

Diurnal variation of chosen airborne pollen at five sites in Poland

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Abstract

The aerobiological investigations were carried out at five sites located in different climatic and geobotanical regions in Poland. The diurnal periodicity of *Alnus*, *Betula*, *Secale*, Poaceae, *Urtica*, and *Artemisia* was studied during two successive years. The taxa were chosen on the basis of pollen grain abundance and allergenicity. The pollen was collected with a Burkard spore trap. Twelve transversal transverses of microscope slides corresponding to two-hour periods were analysed. The diurnal variations of Poaceae, *Alnus* and *Betula* were irregular and varied between sites and years; high concentrations were observed at different hours of the day and night. Diurnal concentrations of *Secale*, *Urtica* and *Artemisia* had only one maximum in the middle of the day, constant between sites and years. The lowest concentrations were observed between evening and early morning. There was no close relation between the time of the liberation of *Alnus*, *Betula* and Poaceae pollen and the time of the maximum pollen counts. There was a several hour delay observed between the time of *Secale* pollen liberation and maximum concentration of airborne pollen.

1. Introduction

The investigations on the incidence of pollen in the air are commonly carried out by aerobiologists. Airborne pollen grains are characterised not only by annual, but also by diurnal periodicity. The first papers concerned with diurnal variation of pollen grains in the air were published by Hyde and Williams (1945) and Hyde (1952). The use of volumetric methods have made it possible to carry out relatively precise analysis of these phenomena. Most papers concern diurnal variations of allergenic airborne pollen (Poaceae, *Betula*, *Urtica*) in relation to meteorological conditions, pollen source areas and the height of sampling (Käpylä, 1981, 1984; Norris-Hill and Emberlin, 1991; Galan et al., 1991; Hart et al., 1994; Berggren et al., 1995). In Poland this kind of research was carried out sporadically (Kasprzyk, 1995; Latałowa and Góra, 1996). The circadian periodicity of pollen grains in the air depends on biological patterns, such as rhythm of the

opening of the anthers or mechanism of pollen liberation, and on meteorological factors such as temperature, photoperiod and relative humidity. These factors, as well as thermal convection and turbulence, result in diurnal variation of airborne pollen concentration, which does not necessarily reflect pollen liberation (Käpylä, 1984; Subba Reddi and Reddi, 1985; Norris-Hill and Emberlin, 1991).

The investigation of these phenomena is very important, not only for cognitive reasons, but also for practical ones. Results concerning allergenic taxa can be of importance to people sensitive to these taxa and can indicate new aspects of allergy prevention.

The aim of this work was to study diurnal variation in the concentration of airborne pollen grains of chosen taxa in the air and to compare results from five sampling sites located in different places in Poland. Pollen types were selected on the basis of their common occurrence in the Polish flora, abundance of airborne pollen grains and pollen

allergenicity. This research formed only part of a general project concerning aerobiological monitoring in Poland (Szczepanek, 1997).

2. Materials and methods

Pollen monitoring was carried out continuously in 1995 and 1996 in five towns in Poland: in Poznań, Warszawa, Ostrowiec Świętokrzyski, Kraków, and Zakopane (Figure 1). The sampling sites were located along a north-south transect. The localities differed in meteorological and geobotanical patterns because of the east-west arrangement of mountains, heights, and lowlands in Poland. Poznań (80 m a.s.l.) is a big city in Wielkopolska Lowland, where the mean annual precipitation is below 500 mm and the vegetative period ranges from 210 to 220 days. The mean January and July temperatures are -1.4°C and 19.2°C respectively. Warszawa (100 m a.s.l.) is a big city in Mazowsze Lowland, where the mean annual precipitation is below 500 mm, and the mean temperature in January is -2.9°C , and in July 18.6°C . The vegetation season ranges from 210 to 220 days. Ostrowiec Świętokrzyski (175 m a.s.l.) is a middle-sized town in Małopolska Height, where the mean annual precipitation is 550–650 mm and the vegetative period is 210 days. The mean temperature in January is 3.5°C and in July 18°C . Kraków (220 m a.s.l.) is a large city in Kraków-Wieluń Height. In this district the duration of the vegetative season is 220 days, but the mean annual precipitation is 700–750 mm. The mean January and July temperatures are -2.5°C and 18.2°C , respectively. Zakopane (900 m a.s.l.) is a small town placed in the Tatra Mountains. The mean annual precipitation ranges from 900 to 1300 mm, and the vegetation period is shorter than 180 days. The mean temperature in January is -4.9°C and in July 14.7°C .

In each town all the plant taxa chosen for analysis occur, but in the close vicinity of the sampling sites the vegetation is different. In Poznań there are *Platanus* sp., *Betula* sp., and grass areas. In Warszawa *Tilia* sp., *Robinia pseudoacacia* and ruderal weeds grow near the sampling site. In Ostrowiec Świętokrzyski, in the close vicinity of the trap, there are *Alnus* sp., *Populus* sp., *Fraxinus* sp. and ruderal weeds. In Kraków, the trap was situated in the Botanical Gardens, while in Zakopane it was placed in the Rock Gardens near the coniferous forest with *Picea excelsa*.

Pollen was collected with a Burkard 7-Day Recording Spore Trap. For technical reasons, the

samplers were located at different heights (Poznań – 34 m, Warszawa – 16 m, Ostrowiec Świętokrzyski – 36 m, Kraków – 20 m, Zakopane – 10 m), but always on roofs of buildings where the airflow was not deflected. The microscope slides were prepared in glycerol jelly. Twelve transversal transverses, one every second hour, were analysed. For the further analysis of diurnal variation, days with 50 or more pollen grains/ m^3 /day of any taxon were considered. When the airborne pollen grains of some taxa occurred continuously, but in small numbers, days with a minimum of 20 pollen grains/ m^3 /day were taken into account. For each day, the values from the transverses were calculated as percentages, and subsequently mean percentages for all selected days were calculated.

3. Results

Analysis of the diurnal variation of airborne pollen grains was conducted for six chosen taxa. Pollen grains of Poaceae, *Betula* and *Urtica* were abundant at all sampling sites during both seasons, whereas *Artemisia* and *Alnus* were found at four sites. *Secale* pollen grains occurred in the air continuously and in small numbers only in Poznań and Warszawa. Because pollen grains of this taxa form one of the main reasons for pollinosis in Poland, its circadian periodicity even in only two sites was interesting. The numbers of days (n) analysed and the total number of pollen grains/ m^3 (N) from these days are presented in Table 1.

Alnus – In Poland there are three species of *Alnus*: *A. viridis* (rare), *A. incana* and *A. glutinosa*. They usually begin to bloom at the end of February, beginning of March, the start of the pollen season in Poland. In four sites, one or two maxima of concentration occurred in the day or even at night. The lowest concentrations were observed in the early morning with the exception of Ostrowiec Świętokrzyski in 1996 (Figure 2). In Warszawa, Ostrowiec Świętokrzyski and Zakopane, the diurnal periodicity also differed from year to year.

Betula – Genus *Betula* has several species; in Poland *Betula pendula* and *B. pubescens* are the most common. Characteristic of the *Betula* pollen grains was their incidence in the air at the end of April. Analysis of concentration maxima at different hours showed large variation between the sites and the years.



Figure 1. Map of Poland showing sampling sites.

Table 1. Amount of pollen (N as number of grains) and numbers of days (n) selected for the analysis. (*days with equal or more than 20 pollen grains/m³/day)

TAXON	POZNAŃ		WARSZAWA ŚW.		OSTROWIEC		KRAKÓW		ZAKOPANE	
	1995	1996	1995	1996	1995	1996	1995	1996	1995	1996
ALNUS	N = 2588 n = 18	N = 655 n = 11*	N = 5396 n = 24	N = 1856 n = 12	N = 2470 n = 13	N = 499 n = 6			N = 663 n = 7	N = 449 n = 9*
BETULA	N = 3237 n = 9	N = 7853 n = 14	N = 4455 n = 11	N = 14251 n = 23	N = 1428 n = 7	N = 10222 n = 13	N = 1102 n = 5	N = 918 n = 6	N = 451 n = 10	N = 1148 n = 6
SECALE	N = 121 n = 4*	N = 261 n = 7*	N = 239 n = 4	N = 340 n = 9						
POACEAE	N = 2143 n = 19	N = 936 n = 13	N = 5806 n = 36	N = 4320 n = 35	N = 3907 n = 28	N = 1696 n = 12	N = 344 n = 12	N = 754 n = 22	N = 1670 n = 15	N = 439 n = 10*
URTICA	N = 5122 n = 45	N = 4592 n = 38	N = 9471 n = 55	N = 11949 n = 60	N = 5661 n = 48	N = 7826 n = 53	N = 582 n = 7	N = 2480 n = 22	N = 3824 n = 35	N = 966 n = 13
ARTEMISIA	N = 345 n = 5	N = 738 n = 11	N = 3277 n = 18	N = 2514 n = 24	N = 939 n = 14	N = 1085 n = 14	N = 475 n = 7*	N = 320 n = 10*		

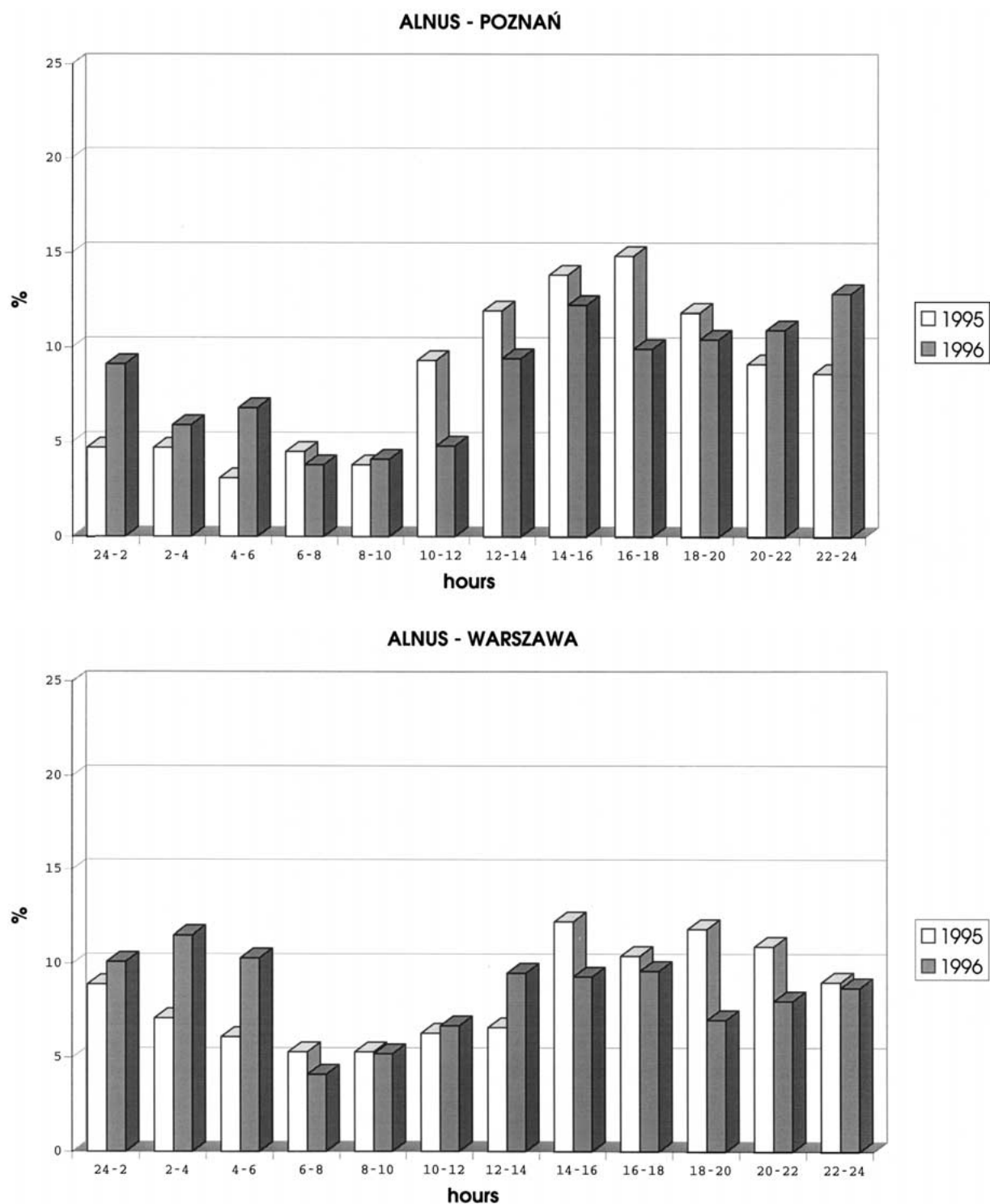


Figure 2. The diurnal variations of *Alnus* pollen in 1995–1996 in Poznań, Warszawa, Ostrowiec Świętokrzyski, Kraków and Zakopane.

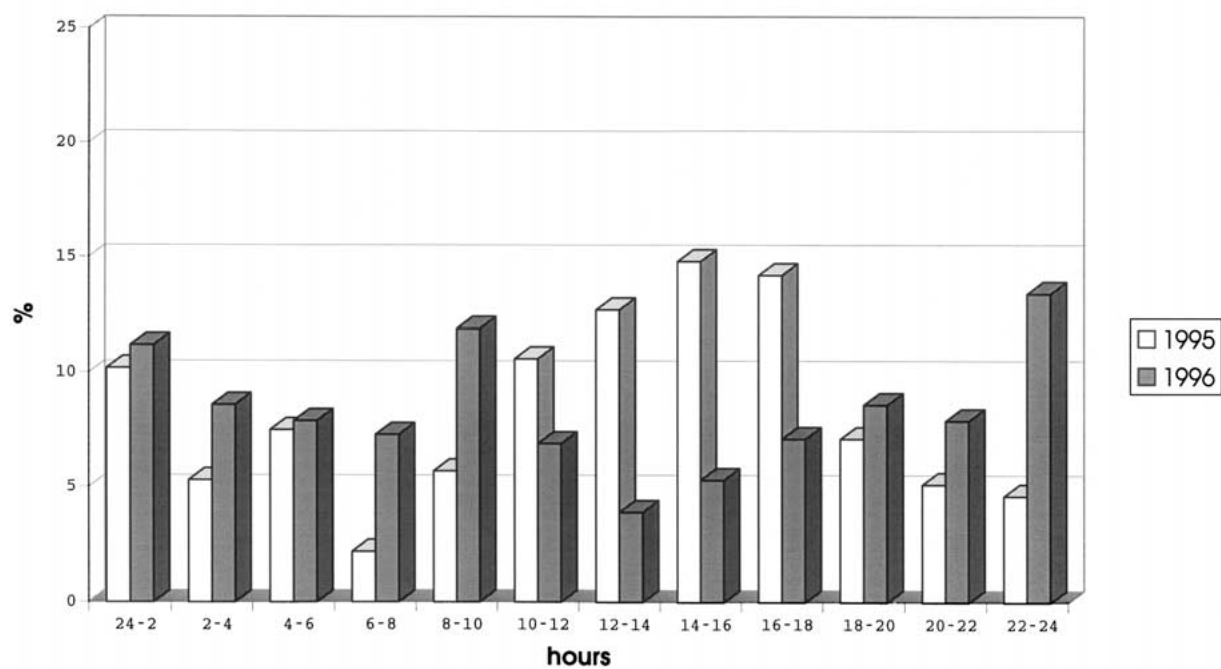
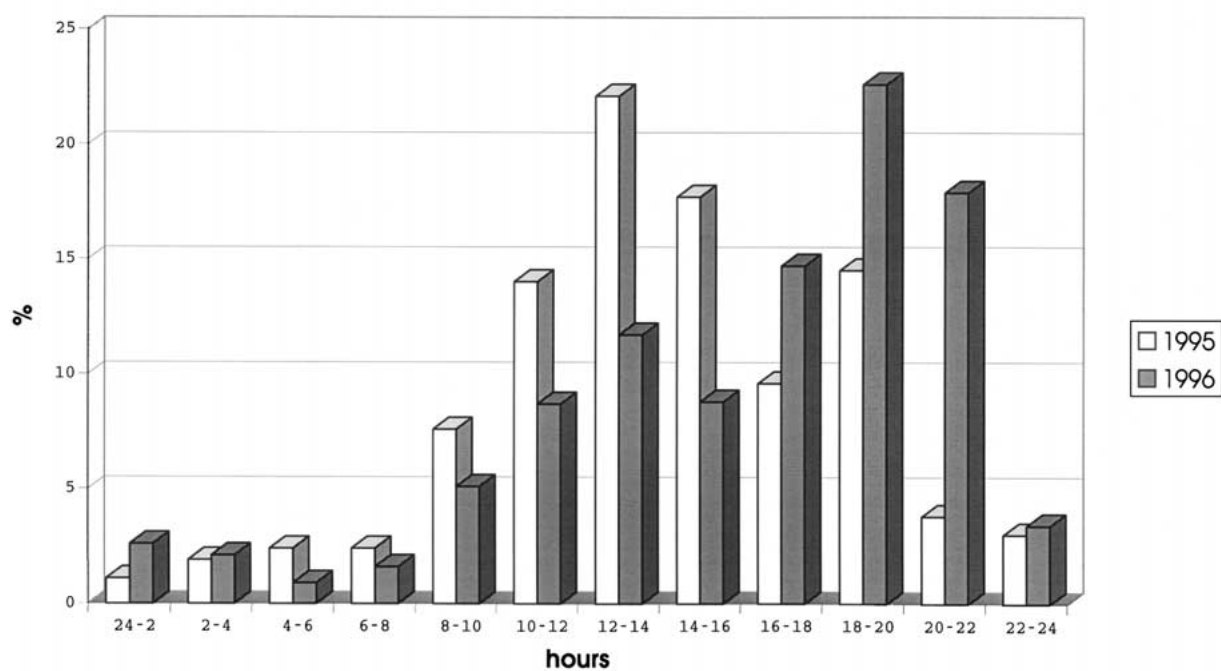
ALNUS - OSTROWIEC ŚW.**ALNUS - ZAKOPANE**

Figure 2. Continued.

The maxima (one or two) occurred in the evening, at night, and also in the morning (Figure 3).

Secale – *Secale cereale* belongs to the Poaceae family, but it was treated separately because its pollen grains are easy to distinguish. In Poland *Secale cereale* is commonly cultivated in villages, while, in towns it occurs as an ephemeral ruderal plant. The main pollen season is end May, beginning of June. The diurnal variation showed one clear maximum during the day, at all the studied sites in both years. In 1995 in Poznań it was between 10 a.m. and 12 a.m., in 1996 between 14 p.m. and 16 p.m. In Warszawa in 1995, the highest concentrations were observed between 12 p.m. and 14 p.m., in 1996 between 14 p.m. and 16 p.m. At night and around the dawn the concentration of pollen grains in the air was very low (Figure 4).

Poaceae – This family has numerous species, which begin to bloom in May and end in September. The diurnal concentrations of Poaceae pollen grains were different at all sites and, with the exception of Warszawa, there also were differences between years. Figure 5 shows that in 1995 in Poznań, Warszawa, and Zakopane there was only one maximum, which was not always very clear. At other sites there were two maxima. At all sites the minima were around dawn.

Urtica – Two genera: *Parietaria* sp. and *Urtica* sp. belong to the Urticaceae family. In Poland *Parietaria* sp. occur very rarely, therefore *Urtica* and not Urticaceae was identified. There are two species of *Urtica*, but only *U. dioica* is common. *Urtica* pollen grains are usually observed in the air from June to August. At all the studied sites, the concentration of pollen grains was low in the morning. Before noon the number of pollen grains started to rise and only reached a maximum after noon. Figure 6 shows that at the same site maxima overlap during the two years, with the exception of Zakopane.

Artemisia – There are several species of *Artemisia*, which occur commonly and are characteristic of urban vegetation. The pollen season usually occurs at the of July, beginning of August. *Artemisia* pollen concentration had only one maximum; in all sites the highest concentrations were observed before noon (Figure 7). At each site, the hours of maximum pollen concentration were the same in two years.

4. Discussion

The seasonal analysis of incidence of airborne pollen grains at 5 sites showed that there were no regional

or seasonal differences in composition. The counts of pollen grains were only smaller in Zakopane than in the other sites. The differences in the pollen seasons occurrence were bigger between years, but only in spring. Because of the low mean temperature in February and March in 1996, the pollen seasons of *Alnus* and *Corylus* started almost two months later than in 1995 (Szczepanek, 1997).

Considering the similarity of diurnal variations of airborne pollen grains observed between sites and years, two groups of pollen taxa can be distinguished: the first group is characterised by regular pollen grain occurrence, while the second group by irregular occurrence.

Secale, *Artemisia* and *Urtica* are herb plants and all belong to the first group. The diurnal variations of concentration of pollen grains of these taxa were relatively constant and similar between sites and years. There was one clear maximum in the middle of the day, while in the evening and at night pollen concentrations were at a minimum (Figures 4, 6, 7). The differences observed between sites were slight.

The diurnal maxima of *Urtica* pollen grains were observed at midday or in the early afternoon (Figure 6). Even though the mean temperature in July in 1996 was significantly lower than in 1995 (Biuletyn Agrometeorologiczny, 1995; Biuletyn Agrometeorologiczny, 1996), the diurnal histograms overlapped in two years. Several authors reported that diurnal periodicity of *Urtica* pollen was characterised by one clear maximum (Galan et al., 1991; Trigo et al., 1996; Corden and Millington, 1991). In Spain it was observed at midday, when the temperature is highest (Trigo et al., 1996), while in England it was observed in the early afternoon (Corden and Millington, 1991). Trigo et al. (1996) announced that this lag can be explained, among other reasons, by the colder English climate. Zakopane has the coldest climate of all the studied sites, but in 1995 there was no lag in the diurnal maxima of *Urtica* pollen concentration. In 1996 there was a lag as compared to Warszawa, Ostrowiec Świętokrzyski and Kraków, but not to Poznań, even though the mean July temperature is highest there.

The highest *Artemisia* pollen concentrations were observed mainly before midday i.e. earlier in the day than in the case of *Urtica* (Figure 7). As in the case of *Urtica*, no regional differences nor differences between years were stated. In Finland the diurnal maxima were also before noon, and there were slight differences in the time of the peak between two

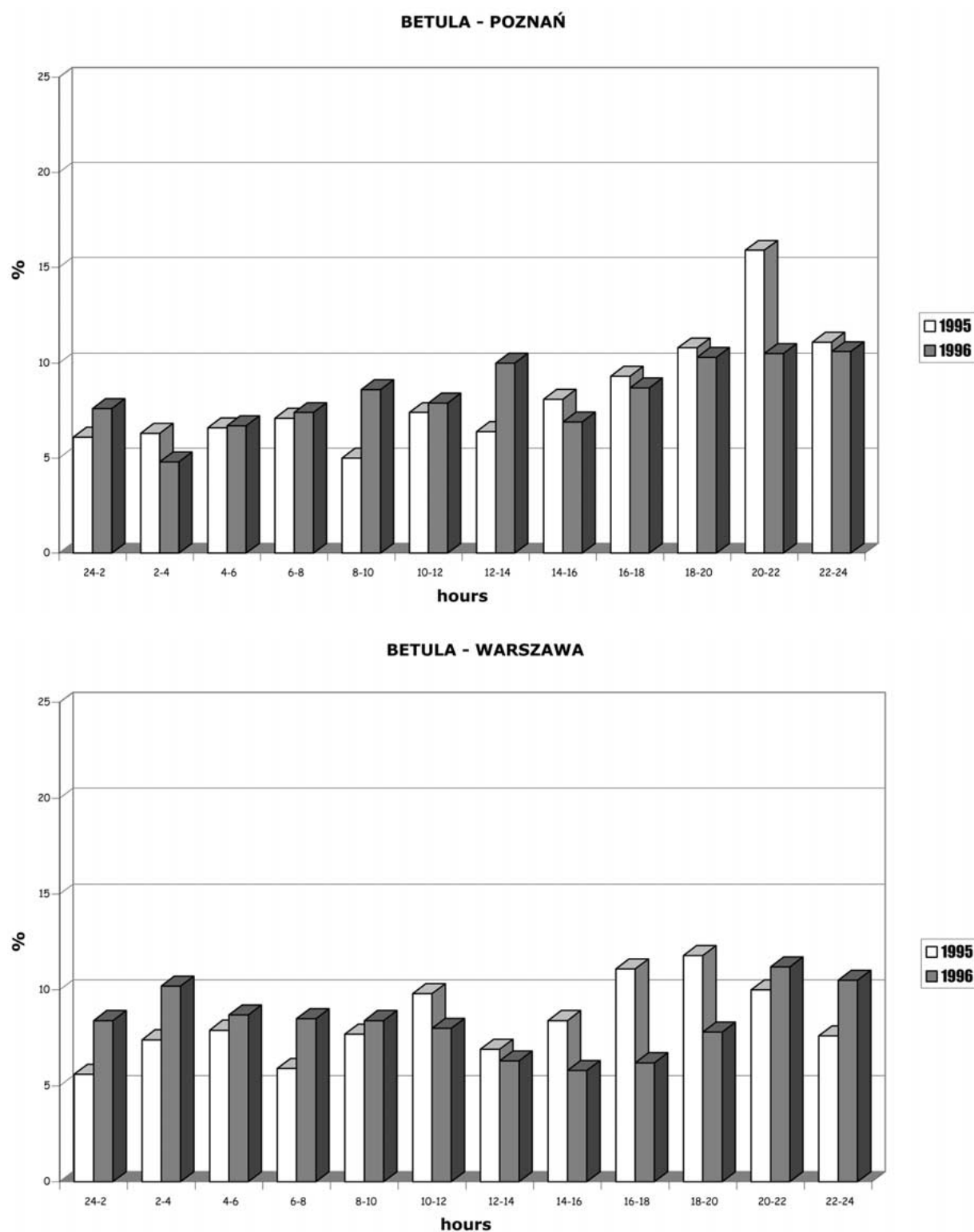
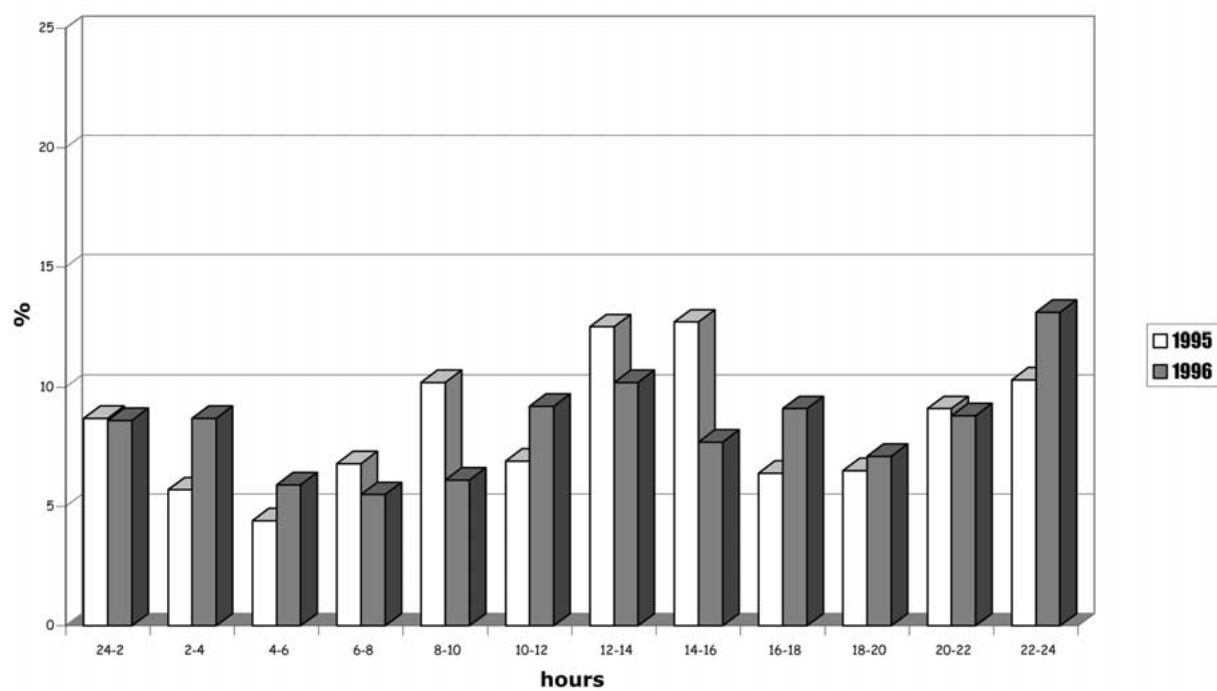


Figure 3. The diurnal variations of *Betula* pollen in 1995–1996 in Poznań, Warszawa, Ostrowiec Świętokrzyski, Kraków and Zakopane.

BETULA - OSTROWIEC ŚW.



BETULA - KRAKÓW

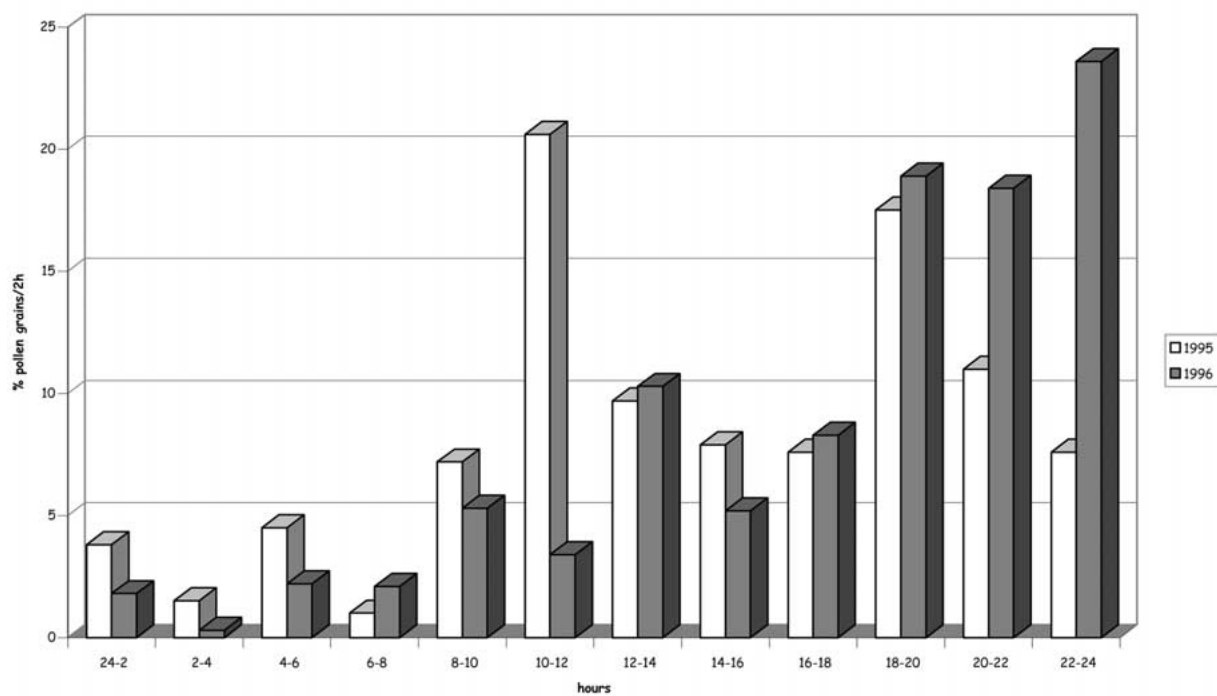


Figure 3. Continued.

BETULA - ZAKOPANE

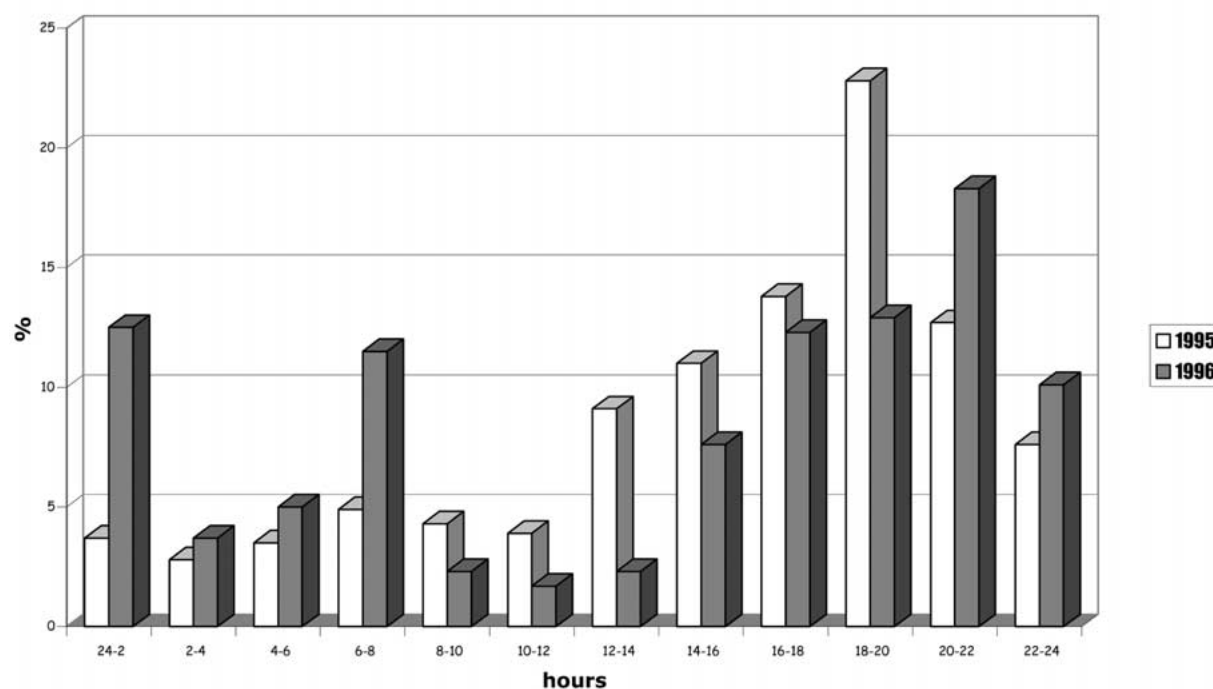


Figure 3. Continued.

sampling sites (Käpylä, 1981). The diurnal periodicity of *Artemisia* was more constant than the periodicity of *Urtica*, although the genus *Artemisia* has many species, while there is only one common species of *Urtica*. This may be due to the fact that *Urtica* pollen grains are small and light and remain longer in the air.

Hart et al. (1994) suggest that the delay in the hours of the maximum herb pollen concentration could be affected – among others – by a higher location of the pollen trap. In the study presented, pollen traps were located at heights ranging from 10 m to 36 m. However, it was not found that the maximum pollen concentration occurred later if the trap was located higher. In Ostrowiec Świętokrzyski, where the trap was located at 36 m, the maximum concentration of *Urtica* and *Artemisia* pollen wasn't observed later than at sites where traps were located lower. The close vicinity of pollen source (ruderal habitats with *Artemisia* sp., *Urtica* sp., *Chenopodium* sp.), and the wind direction might have influenced the results.

Alnus, *Betula* and *Poaceae* belong to the second group. Histograms of diurnal concentrations of their pollen are irregular, with one or more maxima, and

show no similarity between sites and years (Figures 2, 3, 5).

In 1995 *Alnus* started to pollinate at the end of February, while in 1996 in April (Szczepanek, 1997). The mean temperatures in these periods differed significantly (Biuletyn Agrometeorologiczny 1995; Biuletyn Agrometeorologiczny 1996), so it could be one of the causes of the irregular diurnal periodicity of *Alnus*.

Käpylä (1984) reports that the diurnal rhythms of tree pollen concentrations are much more irregular than those of herb pollen. Berggren et al. (1994) confirm that the diurnal variation of *Betula* pollen was irregular and differed between sites and years.

The circadian periodicity of *Poaceae* airborne pollen was studied very often. In Spain maximum concentration was observed before noon (Galan et al., 1991), while in London there were two maxima: in the evening and at night (Norris-Hill and Emberlin, 1991). In the study presented here the highest concentrations were observed in the morning or at noon, as well as in the afternoon or at night. The diurnal periodicity differed much more between sites than between years, the differences being most pronounced

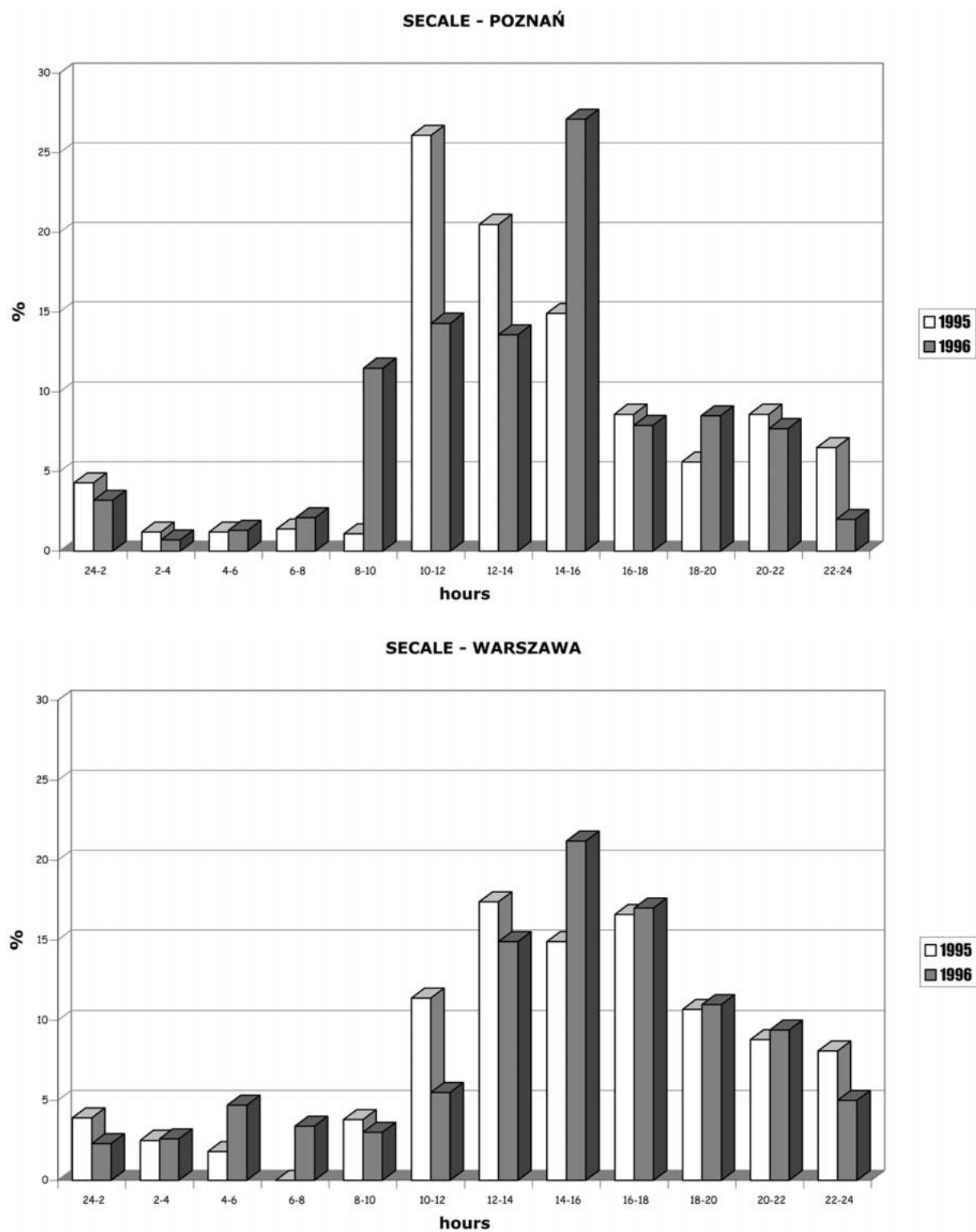


Figure 4. The diurnal variations of *Secale* pollen in 1995–1996 in Poznań, Warszawa.

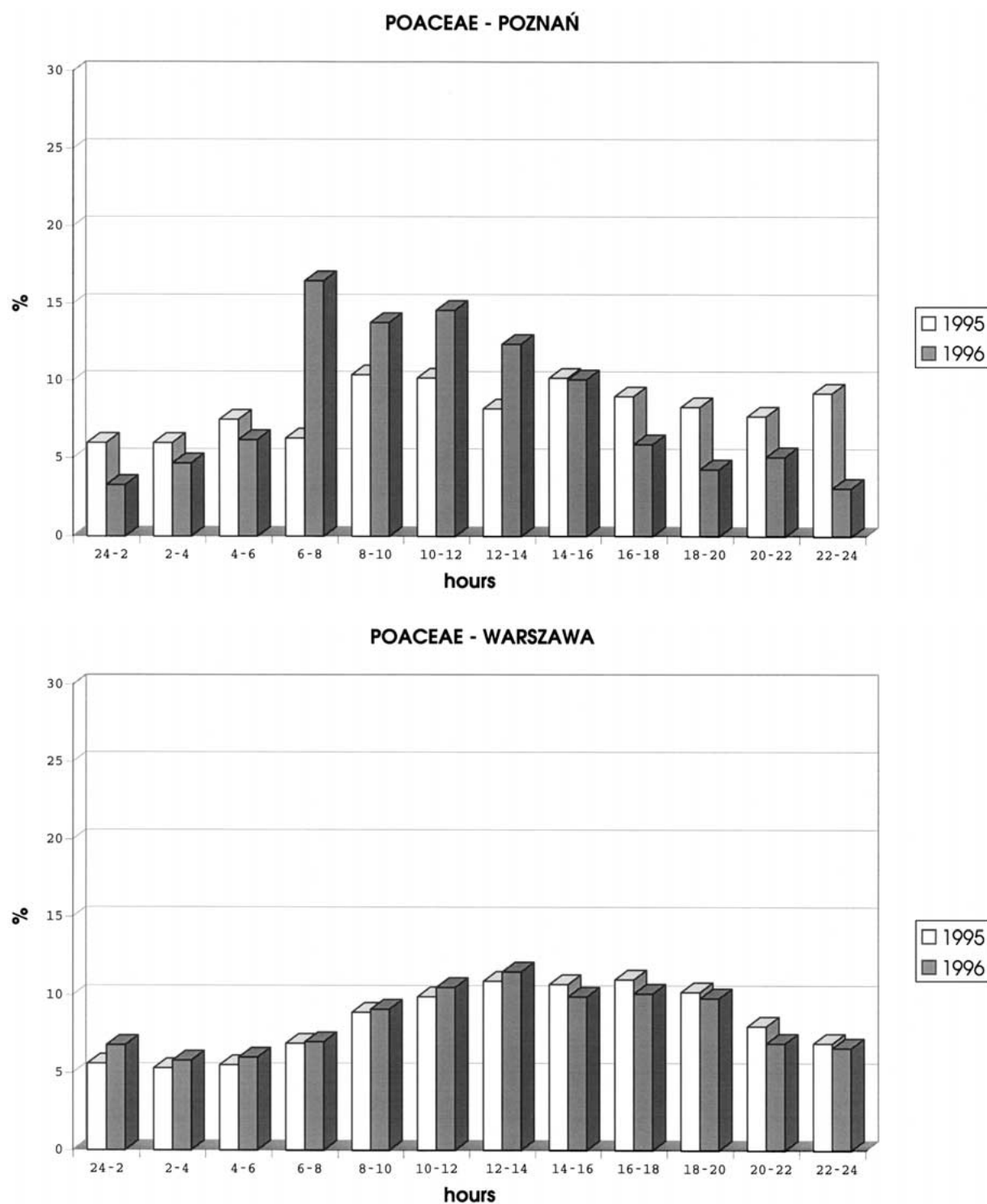
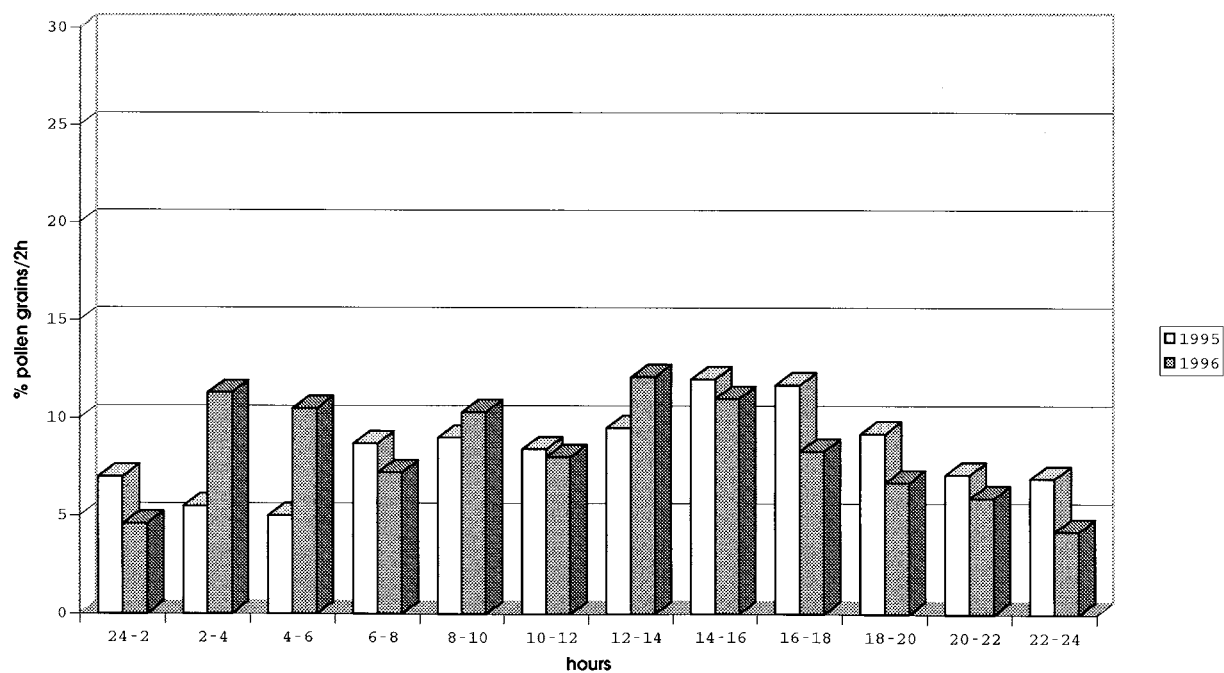


Figure 5. The diurnal variations of Poaceae pollen in 1995–1996 in Poznań, Warszawa, Ostrowiec Świętokrzyski, Kraków and Zakopane.

POACEAE - OSTROWIEC ŚW.



POACEAE - KRAKÓW

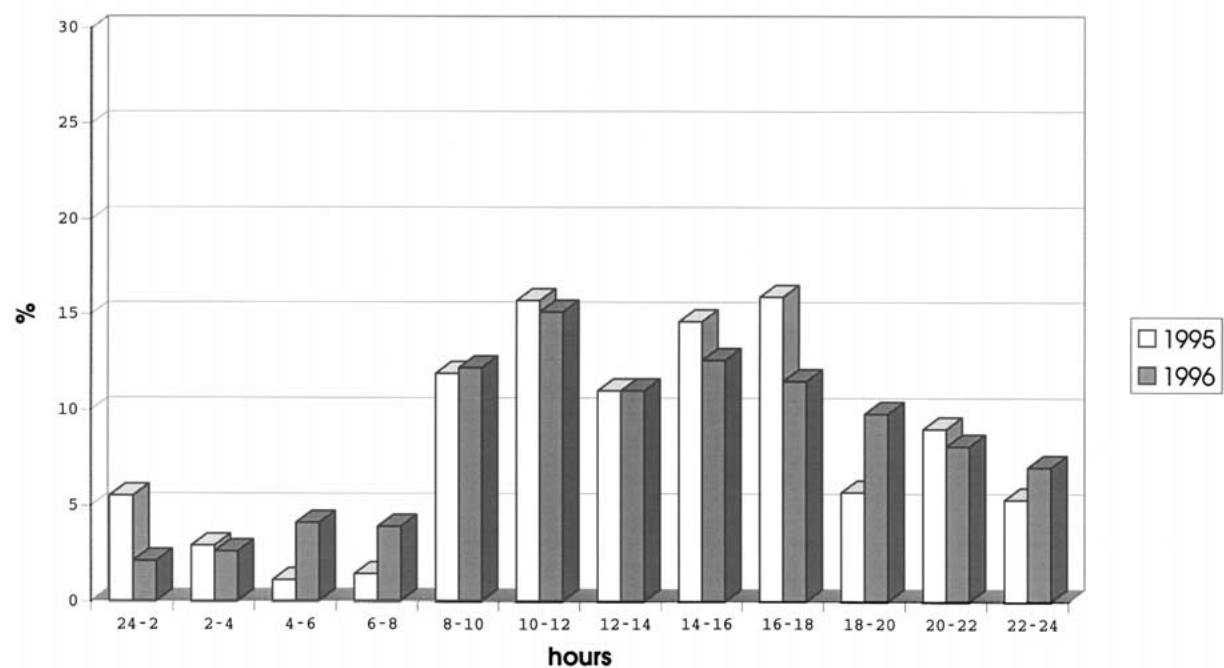


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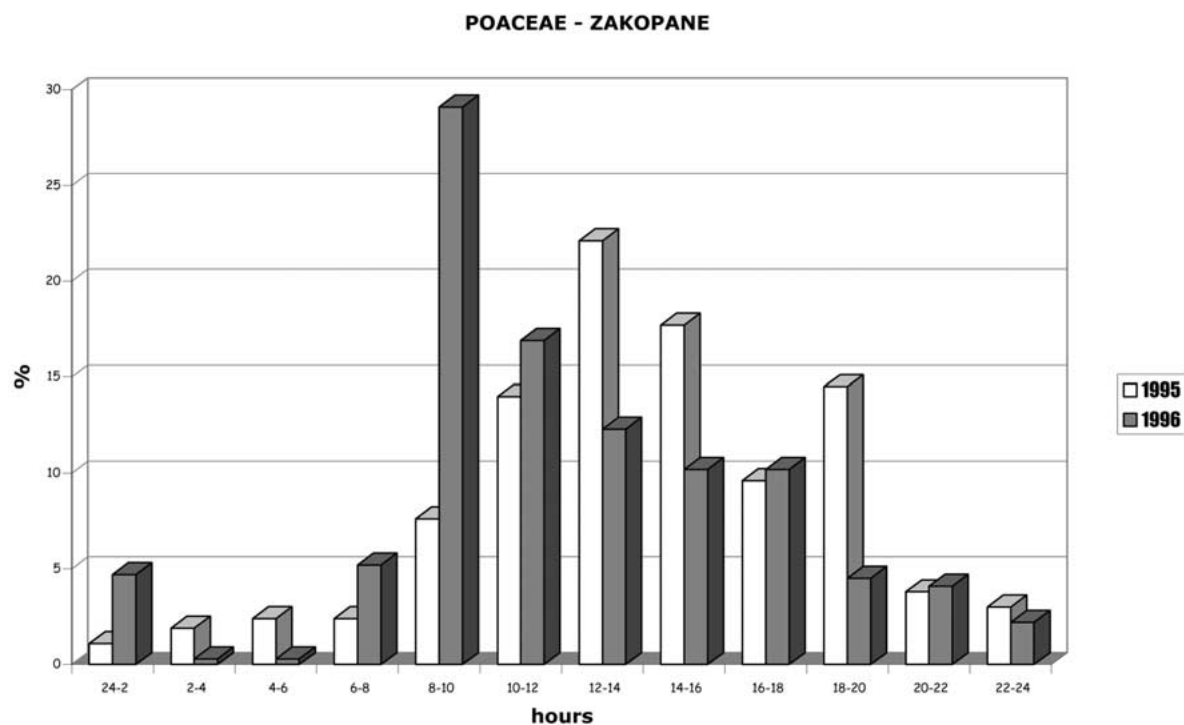


Figure 5. Continued.

in the case of Zakopane. The family Poaceae has a large number of species opening their anthers at different times. For example, some species of *Poa* open their anthers between 4 and 5 a.m., *Briza media* between 5 and 6 a.m., *Molinia* sp. between 12 and 1 p.m., while *Holcus* sp. open their anthers twice a day: between 6 and 7 a.m. and between 7 and 8 p.m. (Maślankiewicz, 1957). Poaceae species also have a characteristic phenology of blooming. For example, in Poland *Anthoxanthum odoratum*, *Poa pratensis*, and *P. annua* start pollination in May, *Dactylis glomerata*, *Agrostis vulgare*, and *Festuca rubra* in June, *Phleum pratense* and *Festuca pratensis* in July, while *Phragmites communis*, *Setaria glauca* in August. Liem (1980) and Norris-Hill and Emberlin (1991) report that meteorological factors, especially temperature, can also strongly influence diurnal periodicity of pollen grains. Therefore, the diurnal periodicity of Poaceae pollen is irregular and it is difficult to predict its maximum concentrations.

Examination of results obtained in Finland, Spain, England and Poland confirms, that circadian periodicity of Poaceae pollen concentration is very irregular, differs between sites and between years and depends on various factors (Käpylä, 1981; Norris-Hill and

Emberlin, 1991; Galan et al., 1991; Kasprzyk, 1995; Latałowa and Góra, 1996).

One of the aims of this study was to ascertain whether the diurnal periodicity of airborne pollen grains differed at sites with a different climate and in different geobotanical regions. Zakopane is the coldest town with the highest mean annual precipitation. Here the diurnal periodicity of pollen concentration of all examined taxa differed from other sites with the highest values of maxima (Figures 2, 3, 5, 6). It is difficult to assume the influence of vegetation on the studied phenomena. In all five towns all the examined taxa are present, they as are common in the Polish flora.

In this study, peaks in pollen airborne abundance of *Alnus*, *Betula*, and Poaceae were observed in the evening or at night, when were usually anthers closed (Figures 2, 3, 5). These results are in agreement with data presented by Käpylä (1984), Norris-Hill and Emberlin (1991) and Norris-Hill (1997). Emission of pollen grains from anthers, as well as their dispersal, depends on the biology of the plant, on weather and on mechanical factors such as wind speed or turbulence (Norris-Hill and Emberlin, 1991). As a result of the differences in the heating of the air, convec-

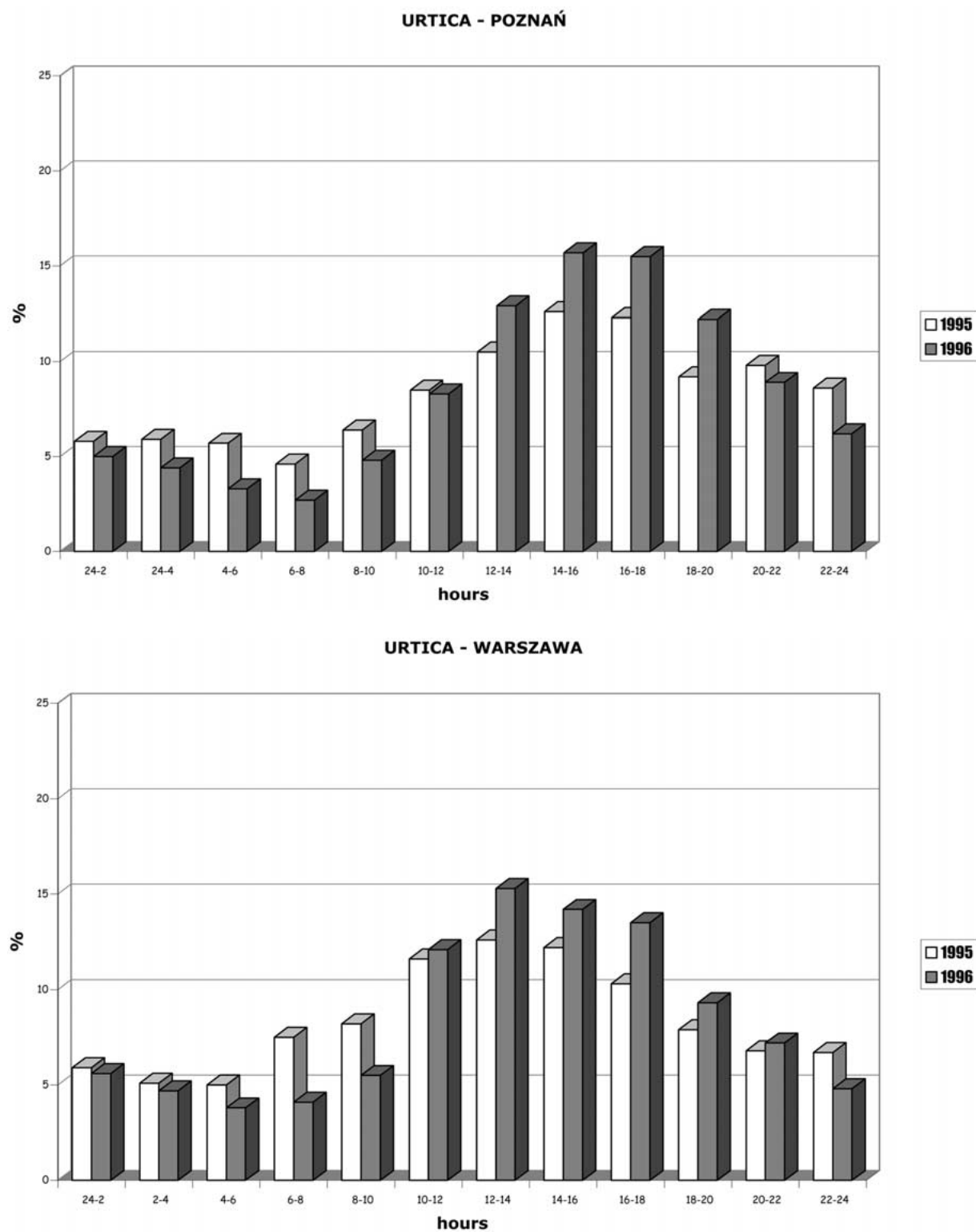


Figure 6. The diurnal variations of *Urtica* pollen in 1995–1996 in Poznań, Warszawa, Ostrowiec Świętokrzyski, Kraków and Zakopane.

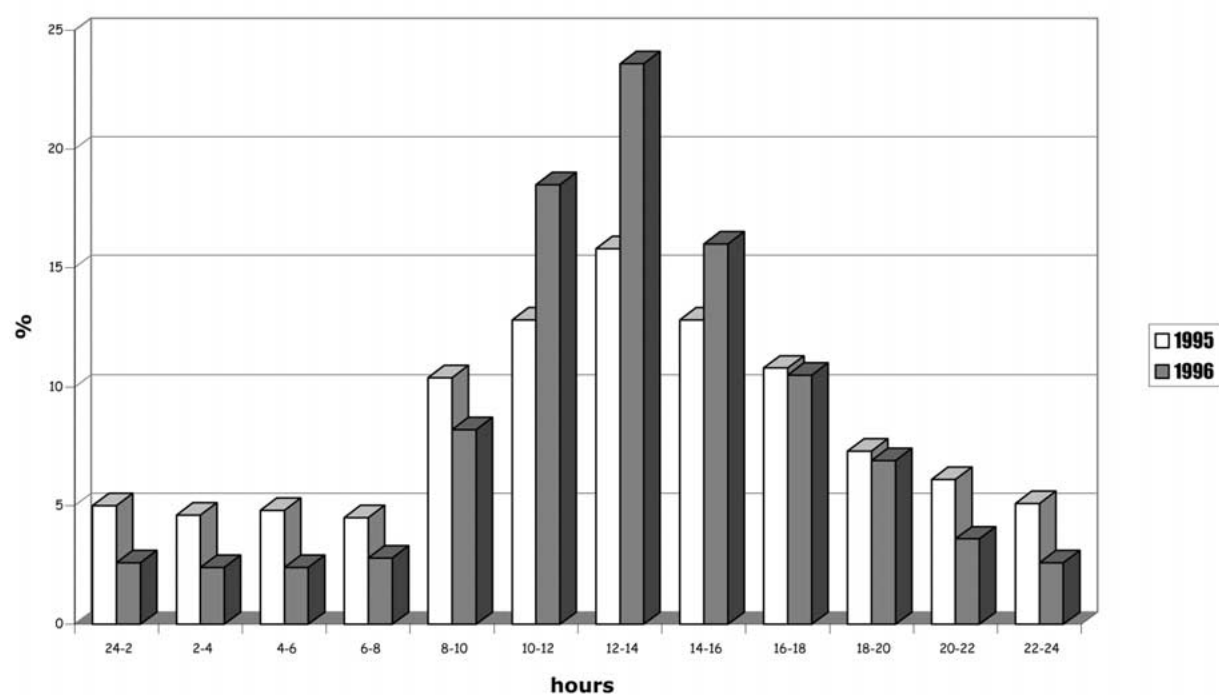
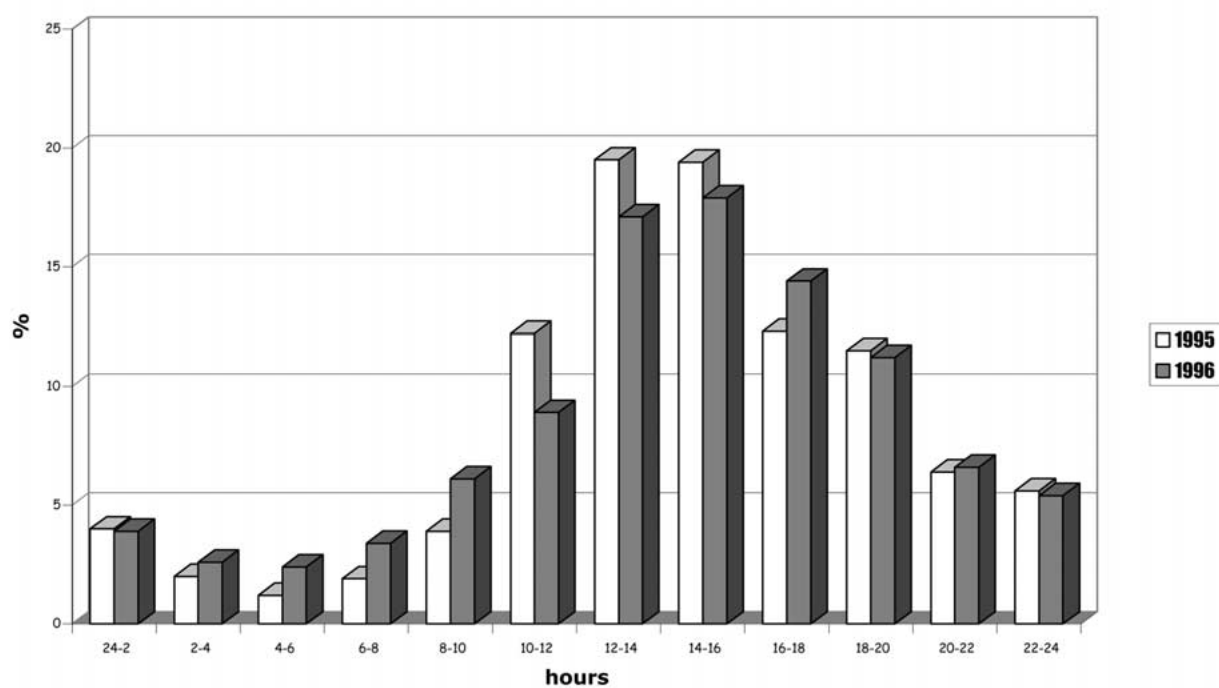
URTICA - OSTROWIEC ŚW.**URTICA - KRAKÓW**

Figure 6. Continued.

URTICA - ZAKOPANE

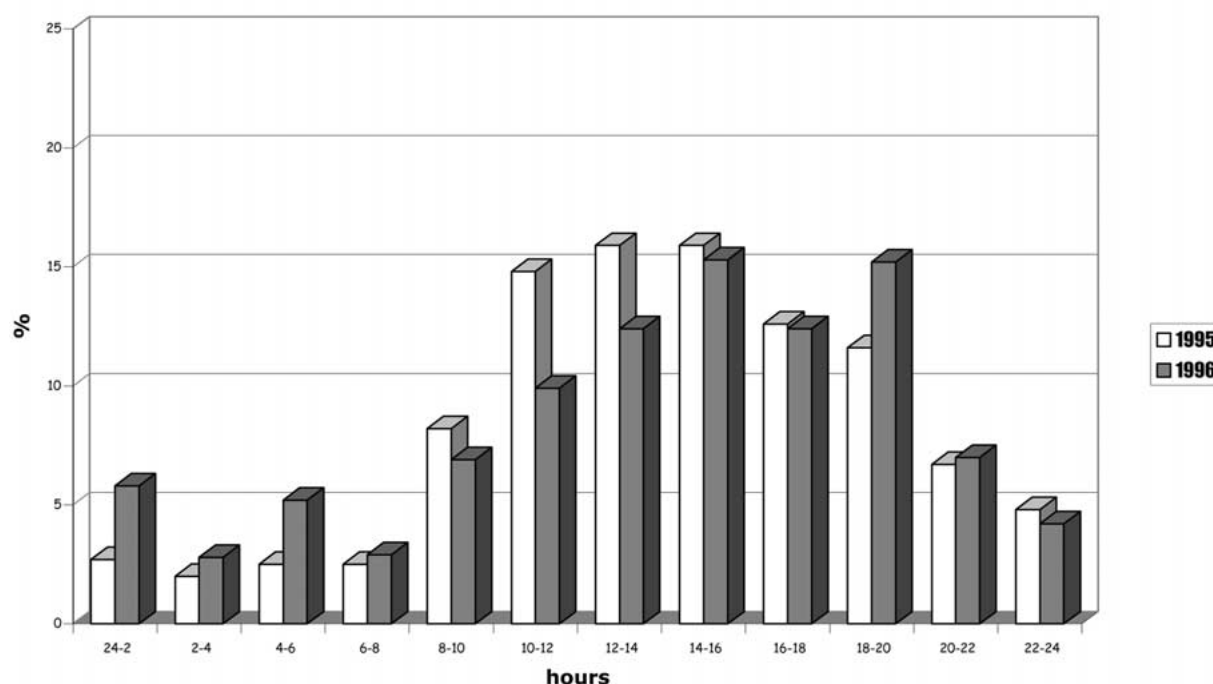


Figure 6. Continued.

tion currents can originate. Thermal convection lifts up pollen grains into the upper atmosphere. In the evening and at night, when there is no convection, airborne pollen grains fall down in large amounts. In spring, when the day is shorter than in summer, convection stops earlier (Norris-Hill and Emberlin, 1991), so that high counts of *Alnus* and *Betula* airborne pollen grains were generally observed earlier than in the case of Poaceae. Higher concentrations of Poaceae pollen grains observed in the evening and at night did not only result from temperature inversion. Another possible explanation is the overnight anthesis (Norris-Hill, 1997). Maślankiewicz (1957) reported that there are genera in Poland which flower late in the evening (*Holcus* sp. at 7–8 p.m.) and very early in the morning (*Poa* sp. at 4–5 a.m.). So it is difficult to say if, for example, the maximum observed in Ostrowiec Świętokrzyski in 1996 (2–6 a.m.) resulted from thermal inversion or from anthesis.

Subba Reddi and Reddi (1985), Kämpylä (1984) and Norris-Hill and Emberlin (1991) explained that rhythm of pollen liberation and circadian periodicity of airborne pollen are two different phenomena which are related but must be considered separately. Meeuse

and Morris (1984) reported that *Alnus* and *Betula* start to pollinate at about 2 p.m., when the temperature is the highest during the day. Their diurnal maxima were observed in the afternoon and in the evening as well as at night and in the early morning (Figures 2, 3). In Poaceae, the time of pollen liberation may be very long during the day (Maślankiewicz, 1957) and is related to the particular species that occur in the vicinity of sampling sites. Therefore, in the case of *Alnus*, *Betula* and Poaceae there is no clear relation between the time of anthesis and the time of diurnal maxima of pollen concentration. Maślankiewicz (1957) reports that *Secale cereale* opens its anthers between 6 and 7 a.m., but the maximum diurnal concentration of airborne pollen was observed from two to eight hours later (Figure 4). This lag was possibly induced by such weather conditions as speed and direction of wind, or air turbulence and the distance from pollen sources (Subba Reddi and Reddi, 1985).

The results of the study of diurnal periodicity of allergenic pollen also have a practical aspect as they can be used in the pollen forecasts. For example in Poland, persons allergic to *Urtica* pollen grains should

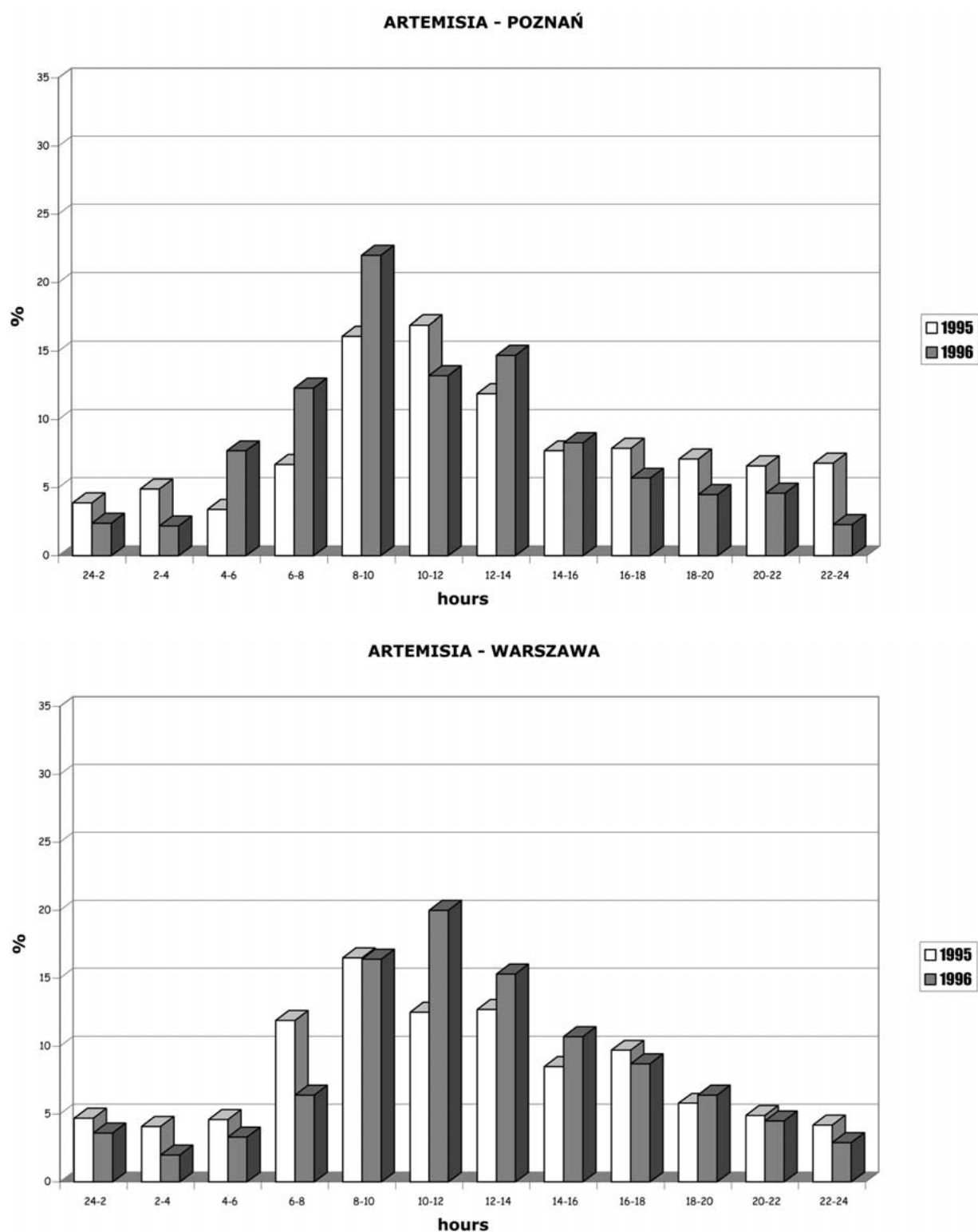


Figure 7. The diurnal variations of *Artemisia* pollen in 1995–1996 in Poznań, Warszawa, Ostrowiec Świętokrzyski and Kraków.

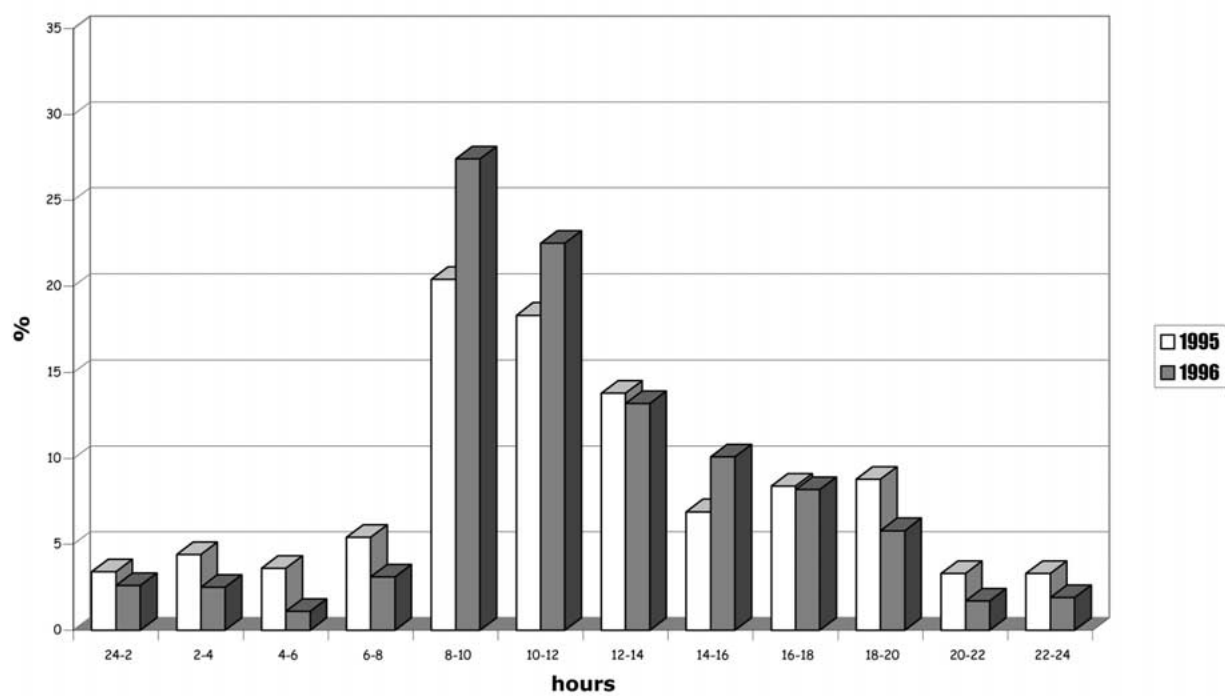
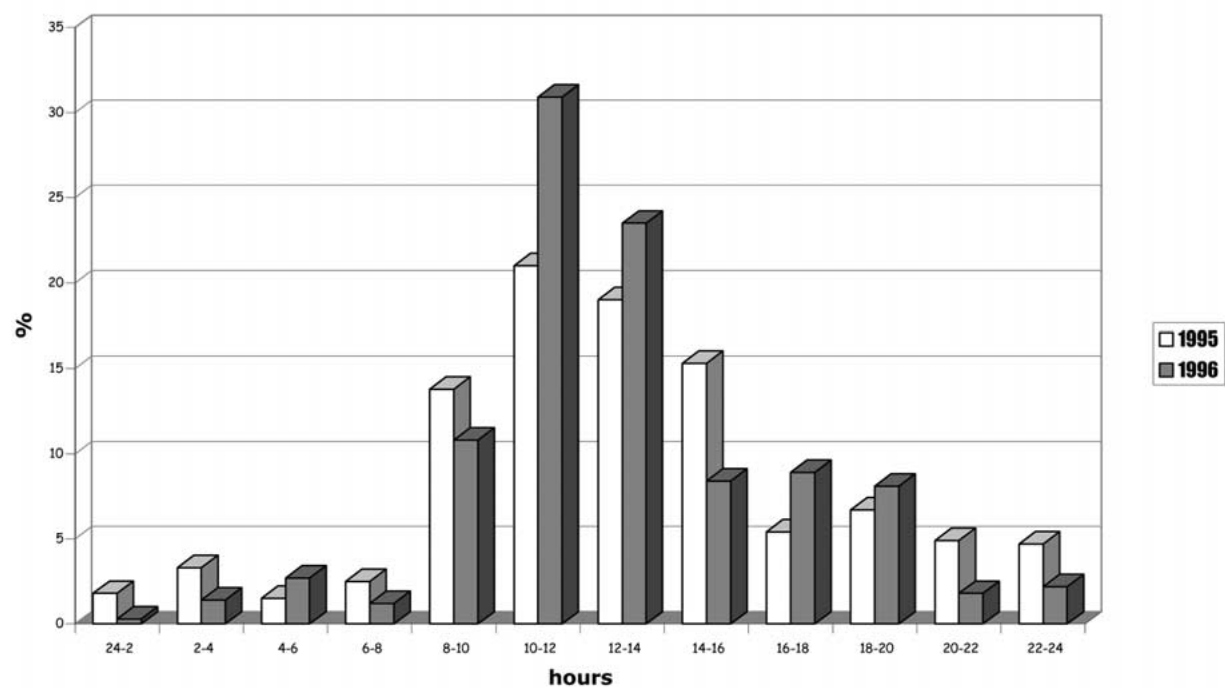
ARTEMISIA - OSTROWIEC ŚW.**ARTEMISIA - KRAKÓW**

Figure 7. Continued.

avoid contact with pollen just before noon and in the afternoon, while those sensitive to *Artemisia* allergens should stay indoors in the morning. Unfortunately, patients suffering from pollinosis because of Poaceae, *Alnus* and *Betula* allergens can be subjected to them almost all day, even at night. In general the concentration of those allergens is only fairly low in the early morning.

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