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ANALYSIS OF AIRBORNE POLLEN CONCENTRATIONS IN ZAGREB, CROATIA, 2002

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Abstract: Employing the volumetric method by use of a Hirst sampler, a total of 71,286 pollen grains, as many as 94.20% of them allergenic, were recorded in the air samples from the city of Zagreb during the 2002 pollen season. Among identified pollen of 35 plant species/genera/families, 23 were allergenic: Taxus/Juniperus, *Alnus* sp., *Fraxinus* sp., *Betula* sp., *Corylus* sp., Poaceae, Urticaceae, *Artemisia* sp., *Ambrosia* sp., *Carpinus* sp., *Castanea* sp., *Chenopodiaceae, Salix* sp., *Populus* sp., *Ulmus* sp., *Juglans* sp., *Quercus* sp., *Platanus* sp., *Fagus* sp., *Plantago* sp., *Pinus* sp., *Picea* sp. and *Abies* sp. The pollen of these plants also cause the majority of pollinosis in Europe. Study results and the pollen calendar designed for the 2002 pollen season for the City of Zagreb provide useful data for allergologists to reach an accurate diagnosis. The calendar also provides timely information on airborne pollen types and air concentrations for individuals with pollen hypersensitivity, thus allowing them to adjust their daily activities so as to minimize their contact with allergens and improve their quality of life both at home and at work.

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Key words: aerobiology, pollinosis, allergenic plants, pollen calendar, Zagreb (Croatia).

INTRODUCTION

Allergic rhinitis is one of the most common allergic diseases, frequently occurring in association with allergic conjunctivitis and asthma, thus usually representing an initial stage of much more complex respiratory and immune system disorders. A large multicenter epidemiologic study performed in 100,000 individuals from eight European countries showed the prevalence of allergic rhinitis to ranging from 3.2% in Denmark to 19.6% in Germany. In Croatia, 15–20% of the population are at a risk of allergic rhinitis [6]. Nowadays, pollen has been definitely demonstrated as one of the most potent allergens. Allergenic plants are characteristic for particular areas, depending on the geographic-climatic zone and vegetation. Pollen concentrations of such plants depend on the particular species phenological stage and weather conditions in the area. Providing preventive information on the occurrence of pollen allergens in the residential and working areas is crucial for allergic individuals to upgrade their quality of life, since avoiding the contact with allergens is the most efficient prevention. With this endpoint, annual pollen calendars have now been designed in many countries of the world [1, 3, 5, 10, 12, 15, 16].

The aim of this study was to determine the types of airborne pollen in the city of Zagreb, and their weekly and monthly variation during 2002, when the monitoring of aeroallergens according to current standards used in most European countries was introduced. Results of the study are expected to help in preventing the symptoms of allergic reaction in individuals with pollen hypersensitivity, thus improving their quality of life.

MATERIAL AND METHODS

Zagreb is situated at 45° 49' N and 15° 59' E in the central part of Croatia, at 157 m above the sea level, with continental climate, closed by the Medvednica mountain

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on the north (effect of forest vegetation) and open southward crossing the Sava river (effect of ruderal, weedy and aqueous vegetation). Standardized volumetric method of pollen sampling from the air by use of a Hirst sampler placed at a height of 19.7 m in the northern part of the city was employed. The sampler allows to determine of pollen concentration in 2-hour intervals. Pollen grains stick to a cellulose strip smeared with a silicone solution. The strip was changed twice weekly. Preparations were embedded in Gelvatol mixed with stain (acid fuchsin). The samples were observed under a microscope (magnification ×400). Results were expressed as daily average of pollen grains per cubic metre of air [18].

RESULTS

Because Zagreb is situated at the foothills of the Medvednica mountain, the composition of airborne pollen in the city of Zagreb is strongly influenced by the forest vegetation from the north, consisting of the following species: *Acer campestre* L., *A. pseudoplatanus* L., *A. platanoides* L., *Ulmus glabra* Hudson, *Fraxinus excelsior* L., *Carpinus betulus* L., *Ostrya carpinifolia* L., *Corylus avellana* L., *Fagus silvatica*, *Quercus petraea* (Mattuschka) Liebl., *Taxus baccata* L., *Abies alba* L. (at higher altitudes), *Ilex aquifolium* L., *Castanea sativa* L., *Tilia cordata*, various species of the genus Rubus, *Sambucus nigra* L., *Robinia pseudoaccacia* L., etc.

Grassy and weedy grounds prevail in rural areas to the east and south of the city. In these areas, the vegetation consists of a number of ruderal and weedy, wild-growing and adventive plants, primarily from the families Poaceae, Chenopodiaceae, Compositae, Brassicaceae, Urticaceae, Lamiaceae and Fabaceae. Of adventive plants, the allergenic species *Ambrosia artemisiifolia* L. and *Artemisia vulgaris* L. are widespread. In the urban area along the Sava river, the species *Alnus glutinosa* (L.) Gaertn. and various species of the genera *Salix* and *Populus* prevail. In addition to this more or less natural vegetation, the city has numerous parks containing the following species: *Betula pendula* L., various species of the family Cupressaceae and of the genera *Pinus* and *Picea*, *Aesculus hippocastanum* L., *Platanus hybridus*, *Populus* sp., *Ligustrum vulgare* L., *Buxus sempervirens* L., *Juglans regia* L., *Tilia* sp., *Cornus sanguinea* L., *Forsythia* sp., various species of the family Rosaceae, etc.

During 2002, pollen of 35 plant species/genera/families, 23 of them allergenic, were identified in the air of the city of Zagreb. A total of 71,286 pollen grains were counted. The highest pollen concentration was recorded in March (17,952 pollen grains), February (16,581), August (11,193) and April (10,178). Allergenic pollen predominated in all months (Fig. 1).

The following plants were found to produce the greatest amount of allergenic pollen: *Betula* sp., *Corylus* sp., Urticaceae and *Ambrosia* sp., accounting for 60.01% of all airborne pollen recorded (Tab. 1).

Table 1. Total annual pollen counts in Zagreb, 2002.

	Total pollen count	%
Allergenic plants (AP)		
Tax. / Jun.	3,602	5.05
Alnus sp.	3,883	5.45
Fraxinus sp.	780	1.09
Betula sp.	14,448	20.27
Corylus sp.	11,106	15.58
Poaceae	3,074	4.31
Urticaceae	7,975	11.19
Artemisia sp.	659	0.92
Ambrosia sp.	9,243	12.97
Carpinus sp.	824	1.15
Castanea sp.	1,362	1.91
Chenopodiaceae	241	0.33
Salix sp.	4,397	6.17
Populus sp.	598	0.84
Ulmus sp.	88	0.13
Juglans sp.	543	0.77
Quercus sp.	2,467	3.47
Platanus sp.	656	0.93
Fagus sp.	51	0.07
Plantago sp.	479	0.68
Pinus sp.	431	0.61
Picea sp.	209	0.30
Abies sp.	11	0.01
Total (AP)	67,127	94.20
Low allergenic plants (LAP)		
Acer sp.	2,051	2.88
Rosaceae	166	0.24
Aesculus sp.	1,094	1.54
Cyperaceae	41	0.05
Asteraceae	226	0.32
Tilia sp.	141	0.19
Robinia sp.	92	0.13
Brassicaceae	21	0.02
Morus sp.	17	0.02
Ligustrum sp.	27	0.03
Umbelliferae	56	0.07
Sambucus sp.	227	0.31
Total (LAP)	4,159	5.80
Total	71,286	100

The earliest airborne pollen grains recorded in January originated from the following species: *Alnus* sp. accounting for 36.5%, *Corylus* sp. for 30.1%, *Salix* sp. for 27.2% and plants of the genera Taxus/Juniperus for 7.2% of all pollen sampled. A similar species composition was found in February, whereas in March the number of various species increased, with the pollen originating from *Betula* sp. as the most common, accounting for 76%

Table 2. Monthly pattern of airborne pollen (%) in Zagreb, 2002.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Allergenic plants (AP)												
Tax. / Jun.	7.2	5.3	5.0	17.7	2.7	0.2	-	-	-	5.5	40.0	-
Alnus sp.	36.5	20.9	1.1	0.2	1.1	-	-	-	-	-	-	-
Fraxinus sp.	-	-	1.7	4.5	2.9	-	-	-	-	-	-	-
Betula sp.	-	-	76.0	6.0	-	-	-	-	-	-	-	-
Corylus sp.	30.1	64.1	1.2	-	-	-	-	-	-	-	-	-
Gramineae	-	-	-	1.6	40.3	26.1	9.0	1.0	1.0	5.5	-	-
Urticaceae	-	-	-	-	0.1	23.6	73.7	36.9	13.3	8.3	-	-
Artemisia sp.	-	-	-	-	-	-	1.5	4.6	2.2	-	-	-
Ambrosia sp.	-	-	-	-	-	-	-	53.0	79.1	77.8-	20.0	-
Carpinus sp.	-	-	0.7	6.7	2.8	-	-	-	-	-	-	-
Castanea sp.	-	-	-	-	-	37.0	3.8	-	-	-	-	-
Chenopodiaceae	-	-	-	-	-	-	0.8	1.1	2.2	-	-	-
Salix sp.	27.2	9.2	9.5	7.9	1.4	-	-	-	-	-	-	-
Populus sp.	-	0.5	2.0	1.5	-	-	-	-	-	-	-	-
Ulmus sp.	-	-	0.2	0.5	-	-	-	-	-	-	-	-
Juglans sp.	-	-	0.1	4.9	0.5	-	-	-	-	-	-	-
Quercus sp.	-	-	-	19.84	12.7	-	-	-	-	-	-	-
Platanus sp.	-	-	-	6.3	-	-	-	-	-	-	-	-
Fagus sp.	-	-	-	-	1.1	-	-	-	-	-	-	-
Plantago sp.	-	-	-	-	1.1	2.8	5.4	1.6	0.4	-	-	-
Pinus sp.	-	-	-	-	6.1	0.5	-	-	-	-	40.0	-
Picea sp.	-	-	-	-	-	1.0	0.3	-	-	-	-	-
Abies sp.	-	-	-	-	0.3	-	-	-	-	-	-	-
Total (AP)	100	100	97.5	77.6	73.1	91.2	94.5	98.2	98.2	97.1	100	-
Low allergenic plants (LAP)												
Acer sp.	-	-	2.4	15.9	1.0	-	-	-	-	-	-	-
Rosaceae	-	-	0.1	0.9	0.2	0.4	1.1	0.5	0.2	-	-	-
Aesculus sp.	-	-	-	5.4	14.3	-	-	-	-	-	-	-
Cyperaceae	-	-	-	0.2	0.3	0.1	-	-	-	-	-	-
Asteraceae	-	-	-	-	0.2	2.4	2.9	0.7	1.1	2.9	-	-
Tilia sp.	-	-	-	-	0.5	3.4	0.4	-	-	-	-	-
Robinia sp.	-	-	-	-	2.3	-	-	-	-	-	-	-
Brassicaceae	-	-	-	-	1.7	-	0.6	-	0.3	-	-	-
Morus sp.	-	-	-	-	0.4	-	-	-	-	-	-	-
Ligustrum sp.	-	-	-	-	1.2	0.9	0.1	-	-	-	-	-
Umbelliferae	-	-	-	-	-	0.5	0.4	0.6	0.2	-	-	-
Sambucus sp.	-	-	-	-	4.8	1.1		-	-	-	-	-
Total (LAP)	-	-	2.5	22.4	26.9	8.8	5.5	1.8	1.8	2.9	-	-

of total pollen sampled. In April, the number of plant species represented in the total pollen continued to rise, the following being most common: *Quercus* sp. 19.8%, plants of the genera Taxus/Juniperus 17.7% and *Acer* sp. 15.9%. The highest number of various plants, as many as 24, was recorded in May, with an absolute predominance of plants from the family Poaceae, which accounted for 40.3% of total pollen. In June, pollination of plants from the family Poaceae continued, accounting for 26.1%; the pollen originating from *Castanea* sp. prevailed however, with 37%. Also, an increasing presence of the pollen from herbaceous plants of the family Urticaceae, accounting for 23.6%, was recorded in June, to become predominant in July with 73.7%. *Ambrosia* sp., the most allergenic plant of our climate, was in full bloom in August, when it accounted for as much as 53% of total airborne pollen. This percentage rose further to 79.1% and 77.8% in September and October, respectively. The pollen season of the plants of the continental climate terminates in November (Tab. 2).

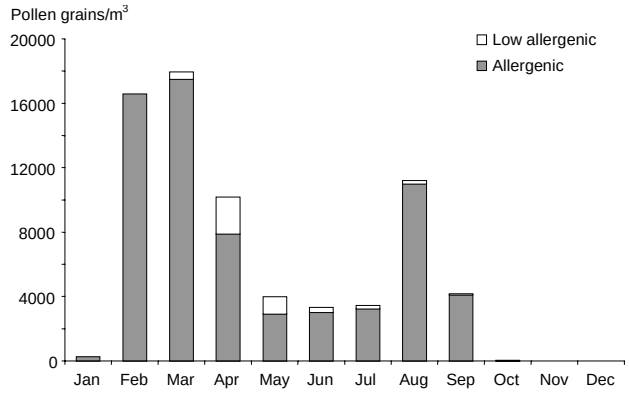

Figure 1. Monthly variation in airborne pollen grains total count according to allergenic/low allergenic species in Zagreb, 2002.

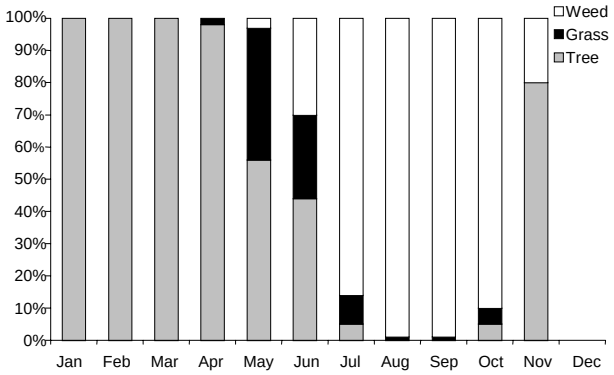

Figure 2. Monthly variation in the percentage of tree, weed and grass airborne pollen in Zagreb, 2002.

Classification of the plant species into groups of trees, grasses and weeds reveals exclusively tree airborne pollen to be found in January, February, March and April then in May and June the grass and weed pollen occurred, whereas an absolute predominance of weed pollen was recorded in July, August, September and October (Fig. 2).

Duration of the pollen season of allergenic plants and respective variation in airborne pollen concentration are presented in the pollen calendar for the year 2002 (Fig. 3). The following genera and families are represented in the calendar:

Cupressaceae/Taxaceae. Pollen season begins in the fourth week of January and terminates towards the end of May, with the highest concentration recorded from the fourth week of February to the second half of March.

***Alnus* sp.** Pollen season begins in the last week of January, reaches highest airborne pollen concentration in the last week of February and terminates in the first week of April.

***Fraxinus* sp.** The pollen season is relatively short, beginning in the second half of March and ending in the last week of May. The highest airborne pollen concentration was recorded in the first week of April.

***Betula* sp.** A very short pollen season starts at the beginning of March and ends in mid-April. During the period of maximal airborne pollen concentration (second week in March), this species produces enormous amounts of pollen.

***Corylus* sp.** Its pollen grains initially occur in the last week of January and reach maximal concentration in the last week of February. Its pollination period terminates in the last week of March.

Poaceae. The pollen of the plants of this family is present in the air for most of the year, from the beginning of April–end of September, with the highest concentration recorded in the second half of May.

Urticaceae. Pollen season begins in the second week of June with relatively high concentrations and terminates towards the end of September. The highest air concentrations were recorded in the last week of July and throughout August.

***Artemisia* sp.** Pollen season begins in the last week of July and lasts until the final week of September, with maximal pollen concentrations recorded in the first week of August.

***Ambrosia* sp.** Pollen season starts at the beginning of August to reach the highest concentration in the last week of the month and terminates in the first week of October.

Carpinus/Ostrya. Pollen of the plants of these two genera occurs in the air in mid-March, reaches highest concentrations at the beginning of April, and gradually disappears at mid-May.

***Castanea* sp.** Pollen season begins at mid-June and reaches the highest concentration in the same month, thereafter gradually decreasing to the end of pollination at the end of July.

***Chenopodium* sp.** The first pollen grains are found in the air at the beginning of July, and the last at mid-September. Pollen concentrations are generally low throughout the period of pollination, being highest in the last week of August and first week of September.

***Salix* sp.** Pollen season begins in the last week of January and terminates towards the first week of May, with the highest concentration recorded from the second week of February to the second half of March.

***Populus* sp.** The first pollen grains are found in the last week of February, and the last in mid-April.

***Ulmus* sp.** A very short pollen season with relatively low concentrations starts in the second week of March and ends in the first week of April.

***Juglans* sp.** Pollen grains initially occur in the last week of March and reach maximal concentration twice - in the first and the last week of April.

***Quercus* sp.** Pollen season begins at the beginning of April to reach highest concentration in the second half of the month.

***Platanus* sp., and *Fagus* sp.** Pollen of the plants of these two genera occur in the air at the beginning of April, reach highest concentrations at mid-April and terminates at the end of April.

***Plantago* sp.** A relatively long pollen season starts at the beginning of May and ends in the first week of September.

***Pinus* sp., *Picea* sp. and *Abies* sp.** Have a short pollen season with low pollen concentrations in the air.

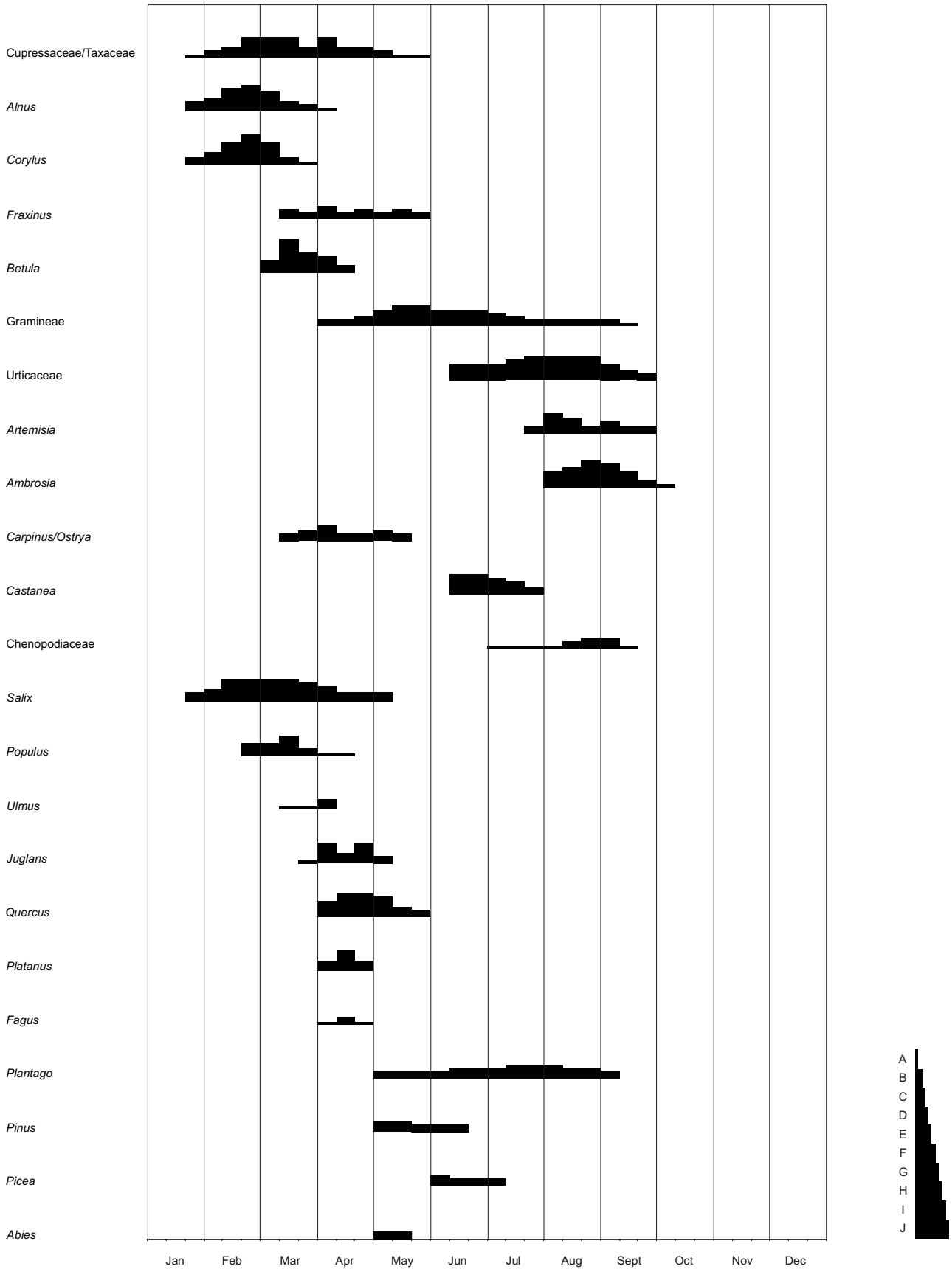

Figure 3. Pollen calendar for Zagreb. The height of bars is proportional to pollen grains number m^{-3} as marked by letters A: 1-2, B: 3-5, C: 6-11, D: 12-24, E: 25-49; F: 50-99, G: 100-199, H: 200-399, I: 400-799, J: 800-1599, K: >1600.

DISCUSSION

Airborne pollen of allergenic plants was found to predominate in the air of the city of Zagreb throughout the year. The pollen of alder (*Alnus* sp.) and hazel tree (*Corylus* sp.) predominate in February, whereas an absolute predominance of the birch (*Betula* sp.) pollen was recorded in March. Comparison of our results with those reported from other Central European studies revealed the highest concentrations of allergenic tree airborne pollen to occur in Zagreb by some two weeks earlier than in other Central European countries, due to the southern geographic localization and milder climate in Zagreb. This is why our results are more consistent with those for central Italy and southern France [2, 4, 9, 14, 17, 19]. Grass pollen (Poaceae) was found to prevail in May and June, along with sweet chestnut (*Castanea* sp.) pollen from mid-June until the end of July. The beginning, duration and termination of sweet chestnut pollen seasone correspond to those recorded in Spain [7]. The pollen of herbaceous plants of the nettle family (Urticaceae) prevails in July, and that of ragweed (*Ambrosia* sp.) in August, September and October, to be continued by predominance of the pollen of nettle (Urticaceae). The pollen of Poaceae, Urticaceae and *Alnus* sp. has also been reported to prevail in Central Europe, in the surroundings of Vienna, Leiden and Brussels [8], and the pollen of Poaceae, Urticaceae, Oleaceae and *Artemisia* sp. in Italy in the surroundings of Ascoli Piceno [11]. In Croatia, the pollen season of these plants terminates towards the end of October, i.e. at the same time as in other Central European countries [13].

CONCLUSION

1. Airborne pollen grains of 35 species, 23 of them allergenic, were recorded in the Zagreb surroundings.

2. These species prevail throughout almost the entire pollen season, from January–November, accounting for 94.20% of the total pollen count. Allergenic pollen of the above-mentioned species also causes most pollinosis in Europe.

3. The results of the present study and the pollen calendar designed for the pollen season for the city of Zagreb and its surroundings provide useful data for allergologists to reach accurate diagnoses, and timely information on airborne pollen types and concentrations to individuals with pollen hypersensitivity, thus allowing them to adjust their daily activities so as to minimize the contact with allergens and improve their quality of life both at home and at work.

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