

Regional differentiation in the dynamics of the pollen seasons of *Alnus*, *Corylus* and *Fraxinus* in Poland (preliminary results)

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Abstract

In 1995–1996 a study of pollen concentrations of *Corylus*, *Alnus* and *Fraxinus* was performed at seven sites in regions of different climatic and natural conditions. The aim of the study was to determine whether regional differences in the course and duration of pollen seasons occur in Poland. The study was performed using a volumetric method. Several phases during the pollen season were defined for each taxon (1, 2.5, 5, 25, 50, 75, 95, 97.5, 99% of annual total) and duration of the pollen seasons was calculated using 98 and 90% methods. Dynamics and duration of the pollen seasons and a start of particular phases of the season were compared among sites. On the basis of the preliminary analysis it could be supposed that regional differences were most evident in the case of *Corylus*. The pollen season of this taxon started the earliest in Poznań where thermal conditions were most favourable and the latest in Gdańsk, a place at the furthest to the north (χ^2 , $\alpha \leq 0.05$). In montane regions (Zakopane, Rabka) last phases of the season were significant extended (χ^2 , $\alpha \leq 0.05$). Probably it results from secondary pollen deposition and a long-distance transport by montane wind. In case of *Fraxinus* the significant regional differences in the start of the pollen season were not found. The study supported that weather conditions have the substantial influence on the start of consecutive phases of the pollen season.

1. Introduction

An increased incidence of inhalant allergies, including pollen allergies, observed in the last tens of years provoked an increased interest in the aerobiological studies, also in their practical application, including prediction of the course of the pollen season. An aerobiological forecast on the basis of data from only one site has a limited importance. It needs more complete and reliable

information on the concentration of allergenic pollen in the air collected for many years and in many sites, with the use of the same methods. On the basis of so obtained results a regional pollen forecast could be worked out; such forecasts for Europe are given by EAN in Vienna (Jäger, 2000).

Studies carried out in many places in Europe and USA confirm the existence of considerable regional differences both in the course and dura-



Figure 1. Map of Poland with monitoring sites.

tion of pollen seasons. Those differences are clearly associated with climatic and weather conditions, as well as with local geography, especially geomorphology and altitude in respect to a sea level (Frenguelli et al., 1991; Emberlin et al., 1994, 2000; Corden et al., 2000; Zannotti and Puppi, 2000).

In Poland there are several centres carrying out continuous aeropalinological observations with the use of the volumetric method. However, there were few studies discussing a regional differentiation of the dynamics of pollen seasons (Szczepanek, 1997). Thermal conditions in Poland deteriorate from the south to the north-east (Woś, 1999), and also a start of phenophases is getting late in this direction (Sokołowska, 1962; Tomaszewska and Rutkowski, 1999). The above-mentioned regularity gave the reason to analyse aeropalinological data obtained from the sites along a north-south transect. The aim of the study was to determine whether there were regional differences in the starts and dynamics of pollen seasons in Poland. In this paper three taxa flowering in early spring, namely *Corylus*, *Alnus*, and *Fraxinus*, were analysed. Pollen of those taxa are recognised as allergenic (Jäger and Horak, 1991; Matthiesen et al., 1991; Vik et al., 1991).

2. Material and methods

Measurements of airborne pollen grain concentrations were carried out in Poland at seven sites along a north-south transect (Figure 1). The reason for such an arrangement of the sites was a deterioration of thermal conditions, particularly during early spring and spring, from the south towards the north-east (Woś, 1999). Zakopane is at the furthest to the south; it is a small town at the foothills of the Tatra Mountains. Climate of the region is cool and typical montane which results in a relatively short vegetation season (180 days). Meadows and farmlands in the foothill zone and spruce forests at higher altitudes occur in surroundings. Also Rabka is located in the foothill zone with the vegetation season of 200–210 days. Rabka is a health resort with microclimate friendly for people suffering from respiratory system diseases. The urban area is quite densely planted with trees such as ash, poplar, lime and willow. In the neighbourhood of the city spruce and fir forests occur. The vegetative season in Kraków is over 220 days long and the mean annual precipitation ranges from 700 to 750 mm. A broad temperature amplitude is characteristic for Kraków. A monitoring site was located in the Botanical Garden where many introduced species grow. Ostrowiec

Table 1. Description of sites and some meteorological factors

Site	Coordinates	Altitude (m a.s.l.)	Mean precipitation (mm)	Mean yearly temp. (°C)	Mean January temp. (°C)	Mean July temp. (°C)
Zakopane	49°17' N, 19°58' E	846	1122	5	−4.9	14.7
Rabka	49°36' N, 19°58' E	530	700–800	6–7	−3 to −4	16–17
Kraków	50°03' N, 19°57' E	232	722	8.2	−2.5	18.2
Ostrowiec Św	50°58' N, 21°23' E	175	550–650	7	−3.5	17–18
Warszawa	52°15' N, 21°00' E	112	535	7.8	−2.9	18.6
Poznań	52°25' N, 16°55' E	66	517	8.5	−1.4	19.2
Gdańsk	54°22' N, 18°38' E	8	555	7.7	−1.5	17.6

Świętokrzyski is situated in the valley of the Kamienna river. A vegetation season is 210 days long here. Around the city mainly pine forests occur. Poznań is at the furthest to the west. Average annual temperature and average temperature of the warmest and coldest month are the highest in the region. A large part of the urban area is covered by greens. In the surroundings of Poznań typical farmlands spread out. In Warszawa very warm but cloudy days occur frequently with characteristic urban heat island. The vegetation season is 210–200 days long. In the vicinity of Warszawa pine forests occur. Gdańsk as a city at the furthest to the north show cool climate modified by the influence of Atlantic air masses and proximity of the Baltic Sea. There are often cool and cloudy days with no rains. In the city area synanthropic plants and trees introduced by man occur. Description of sites is given in Table 1 (Tablice Geograficzne, 1998).

Aeropalinalogical studies were carried out continuously in 1995–1996 with the use of the volumetric method. Burkard traps were placed on building roofs in the centres of the cities. For technical reasons traps were installed at various heights: Zakopane – 10 m, Rabka – 10 m, Kraków – 20 m, Ostrowiec Świętokrzyski – 36 m, Warsaw – 16 m, Poznań – 34 m, Gdańsk – 30 m. Twelve transverse bands were analysed on each microscopic slide. Average daily concentrations are expressed as the number of pollen grains per cubic metre of the air. The analysis of the dynamics of pollen seasons was performed for *Corylus*, *Alnus*, and *Fraxinus*. Those trees flower in spring and then their pollen occur in the air in high or relatively high concentrations being a reason for pollen allergies.

Every year, between the 1st January and the 31st October, several phases of pollen seasons were distinguished as starting with 1, 2.5, 5, 25, 50, 75, 95, 97.5, and 99% of the seasonal sum of pollen grains of each studied taxon. The beginning of those phases was expressed as a number of days from the 1st January. The course of the pollen seasons (Figures 3–8) was presented graphically in a way proposed by Latałowa et al. (2002). For each taxon duration of its pollen season was calculated with the two method of 98 and 90% of the seasonal total of pollen grains in the studied year (Emberlin et al., 1994; Kasprzyk, 2003). The significance of differences in the starts of particular phases and in the duration of pollen seasons among the sites was determined by the χ^2 test for each year separately. The following zero hypotheses were assumed: 1 – number of days between the 1st January and the beginning of a given phase do not differ among the sites, 2 – number of days in a season is the same in the seven sites. The level of significance is $\alpha \leq 0.05$. In the statistical analysis the data for *Alnus* and *Corylus* in Kraków in 1996 were excluded because of their very low SPI values (seasonal sum of pollen grains) (Table 2).

The weather conditions were different in both studied years. Following Dekadowy Biuletyn Agrometeorologiczny (1995–1996) in 1995 average temperature of January, February and first 10 days of March was over or even much over many years' average temperature while in next days of March average temperature was on a standard level. In 1996 average temperature of February, March and first 20 days of April was much below many years' average temperature (Figure 2). Mean annual precipitation in this year was clearly lower than in 1995.

Table 2. Seasonal pollen grain totals (SPI) of *Corylus*, *Alnus*, and *Fraxinus* at 7 sites from 1st January to 31st February in 1995 and 1996

Site	<i>Corylus</i>		<i>Alnus</i>		<i>Fraxinus</i>	
	1995	1996	1995	1996	1995	1996
Zakopane	413	121	1198	632	509	619
Rabka	741	85	1515	176	304	103
Kraków	95	13*	265	47*	512	*
Ostrowiec Św	701	220	3070	661	385	195
Warszawa	1093	400	6396	1933	1623	1129
Poznań	464	151	4626	769	442	250
Gdańsk	54	34	468	272	40	65

* In case of absence or very low number of pollen grains sites were excluded from the statistical analysis.

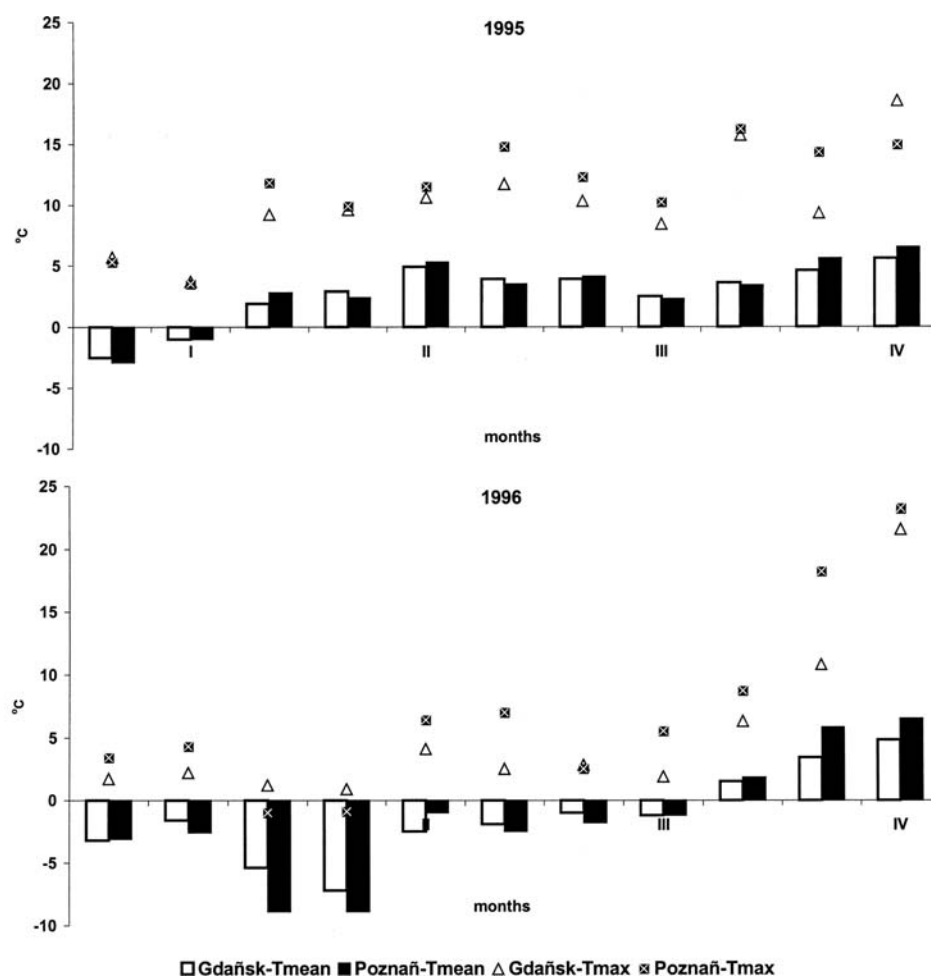


Figure 2. Temperature data for Poznań and Gdańsk in studied period in 1995–1996.

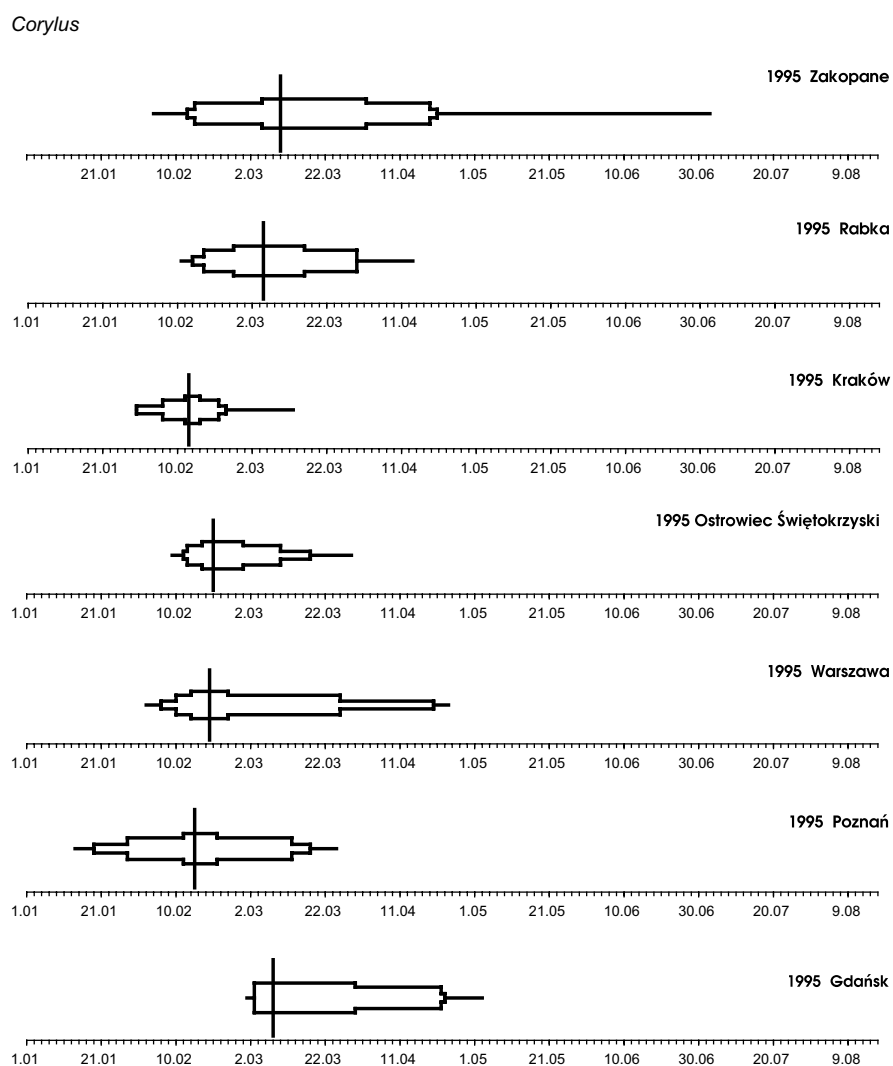


Figure 3. The dynamics of the pollen seasons of *Corylus* at 7 sites in 1995 (diagrams of consecutive stages of the pollen season; 1, 2.5, 5, 25, 50% – vertical line, 75, 95, 97.5, 99%).

3. Results

3.1. *Corylus*

Diagrams illustrating the dynamics of the *Corylus* pollen occurrence are asymmetric. Except at Poznań and Rabka they are skewed to the right – the final phases were considerably longer than the initial ones (Figure 3). In that year, statistically significant differences in the dates of the beginning of the initial and final phases were determined (χ^2 , $\alpha \leq 0.05$). The earliest dates of the initial stages (1, 2.5, 5%) were recorded in Poznań (first pollen grains appeared already in January), and the latest

in Gdańsk (in March). The final stages (75, 95, 97.5, 99%) lasted longest in Gdańsk and Zakopane. Significant differences in the duration of pollen seasons were also observed among the studied sites (χ^2 , $\alpha \leq 0.05$). The pollen season (calculated using a 98% method) was the longest in Zakopane (150 days) and the shortest in Kraków (43 days). Using a 90% method it appeared the season in Kraków was much shorter – 16 days.

The diagrams for 1996 are also very irregular and strongly skewed to the right (Rabka, Ostrowiec Świętokrzyski) or to the left (Zakopane, Poznań). The initial and final phases were very long in Zakopane, Rabka, and Poznań. In Ostrowiec

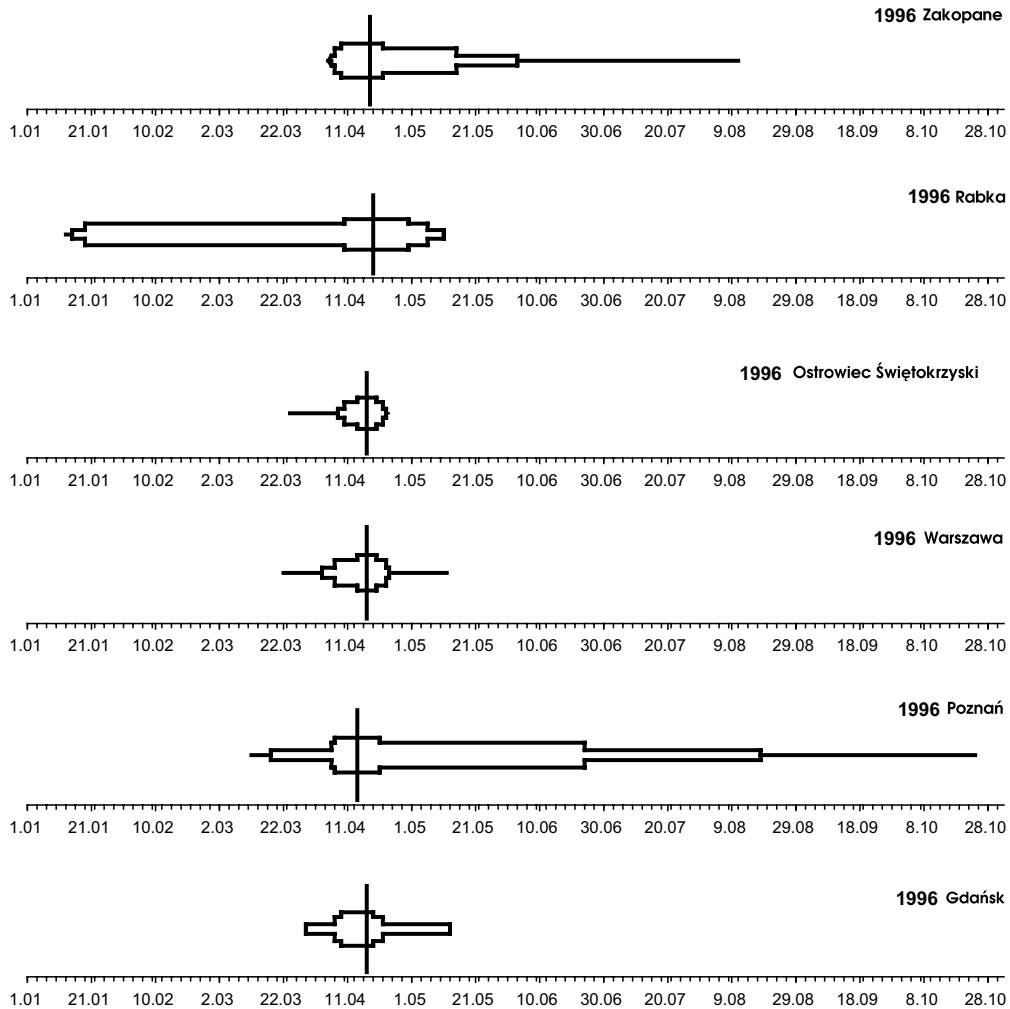
Corylus

Figure 4. The dynamics of the pollen seasons of *Corylus* at 7 sites in 1996.

Świętokrzyski, Warszawa and Gdańsk the seasons were compact with short particular phases (Figure 4). Statistically significant (χ^2 , $\alpha \leq 0.05$) regional differences in the starts of the first three phases were determined. In Rabka first pollen grains were recorded already in January while in remaining sites the pollen seasons started in February or March (the latest in Gdańsk, in the end of March). Regardless of the method used, considerable differences in the duration of the pollen season among the studied sites were recorded. In Zakopane, Rabka and Poznań the seasons were very long.

In 1996 at all sites the starts of the three initial phases were considerably delayed, as compared to

1995, e.g. in Ostrowiec Świętokrzyski, Warszawa, and Poznań it was nearly 2 months delayed (Figures 3 and 4).

3.2 *Alnus*

In 1995 the diagrams illustrating the dynamics of the occurrence of *Alnus* pollen in the air are similar for all the sites (Figure 5). No significant differences in the starts of the phases were found among sites. The first phase occurred generally in the first 10 days of February, the last one on average in the second half of April. No differences in the duration of the pollen season were noted, irrespective of the method used.

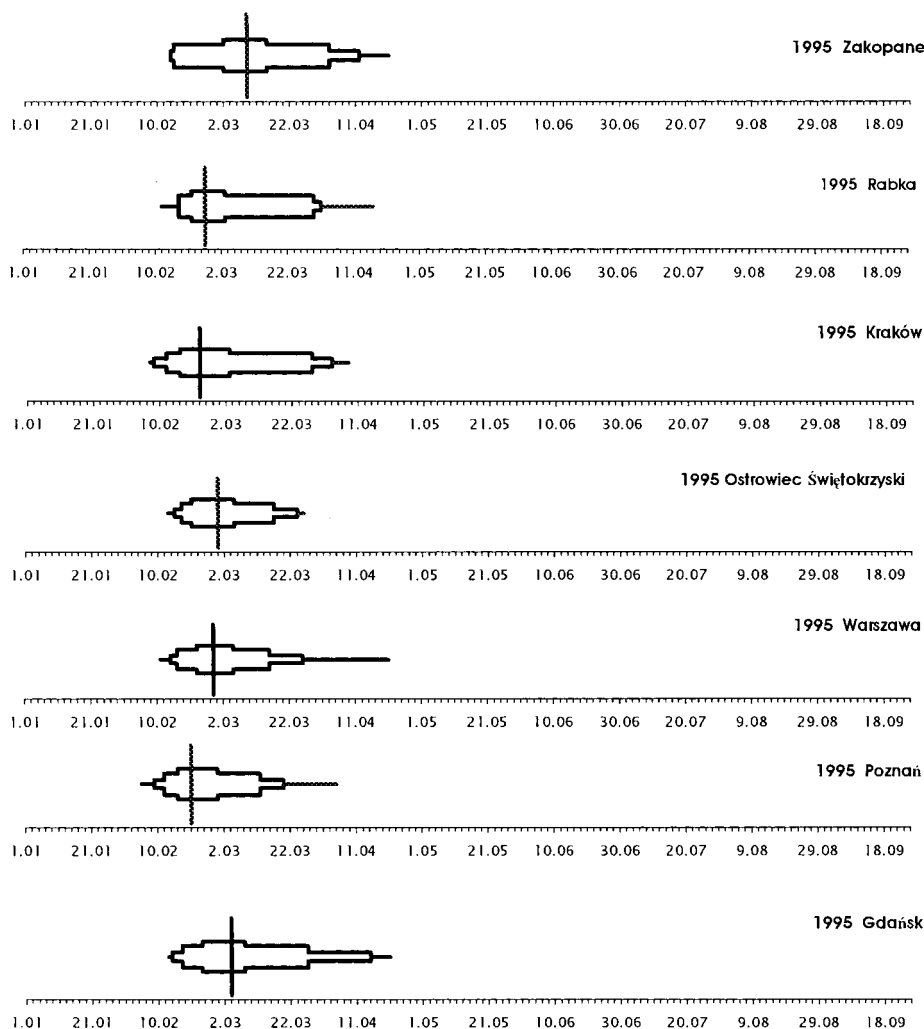
Alnus

Figure 5. The dynamics of the pollen seasons of *Alnus* at 7 sites in 1995.

The diagrams for 1996 are also asymmetric (Figure 6). In all the sites, except at Kraków and Ostrowiec Świętokrzyski, a rapid increase in the number of pollen grains in the air was observed; the decrease was much slower. Comparison of the start of consecutive phases revealed significant differences only for the 99% stage (χ^2 , $\alpha \leq 0.05$). The pollen season ended the latest in Zakopane; also duration of the pollen season, calculated with a 98% method, was significantly longer there than at other sites (χ^2 , $\alpha \leq 0.05$).

In all sites the beginning of first phases in 1996 was delayed about 1 month and half in comparison with the preceding year (Figures 5 and 6).

3.3. *Fraxinus*

In 1995 no statistically significant differences in the starts of consecutive phases were noted among the sites. At all the studied sites the first phase (1%) started in the first 10 days of April. In Rabka and Zakopane, in comparison with other sites, the number of pollen grains was increasing slower and the pollen was present in the air longer; the differences in the duration of pollen grain seasons, calculated with the 98% and the 90% methods, were statistically significant (χ^2 , $\alpha \leq 0.05$, Figure 7). In 1996, similarly as in 1995, in Rabka and Zakopane the beginning of last three phases differed significantly from other sites. The beginnings

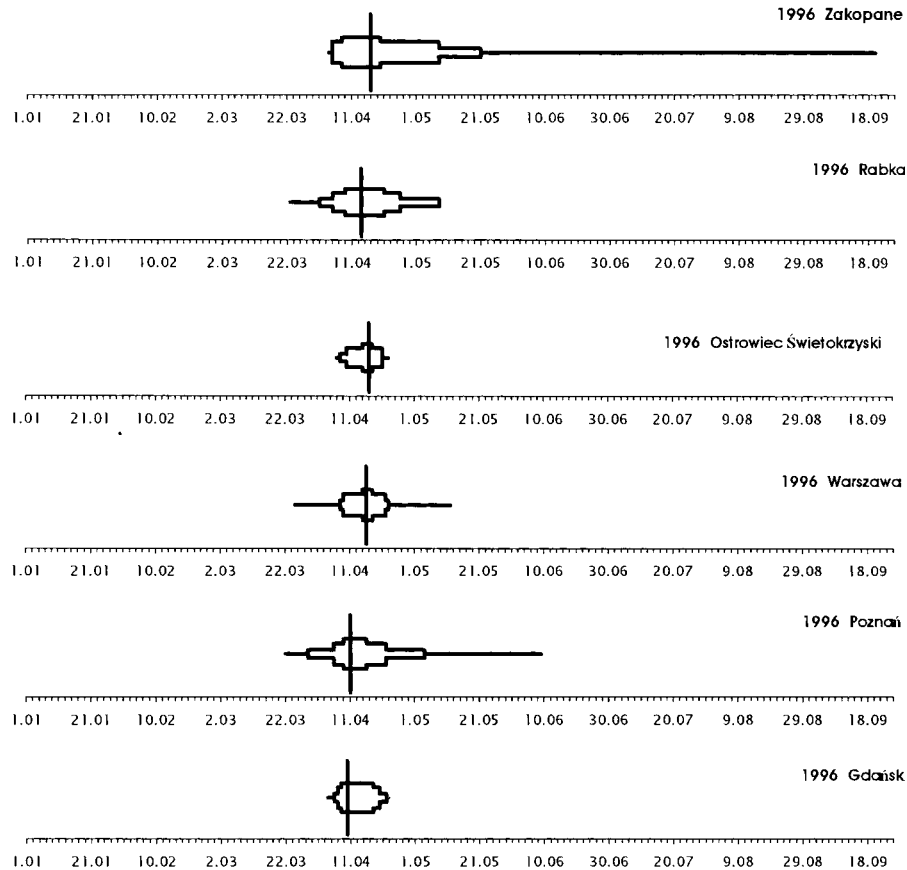
Alnus

Figure 6. The dynamics of the pollen seasons of *Alnus* at 7 sites in 1996.

were delay which results in longer pollen seasons (χ^2 , $\alpha \leq 0.05$; Figure 8). The starts of first and last phases at an the sites did not differ much between similarly as pollen season duration calculated using 98 and 90% methods.

4. Discussion

According to the temperature gradient, plant flowering and thus pollen seasons start later in the north than in the south. According to Emberlin et al. (2000), the beginning of the grass pollen season is delayed by 2–3 days for one degree of latitude. This is particularly clear at the beginning of the growing season (Frenguelli et al., 1991; Emberlin et al., 1994; Galan et al., 1995; Corden et al., 2000). During very early spring according to

Tomaszewska and Rutkowski (1999) the earliest flowering of *Corylus* is observed in south-western and southern part of Poland, while the latest – in the north-eastern part of the country. Theoretically, the *Corylus* pollen season should start earlier in the southern site (Zakopane) than in the northern one (Gdańsk). However, those trends are observed only at sites below 300 m a.s.l. In this study the sites are located approximately along a south-north transect, but Rabka and Zakopane situated at the furthest to the south are above 300 m a.s.l. (Table 1). In montane regions a beginning of flowering is getting delayed with altitude (Emberlin et al., 2000; Zanotti and Puppi, 2000). During the two studied years regional differences in the starts of the consecutive stages of the pollen seasons were observed only in *Corylus*. Among the studied sites, Poznań seems to be the

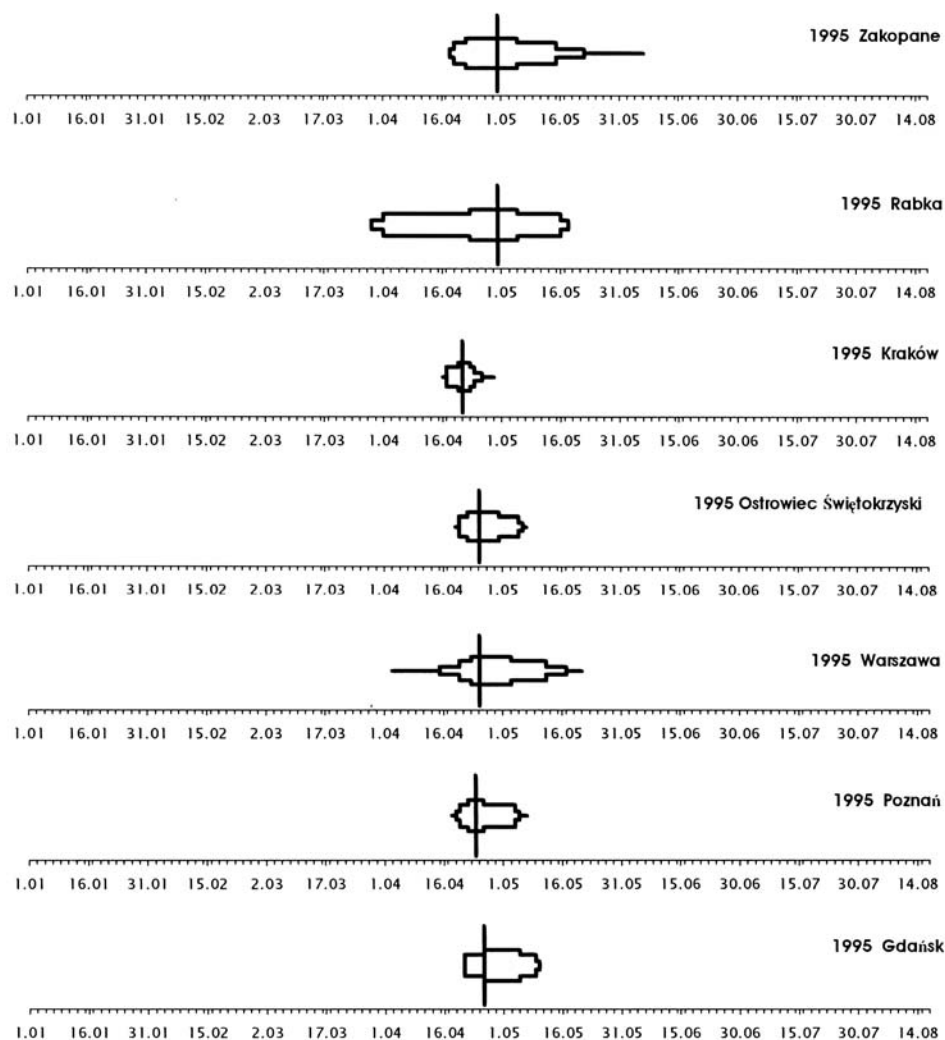
Fraxinus

Figure 7. The dynamics of the pollen seasons of *Fraxinus* at 7 sites in 1995.

area where *Corylus* pollen first appears, whereas in Gdańsk the pollen season begins at the latest. Poznań and Gdańsk regions differ considerably in thermal conditions (Table 1). Poznań city is a warmer place where the beginning of early spring is 2 weeks earlier than in Gdańsk (Woś, 1999). Such differences took place in the studied period. Average temperature for a decade was similar in both sites although maximum temperature for a decade was clearly higher in Poznań (Figure 2). Undoubtedly it was a reason for the earliest start of the first phases in the pollen season at this site. These results correspond to the general pheno-

logical tendency observed in Poland (Tomaszewska and Rutkowski, 1999), but it should be stressed that they are only preliminary results which need to be confirmed by long-term aeropalinological and phenological studies. Further researches could reveal whether regional differences are characteristic only for the taxa flowering very early in spring, or also for those flowering later, e.g. *Fraxinus*.

Aeropalinological literature gives various retrospective methods of calculation of pollen seasons (Frenguelli et al., 1991; Emberlin et al., 1994). In our study the 90 and 98% methods were com-

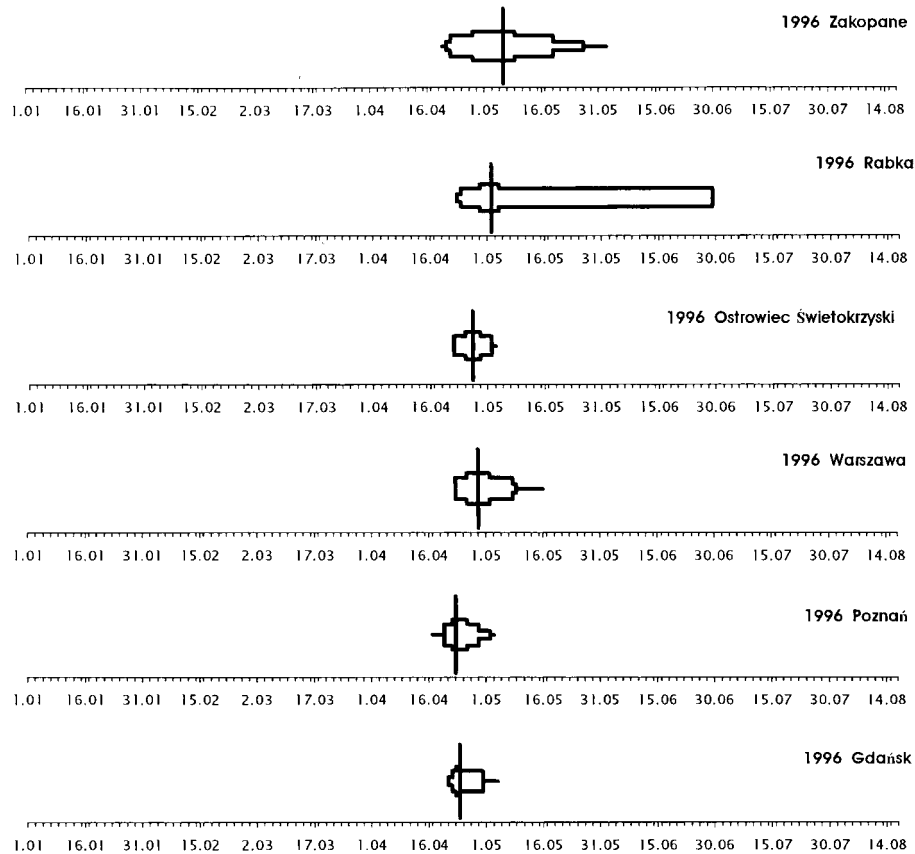
Fraxinus

Figure 8. The dynamics of the pollen seasons of *Fraxinus* at 7 sites in 1996.

pared. In sites situated in montane regions (Zakopane, Rabka) pollen seasons of the studied taxa were generally longer than in other sites, primarily because of extended last phases of the pollen seasons. It could be influenced by flowering delayed with increase in altitudes above sea level and the long-distance transport stimulated by montane wind. Apparently the 90% method is more suitable for the taxa flowering early in spring, when a long-distance transport often occurs (*Alnus*, *Corylus*) (Kasprzyk, 2003) and when the concentrations of pollen grains are not high (*Corylus*). This method allows to exclude low concentrations of pollen coming from distant regions or from secondary fall.

Weather conditions, especially temperature, in our climatic zone strongly affect the beginning and the course of the pollen season (Sokołowska 1962; Kozłowski 1971; Frenguelli et al., 1991), thus to forecast the beginning of flowering and pollen

season, particularly of taxa flowering in early spring, is extremely difficult (Tomaszewska and Rutkowski; 1999). Lower temperature in February and March in 1996 caused nearly a 2 month delay in the beginning of hazel and alder pollen seasons in comparison with 1995. In April of both years temperature was similar and no delay in the beginning of ash pollen season was found.

Different weather conditions in 1995 and in 1996 affected considerably the duration of the pollen seasons (90% method) of the early flowering taxa, i.e. *Alnus* and *Corylus*. In 1995 at nearly all sites pollen seasons of those taxa were longer. Unsteady weather conditions occurring often in February and March, when *Alnus* and *Corylus* start to flower, influence duration of pollen seasons (Corden et al., 2000). In a typical phenological cycle *Alnus incana* starts to flower first, followed by *A. glutinosa* flowering about 2 weeks later (Pancer-Kotejowa and Zarzycki, 1980). When a sudden

warming up occurs both *Alnus* species can flower simultaneously (Kasprzyk, 2003). It could have explained the shorter 1996 season, when temperature raised rapidly in April. In this year the SPI values of the studied taxa were lower at all sites (Table 2). The results were surely affected by external factors; long winter might have eliminated of part of the inflorescence due to freezing.

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