to allergy sufferers throughout the season, which must be taken into account in the areas where it grows.

Plantains are most abundant in the pollen rain in residential and recreational zones, and less so in educational and industrial zones (due to their association with trampled habitats). In contrast, in soil samples, plantain pollen is present in small but equal quantities in all zones, further confirming its good volatility and preservation (Blagoveshchenskaya, 2016).

Sedge pollen is most abundant in the atmosphere in residential areas (used for landscaping lawns) and recreational areas (as an edifier or co-edifier of the grass layer of forest parks and suburban forests). Forbs (especially Rosaceae, and to a lesser extent Cruciferae, Legumes, Polygonaceae, and others) are more abundant in pollen rain in recreational (in the natural grass layer, cultivated, and ornamental) and educational (as ornamental) areas.

A comparison of the pollen occurrence of allergenic plants in subrecent spectra of soil samples and the occurrence of the plants themselves in phytocenoses at sample sites revealed that the observed ratios are virtually identical for all districts of Ulyanovsk. Therefore, we present generalized data for the entire city and its environs (Table 3). Most species in this table are grouped by family, with the exception of the family Salicaceae, where poplar and willow species are considered separately due to their significantly different occurrence in phytocenoses. The genus *Artemisia* is also considered as the most significant allergenic taxon in the family Asteraceae, with a high pollen abundance in the spectra. In our opinion, the presence of a plant and its pollen is important for assessing allergenic hazard, rather than its contribution to the phytocenosis, since an allergenic response in a person suffering from hay fever occurs in the presence of at least one flowering plant.

Table 2. Results of pollen analysis of soil samples (subregional pollen spectra) and aeropalynological studies of the city of Ulyanovsk.

Zone	Composition of pollen spectra in soil/air, %									Total
	Trees and shrubs	Cereals	Goosefoots	Daisy	Nettle	Amaranths	Plantain	Sedges	Mixed herbs and others	
Industrial	34/21	58/43	8/16	12/12	2/2	0.5/0.3	0.5/2	0/1	5/3	100
Residential	24/10	18/26	42/20	15/12	1/5	1/2	0.5/5	0.5/6	1/15	100
Recreational	65/25	10/18	11/14	5/6	0.1/4	0/1	0.5/3	0.5/3	8/27	100
Educational	21/15	28/27	14/15	26/13	0.1/3	1/1	0.5/2	0/2	10/21	100

As can be seen from Table 3, the highest pollen abundance in relation to the pollen-producing plants themselves in the test plots is characteristic of representatives of the families Pinaceae, Brassicaceae, Amaranthaceae, Chenopodiaceae, Plantaginaceae, Betulaceae, Urticaceae, Polygonaceae, Asteraceae, as well as the genera *Salix* spp. and *Artemisia* spp., confirming the high pollen productivity and volatility of their pollen (Andersen, 1970; Bennet and Hicks, 2005; Blagoveshchenskaya, 2016; Giesecke et al., 2010; Heide, 1982; Lapteva, 2013; Nosova et al., 2015; Novenko et al., 2011; Rudenko and Novenko, 2015). Consequently, the absence of plants in a certain area (or their disappearance after the end of pollination) does not guarantee the absence of an allergic reaction in patients with hay fever due to their possible contact with the soil or if, for example, when the topsoil is disturbed.

For the families Poaceae, Cyperaceae, Rosaceae, and Tiliaceae, pollen in subrecent spectra is approximately equal in frequency to the plants themselves in phytocenoses. Furthermore, pollen from representatives of these families is also found in spectra outside their native habitats.

Many families are much less represented in soil samples than in phytocenoses: Fabaceae, Fagaceae, Liliaceae, Ulmaceae, Oleaceae, Aceraceae. Some (genus *Populus*) were not reflected in the subrecent spectra at all – we found only isolated, half-destroyed poplar pollen grains in some plots established during flowering. This ratio indicates a relatively low pollen productivity of these plants and/or their poor preservation (Hall, 1981; Nicholas, 1970; Novenko et al., 2011; Vershinin, 2012), meaning that in their habitats they pose a threat to allergy sufferers only when flowering.

As our previous studies have shown, the highest risk pollen waves are the second (the flowering time of cereal and meadow grasses from late May to mid-July) and the third (the flowering time of weeds, especially *Artemisia* and goosefoot, from mid-July to September), since they include pollination of highly allergenic plants with a high concentration of pollen in the air (Golodnova et al., 2021). It is generally accepted that the first wave is the lowest risk (the flowering time of trees and shrubs from April to May), since many woody plants are weakly allergenic and the pollen concentration at this time is low (Dikareva and Rummyantsev, 2015; Golodnova, 2020; Golovko, 2004; Shamgunova and Zaklyakova, 2010). However, as shown in this work, it is the pollen of woody plants that has a high occurrence in subrecent spectra (especially in industrial and recreational zones). Therefore, the likelihood of it being included in the pollen rain at any time throughout the season is very high.

Conclusions

Floristic and aero-palynological studies show that all allergenic plant species are present both in pollen rain (dispersed by air) and in the subrecent spectra of soil samples.

Analysis has shown that the composition of pollen rain of allergenic flora depends not only on the pollination of plants growing in a specific area at specific times. subrecent" or lingering pollen in topsoil poses a year-round hay fever hazard. This is particularly true for members of the families Pinaceae, Brassicaceae, Amaranthaceae, Chenopodiaceae, Betulaceae, Plantaginaceae, Urticaceae, Polygonaceae, Asteraceae, Poaceae, Cyperaceae, and Rosaceae, as well as the genera *Salix* spp. and *Artemisia* spp., pollen of which is found in significant quantities in pollen spectra, often representing a high percentage of air samples even outside their actual coverage in the local vegetation.

On the contrary, representatives of the families Fagaceae, Oleaceae, Ulmaceae, Aceraceae, Fagaceae, Fabaceae, Liliaceae, as well as the genus *Populus* spp. in their growing areas pose a threat to allergy sufferers only during the flowering period.

The composition of the subrecent spectra of soil samples from the industrial zone indicates a significant risk of hay fever throughout the snowless period, caused primarily by the flowering of trees, shrubs, and grasses. In the residential zone, the greatest risk is posed by members of the families Chenopodiaceae, Asteraceae (mostly *Artemisia*), Amaranthaceae, Plantaginaceae, and Cyperaceae families. In the recreational zone, the greatest risk is posed by Cyperaceae, Plantaginaceae, and forbs. In the educational zone, the greatest allergy risk is posed by forbs (Rosaceae).

An analysis of the occurrence of allergenic plants and their pollen in soils showed that the absence of plants in a particular area does not guarantee the absence of allergic reaction in hay fever sufferers in that area due to possible contact with the soil or, for example, disturbance of the topsoil (wind, water, anthropogenic erosion).

These research findings should be taken into account when planning preventive measures and treating hay fever. In particular, the species composition of plants used in urban landscaping should be carefully reviewed.

Table 3. Occurrence of plants in phytocenoses of sample plots and their pollen in sub-recent spore-pollen spectra.

Group of plants	In sub-recent spectra	Plant occurrence, %	
		In phytocenoses	Ratio of occurrence in spectra and in phytocenoses
Aceraceae	1.3	9.0	0.1
Amaranthaceae	16.5	2.2	7.5
<i>Artemisia</i> spp.	99.0	15.8	6.3
Asteraceae	89.5	61.8	1.5
Betulaceae	21.5	11.4	1.9
Brassicaceae	36.7	3.5	10.5
Chenopodiaceae	82.6	17.7	4.7
Cyperaceae	83.7	81.9	1.0
Fabaceae	55.8	78.5	0.7
Fagaceae	20.3	39.3	0.5
Liliaceae	30.8	69.4	0.4
Oleaceae	0.17	1.6	0.1
Pinaceae	31.1	2.9	10.7
Plantaginaceae	40.1	14.8	2.7
Poaceae	83.6	79.9	1.1
Polygonaceae	15.8	10.2	1.6
<i>Populus tremula</i>	0	17.8	0
<i>P. nigra, P. alba</i>	0.1	52.0	0
Rosaceae	84.0	83.8	1.0
<i>Salix</i> spp.	3.4	0.5	6.8
Tiliaceae	21.6	22.3	1.0
Ulmaceae	1.0	4.8	0.2
Urticaceae	56.3	31.7	1.8

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