

This article was downloaded by: [94.34.8.216]

On: 29 December 2011, At: 01:47

Publisher: Taylor & Francis

Informa Ltd Registered in England and Wales Registered Number: 1072954 Registered office: Mortimer House, 37-41 Mortimer Street, London W1T 3JH, UK



Grana

Publication details, including instructions for authors and subscription information:

<http://www.tandfonline.com/loi/sgra20>

A comparative study of airborne pollen concentrations of three allergenic types

Agneta Ekebon^a, Siwert Nilsson^a, Maret Saar^b & Marianne Van Hage-Hamsten^c

^a Palynological Laboratory, Swedish Museum of Natural History, Roslagsvägen 101, Stockholm, S-104 05, Sweden

^b Institute of Zoology and Botany, 181 Riia St., Tartu, Estonia

^c Department of Laboratory Medicine, Division of Clinical Immunology, Karolinska Hospital, Stockholm, S-171 76, Sweden

Available online: 03 Sep 2009

To cite this article: Agneta Ekebon, Siwert Nilsson, Maret Saar & Marianne Van Hage-Hamsten (1997): A comparative study of airborne pollen concentrations of three allergenic types, *Grana*, 36:6, 366-372

To link to this article: <http://dx.doi.org/10.1080/00173139709362630>

PLEASE SCROLL DOWN FOR ARTICLE

Full terms and conditions of use: <http://www.tandfonline.com/page/terms-and-conditions>

This article may be used for research, teaching, and private study purposes. Any substantial or systematic reproduction, redistribution, reselling, loan, sub-licensing, systematic supply, or distribution in any form to anyone is expressly forbidden.

The publisher does not give any warranty express or implied or make any representation that the contents will be complete or accurate or up to date. The accuracy of any instructions, formulae, and drug doses should be independently verified with primary sources. The publisher shall not be liable for any loss, actions, claims, proceedings, demand, or costs or damages whatsoever or howsoever caused arising directly or indirectly in connection with or arising out of the use of this material.

A comparative study of airborne pollen concentrations of three allergenic types

In Tartu (Estonia), Roma/Gotland and Stockholm (Sweden) 1990–1996

AGNETA EKEBOM, SIWERT NILSSON, MARET SAAR and MARIANNE VAN HAGE-HAMSTEN

Ekebon, A., Nilsson, S., Saar, M. & van Hage-Hamsten, M. 1997. Airborne pollen concentrations of allergenic types in Estonia and Sweden 1990–1996. – Grana 36: 366–372. ISSN 0017-3134.

Airborne concentrations of pollen from *Betula* (birch), Poaceae (grasses) and *Artemisia* (mugwort) are compared during a seven year period (90–96) with respect to both quantitative and seasonal aspects, at three different sampling sites, one in Estonia (Tartu) and two in Sweden (Stockholm and Roma on the island of Gotland). All three taxa occur in the region and are well-known causes of allergic sensitisation. The annual total and peak values of birch, grass and mugwort pollen were found to be much higher in Tartu than in Stockholm and Roma. Both the birch and the grass pollen seasons ended later in Stockholm than in Roma and Tartu. The mugwort flowering season always began earlier in Stockholm than at the other sites, and more days elapsed between start day and peak day in Stockholm than in Tartu.

A. Ekebon & S. Nilsson, Palynological Laboratory, Swedish Museum of Natural History, Roslagsvägen 101, S-104 05 Stockholm, Sweden; M. Saar, Institute of Zoology and Botany, 181 Riia St., Tartu, Estonia; M. van Hage-Hamsten, Department of Laboratory Medicine, Division of Clinical Immunology, Karolinska Hospital, S-171 76 Stockholm, Sweden.

(Manuscript accepted 30 December 1997)

Studies have shown evidence of long-distance transport of *Betula* pollen along the Swedish east coast; this pollen originating from Eastern Europe and the Baltic States, arrives before the local birch flowering season (Hjelmroos 1991, Wallin et al. 1991). It is believed that a large part of the birch pollen sampled on the Baltic island Gotland originates from long-distance transport (Hjelmroos & van Hage-Hamsten 1993).

Betula pollen is one of the major airborne allergens in Northern Europe, and a large number of people are exposed. Even though the birch pollen concentrations on Gotland are about the same as on the mainland of Sweden, a lower prevalence of birch pollen allergies has been found in the farming population on the island (van Hage-Hamsten et al. 1987, Kronqvist et al., in prep.).

Interestingly, birch pollen allergy seems also to be less prevalent in the Baltic countries than in the mainland of Sweden. The prevalence of atopic sensitisation, including sensitisation to pollen allergens, among schoolchildren in Estonia is much lower than in Western Europe (Riikjärv et al. 1995). In a survey among adults in Tartu, Estonia and Uppsala, Sweden asthmatic symptoms and allergic rhinitis were less prevalent in Tartu (Jögi et al. 1996).

A comparative study like this one is needed to evaluate and compare aeroallergenic load of the air in the sites, and to find places that might serve for predicting start days and peak days in other places.

The aim of the study was to compare airborne pollen concentrations of three taxa of allergic significance, typical for the three seasons of the flowering period (spring, summer and autumn) in three localities, Stockholm and Roma (Sweden) and Tartu (Estonia). At these sites continuous

long-term sampling has been carried out. As the sites are located in the same geographical area although separated and influenced by the Baltic Sea, it was of special interest to make a comparative study. Differences and similarities in the periods of presence of pollen from three common taxa – *Betula* (birch), Poaceae (grasses) and *Artemisia* (mugwort) – are dealt with over a seven year period (1990–96).

A season could be characterised in two ways. A quantitative aspect described by annual total (AT), peak value (PV) and duration of season (DS) would characterise a rate of input of pollen to the air. A temporal aspect described by start day (SD), peak day (PD) and end day (ED) would characterise pollen input timing.

In this study we wanted:

- to compare sites both on the basis of 7-year-mean input rate and on the basis of 7-year-mean timing of pollen input.
- to compare years both on the basis of 3-site-mean input rate and on the basis of 3-site-mean timing of pollen input.
- to study correlations in annual variations of input characteristics among sites.

MATERIALS AND METHODS

At every site sampling was performed with Burkard Seven Day Pollen and Spore traps (Hirst 1952). The locations of the sampling sites are shown in Fig. 1. All traps were placed at roof level, in Tartu and Stockholm about 15 m above ground and on Gotland 7 m above ground. The trap on Gotland was placed in a village named Roma situated in an agricultural area, in the centre of the island. Gotland has only a few scattered birches and the vegetation sur-

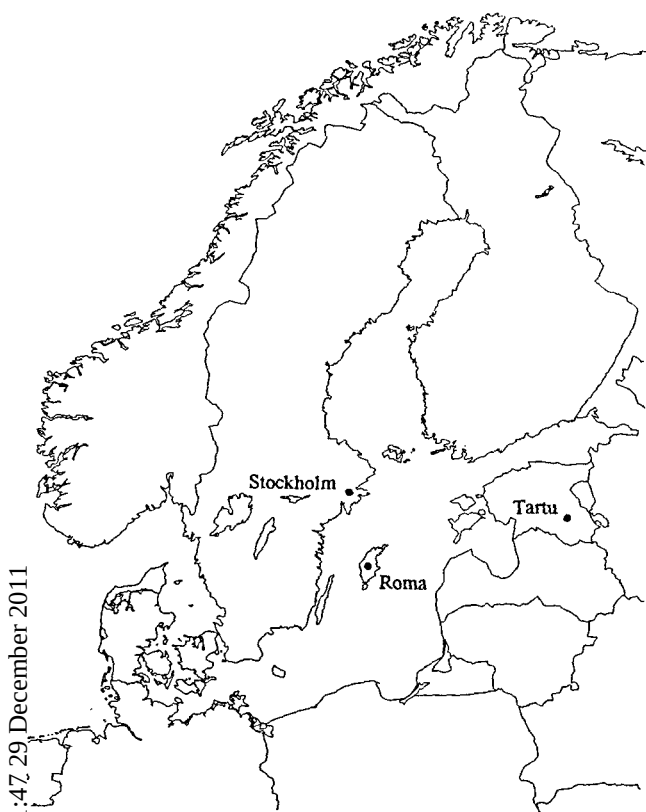


Fig. 1. Sampling sites.

rounding the trap was a mixed wood and grass areas. In Stockholm, birch is one of the main components of the vegetation, the vicinity of the trap was a park with oak (*Quercus*) and birch, grass areas and ornamental shrubs. In Tartu, green areas with ornamental

shrubs and trees, and waste areas occupied the direct vicinity of the trap. At some greater distance there were mixed forests and agricultural landscape.

Daily pollen counts for the period 1990-96 for Stockholm and Roma were made at the Palynological Laboratory, Swedish Museum of Natural History and for Tartu at the Institute of Zoology and Botany. In Stockholm and Roma 12 transverse strips were counted for every second hour (analysed area 5%), whereas in Tartu the method of random microscope fields (Käpylä & Penttinen 1981) was used (analysed area 1.2%). According to Käpylä and Penttinen (1981) the results of these two different types of counting procedures are comparable.

In this study the pollen season (main pollen season) was defined as 90% of the annual total (Nilsson & Persson 1991).

In 1995 there was no sampling in Roma. At the other sampling sites full data sequences for the period were obtained.

The SAS System carried out the statistical analyses and "The General Linear Models Procedure" was used.

The distribution of four variables – SD (start day), PD (peak day), ED (end day), DS (duration of season) – was not significantly different from a normal distribution. Two variables – AT (annual total), PV (peak value) – were square-root-transformed to make their distribution more normal-like. After that the testing did not detect any significant difference from a normal distribution. All results concerning AT and PV are expressed on the basis of pollen concentration (pollen/m³). The values for SD, PD and ED are the number of days from January 1, and for DS the values are the number of days.

The season characteristics – means, standard deviations and extreme values of SD, PD, ED, DS, PV and AT – for all three sites and pollen groups are given in Table I. To correct for the missing values for Roma in 1995, the "Least Squared Means Method" was used to calculate mean values for this sampling site.

RESULTS

Betula

A comparison of the sites on the basis of the three timing characteristics, start day, peak day and end day can be seen

Table I. Pollen seasons of *Betula*, *Poaceae* and *Artemisia* in Roma, Stockholm and Tartu in the 7-year period 1990–1996. Means, standard deviations and extreme values.

SD – standard deviation; * – 7-year-mean, calculated value using least squared mean method; ** – extreme values in data of 6 years; ? – no data.

		Roma		Stockholm		Tartu	
		Mean	Min.–Max.	Mean ± SD	Min.–Max.	Mean ± SD	Min.–Max.
Start day	<i>Betula</i>	110*	94–127**	115 ± 10.8	93–125	118 ± 7.1	106–129
	<i>Poaceae</i>	159*	146–170**	162 ± 8.7	153–177	160 ± 7.4	148–173
	<i>Artemisia</i>	207*	197–216**	198 ± 5.4	191–207	208 ± 3.2	205–212
Peak day	<i>Betula</i>	120*	97–135**	128 ± 3.9	111–149	122 ± 8.8	111–136
	<i>Poaceae</i>	174*	159–191**	185 ± 15.3	167–205	178 ± 9.0	164–191
	<i>Artemisia</i>	218*	202–230**	216 ± 3.9	213–224	216 ± 3.3	212–220
End day	<i>Betula</i>	139*	122–150**	144 ± 9.8	126–152	139 ± 10.3	123–151
	<i>Poaceae</i>	207*	198–223**	220 ± 8.2	207–231	212 ± 12.4	193–233
	<i>Artemisia</i>	?	?	?	?	236 ± 4.5	229–244
Annual total	<i>Betula</i>	5329*	949–19693**	6249 ± 2448.3	403–26859	17311 ± 5102.5	2548–65975
	<i>Poaceae</i>	896*	359–1250**	1260 ± 74.2	565–2513	2922 ± 24.9	2241–3769
	<i>Artemisia</i>	191*	113–353**	159 ± 5.2	111–294	2046 ± 135.3	799–3714
Peak Value	<i>Betula</i>	759*	127–2993**	907 ± 570.7	53–6097	2770 ± 749.3	377–10722
	<i>Poaceae</i>	99*	40–113**	95 ± 17.5	34–353	231 ± 6.3	145–377
	<i>Artemisia</i>	54*	17–115**	19 ± 1.5	8–47	230 ± 10.4	126–393
Duration of season	<i>Betula</i>	29*	17–53**	29 ± 6.6	18–37	21 ± 5.9	13–29
	<i>Poaceae</i>	48*	40–69**	59 ± 8.5	44–69	52 ± 13.0	36–72
	<i>Artemisia</i>	?	?	?	?	27 ± 5.0	18–32

in Table I. The start day of the birch pollen season differed only one to two days between Stockholm and Roma, except in 1991 (Fig. 2A), but there was no clear tendency for either of the two localities to precede the other. This difference is not significant ($p=0.19$). The start day in Tartu was generally a few days later than in Roma and Stockholm, except in 1995. The difference between Tartu and Stockholm is not significant ($p=0.37$). The difference between Tartu and Roma is at the significance level $p=0.042$, that is near the

limit ($p=0.05$) considered to be statistically significant. This means that the number of observations used in this analysis was sufficient to show that a statistically significant difference exists between Tartu and Roma, but many more observations are needed to determine how reliable the observed difference is. The general appearance of the peak day pattern over the years matches that of the start of season: an early start means an early peak day (Fig. 2A, B). The relative order of the three sites' peak days, however, was not the same as the order of the start of the season. The difference in peak day was significant only between Roma and Stockholm ($p=0.047$), but once again, many more observations are needed to determine its reliability.

A comparison of the end day at the three sites showed a significant difference between Stockholm and Roma (4 days, $p=0.024$), and Stockholm and Tartu (5 days, $p=0.009$; Table II). The end of the season was always later in Stockholm than in Roma and Tartu as can be seen in Fig. 2C.

Comparison of the sites on the basis of the season's quantitative aspects, annual total, peak value and duration of season can be seen in Table II. Annual totals and peak concentrations differed significantly ($p=0.007-0.015$) between Tartu and the other sites, both concentrations were as a rule higher in Tartu, but whether it was Stockholm or Roma that had the next highest annual totals (Fig. 2D) and peak concentrations varied between the years. There was no significant ($p>0.05$) difference in season duration between any of the sites.

The years differed significantly with regard to all three aspects of input timing of *Betula* pollen ($p=0.0001-0.004$) as well as in the case of annual total ($p=0.006$) and peak value ($p=0.003$). The three sampling sites generally had the same rhythm of high, low and moderate reproduction years. In 1993 the amount of birch pollen present in the air was very high at all three sites; the highest annual totals during the period investigated were observed for Stockholm and Tartu in 1993, though for Roma the annual total was even higher in 1990 (Fig. 2D). During the seven-year period investigated, the biennial rhythm found by Nilsson and Persson (1981) and by Atkinson and Larson (1990) was most clearly expressed in Stockholm but there was a phase-displacement in 1993 (Fig. 2D). The same rhythm as in Stockholm was seen in Roma but there the data sequence is not complete for the period. In Tartu the two-year reproductive rhythm was less pronounced, with a phase-displacement in both 1993 and 1996.

Study of correlation in annual variations of seasonal characteristics among sites showed that significant positive relationships exist, both in the case of the pollen input timing and in the case of input rate (Table III). Stockholm and Tartu were linked in more aspects (start day, $p=0.04$; end day, $p=0.008$; annual total, $p=0.02$; peak value, $p=0.004$) than the other pairs of sites. Stockholm and Roma were linked in two aspects (end day, $p=0.002$; annual total, $p=0.04$) while Roma and Tartu were linked only in one (end day, $p=0.02$). It is worth pointing out that the correlations of end day were very strong and at a high level of significance between sites of all three pairs. The linkage was strongest and most significant between Stockholm and Roma ($r=0.97$; $p=0.002$), followed by the correlation between Stockholm

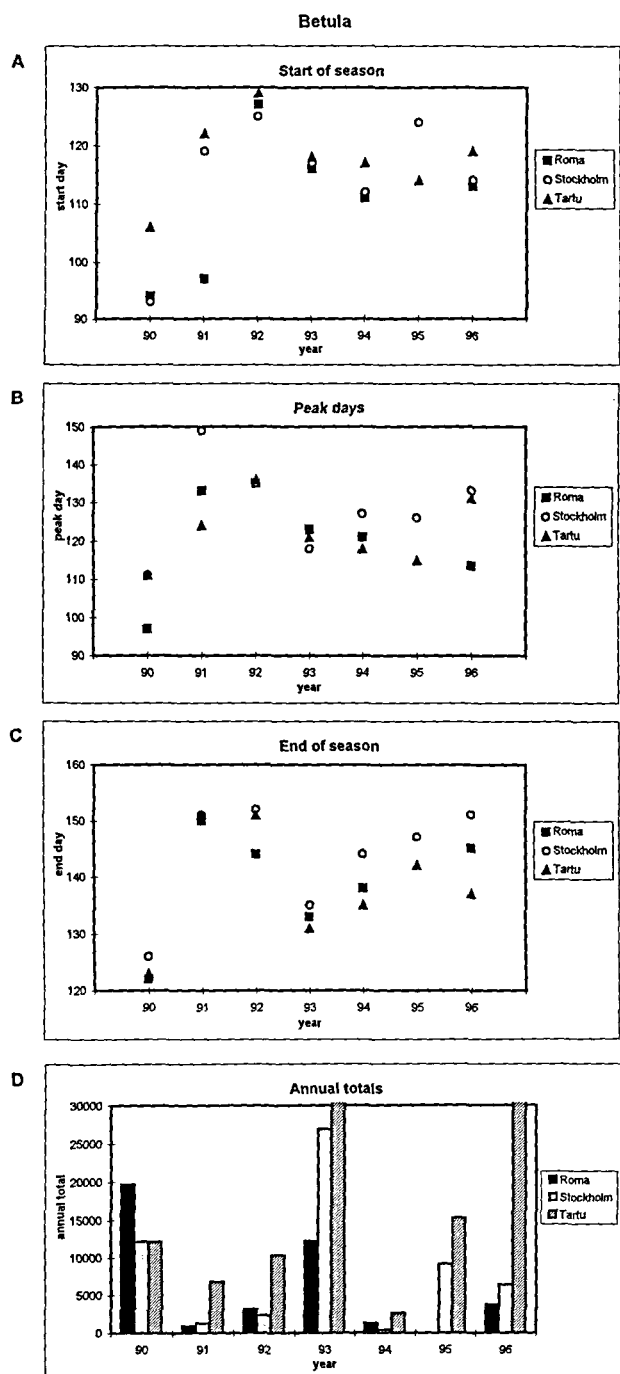


Fig. 2A–D. *Betula*. (A) Beginning of pollen season. (B) Peak days. (C) End of pollen season. (D) Annual totals.

Table II. Differences in characteristics of pollen seasons between sites.

Upper numbers indicate the estimate difference in 7 year mean values of characteristic and the standard error of the estimate; the lower numbers, a significance level (p). R–Roma; S–Stockholm; T–Tartu.

*, ** and *** – indicate significance at $0.05 > p \geq 0.01$, $0.01 > p \geq 0.001$ and $p < 0.001$, respectively; ? – no data.

	Pairs of sites	Characteristics of input timing			Characteristics of input rate		
		Start day	Peak day	End day	Annual total	Peak value	Duration of season
<i>Betula</i>	R–S	–(5±3.4) 0.19	–(9±3.9) 0.047*	–(4±1.7) 0.024*	–(37±377.8) 0.76	–(7±57.4) 0.74	0±4.0 0.95
	R–T	–(8±3.4) 0.042*	–(3±3.9) 0.52	1±1.7 0.71	–(3431±377.8) 0.012*	–(629±57.4) 0.007**	8±4.8 0.058
	S–T	–(3±3.2) 0.37	6±3.7 0.12	5±1.6 0.009**	–(2759±335.8) 0.015*	–(507±51.0) 0.009**	8±3.7 0.052
Poaceae	R–S	–(3±2.5) 0.31	–(11±4.7) 0.042*	–(13±5.0) 0.023*	–(31±7.1) 0.061	0±1.7 0.89	–(11±5.4) 0.079
	R–T	–(1±2.5) 0.71	–(4±4.7) 0.38	–(5±5.0) 0.34	–(582±7.1) 0.0001***	–(28±1.7) 0.002**	–(4±5.4) 0.48
	S–T	2±2.4 0.49	7±4.5 0.17*	8±4.7 0.11	–(345±6.3) 0.0001***	–(30±1.5) 0.0009***	7±5.1 0.23
<i>Artemisia</i>	R–S	10±2.8 0.005**	3±3.6 0.50	?	1±16.4 0.77	9±1.7 0.046	?
	R–T	–(1±2.8) 0.79	2±3.6 0.62	?	–(987±16.4) 0.0001***	–(61±1.7) 0.0001***	?
	S–T	–(11±2.7) 0.002**	–(1±3.4) 0.84		–(1064±14.6) 0.0001***	–(116±1.5) 0.0001***	?

and Tartu ($r=0.88$; $p=0.008$), and Roma and Tartu ($r=0.89$; $p=0.02$).

Poaceae

There were no significant differences among the pairs of sites for the start of the flowering season for Poaceae (Table II). The first five years though, the start of the season was a few days earlier in Roma than in Stockholm (Fig. 3A). In correspondence with the earlier start dates in Roma compared to Stockholm, the first peak day mostly occurred earlier in Roma or at the same time as in Stockholm (Fig. 3B), and the difference was significant ($p=0.042$; Table II).

As can be seen in Fig. 3C, the end of season in Stockholm was later than in both Roma and Tartu, except in two years, 1993 and 1996. Only Roma and Stockholm differed significantly ($p=0.023$; Table II) from one another.

The annual totals were always much higher in Tartu (highly significant ($p=0.0001$) difference; Table II) whereas the amounts in Stockholm and Roma were lower and more closely matched (Fig. 3D). In the same manner the peak concentrations differed very significantly between Tartu and Roma ($p=0.002$), and Tartu and Stockholm ($p=0.0009$; Table II).

The years differed significantly with respect to start day ($p=0.001$) and peak day ($p=0.021$), and in the case of annual total ($p=0.024$) and peak value ($p=0.043$).

Study of correlations in annual variations of the seasonal

characteristics of Poaceae pollen input at the three sites showed only one significant relationship (Table III). Start days were positively linked between Stockholm and Roma, and this correlation was strong ($r=0.94$) and very significant ($p=0.006$).

Artemisia

For the years investigated there was a significant difference in the start of the mugwort pollen season between Stockholm and the other sites. On average, the start day came earlier in Stockholm than in Roma (10 days, $p=0.005$) and in Tartu (11 days, $p=0.002$; Table II). The site where a season started second was sometimes Roma, sometimes Tartu (Fig. 4A) and there was no significant ($p=0.79$) correlation between these sites.

The pollen input characteristics of the mugwort season did not vary much between the years: the differences were insignificant in the case of start day and the peak day, and in the case of annual total and peak value. In Stockholm, especially from 1990 to 1994, the season started within the same six days (Fig. 4A). The same went for Tartu, while the start day in Roma varied more over the years. As was the case for birch, for mugwort there was no agreement between the relative order of the sites' peak days and the order of the start of season.

The number of days that elapsed between start day to the peak day was quite constant over the years in both Stockholm and Tartu (Fig. 4B). A comparison between the sites shows

Table III. Correlation of characteristics of pollen seasons between sites over a 7-year period.

Upper numbers indicate the Pearson's correlation coefficient (r), the lower numbers, a significance level (p). R–Roma; S–Stockholm; T–Tartu. * = 0.05 > p ≥ 0.01, ** = 0.01 > p ≥ 0.001, ? = no data.

		Characteristics of input timing			Characteristics of input rate		
	Pairs of sites	Start day	Peak day	End day	Annual total	Peak value	Duration of season
Betula	R–S	0.70	0.76	0.97	0.83	0.69	0.55
		0.12	0.08	0.002**	0.04*	0.13	0.26
	R–T	0.71	0.68	0.89	0.47	0.52	0.76
		0.11	0.14	0.02*	0.35	0.29	0.08
	S–T	0.78	0.61	0.88	0.84	0.92	0.08
		0.04*	0.14	0.008**	0.02*	0.004**	0.87
Poaceae	R–S	0.94	0.57	−0.36	0.46	0.32	−0.09
		0.006**	0.24	0.48	0.35	0.54	0.86
	R–T	0.53	0.27	0.54	0.65	0.18	0.56
		0.29	0.60	0.27	0.16	0.74	0.25
	S–T	0.75	0.70	0.47	0.50	0.43	0.16
		0.052	0.08	0.29	0.25	0.33	0.73
Artemisia	R–S	0.29	0.10	?	−0.69	−0.68	?
		0.57	0.85		0.13	0.14	
	R–T	0.39	0.35	?	0.23	0.28	?
		0.44	0.50		0.66	0.59	
	S–T	0.34	0.39	?	0.17	0.50	?
		0.45	0.39		0.71	0.25	

a remarkable difference between Stockholm and Tartu, however: in Stockholm the peak day came on average 18 days after the start of season, and in Tartu 8 days after. Roma varied a lot more.

During the period investigated, pollen sampling generally stopped at the end of August in Stockholm and a few days earlier in Roma; in Tartu, airborne particles were sampled continuously, 12 months a year. It is believed that some *Artemisia* pollen appeared in the air after the sampling ended in Stockholm and Roma. It is therefore not possible to compare the end of season, and the annual totals for Stockholm and Roma could thus be somewhat lower than if the sampling had continued. Even bearing that in mind, the annual totals in Tartu were still very much higher than in Stockholm and Roma (Fig. 4C), the differences in annual total and peak value for *Artemisia* were highly significant ($p=0.0001$; Table II). In Tartu, the mean annual totals (Table I) were about 13 times higher than in Stockholm and about 11 times higher than in Roma. The peak concentrations in Tartu are even higher than the annual totals in Stockholm and Roma (Table I).

Study of correlations in annual variations of seasonal characteristics among sites did not reveal any significant ($p<0.05$) relationships (Table III). We found no significant relationships between sites in year to year variations of seasonal characteristics,—neither from the aspect of pollen input timing nor from that of input rate.

DISCUSSION

The growing season on Gotland is delayed by about one week compared to the season at the corresponding latitude on the mainland (Ekström et al. 1988). In this investigation the starting dates of the birch pollen season in Stockholm and Roma were found to be very close. This implies that the early birch pollen in the air in both Stockholm and Roma is long-distance transported instead of originating from the local flowering. The start date only differs two days between Stockholm and Roma except in 1991, when the birch pollen season started very early in Roma (7 April). This was due to the unusually high pollen count (35 pollen m^{−3} air) observed, already on the second day that birch pollen was detected in the air for the season. Usually the early long-distance transported pollen grains only reach a concentration of one to ten pollen m^{−3} air (=low concentration). Disregarding this high count would put the start of season on the 23rd of April, closer to the start in Stockholm. Because of the low annual totals in 1991 the relatively high counts in the early season in Roma make a great contribution to the annual total, and the season, defined as 90% of the total, starts very early.

At many sampling sites in the south and centre of Sweden (Ekebom et al. 1996) as well as in Tartu, one can register pollen after the local birch flowering season, due to a long-distance transport of pollen, probably originating from the

Poaceae

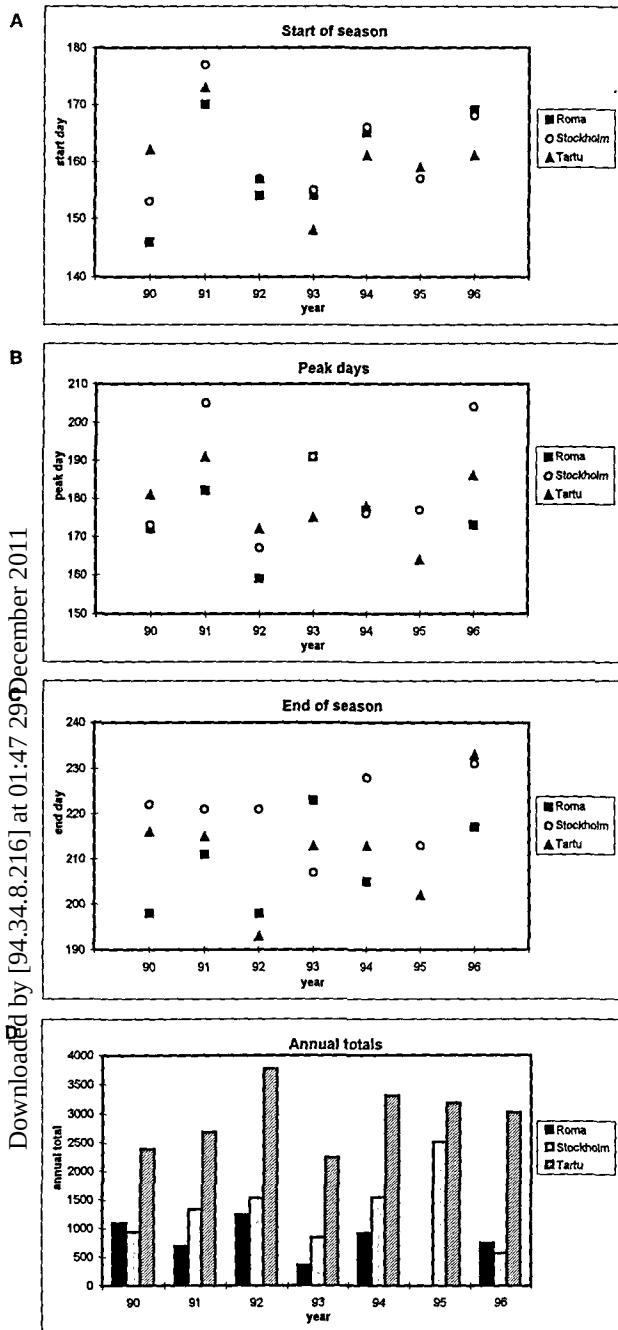


Fig. 3A-D. Poaceae. (A) Beginning of pollen season. (B) Peak days. (C) End of pollen season. (D) Annual totals.

later birch flowering in the north and carried southward when the winds were northerly. The birch pollen season can therefore sometimes become prolonged. Stockholm had a latter end day of the birch pollen season compared to Roma and Tartu. Perhaps Stockholm, placed furthest north of the three sampling sites, in some way is more affected by pollen transport originating from the later flowering in the north.

The investigation of Hjelmroos and van Hage-Hamsten (1993) concluded that the concentration of birch pollen on

Artemisia

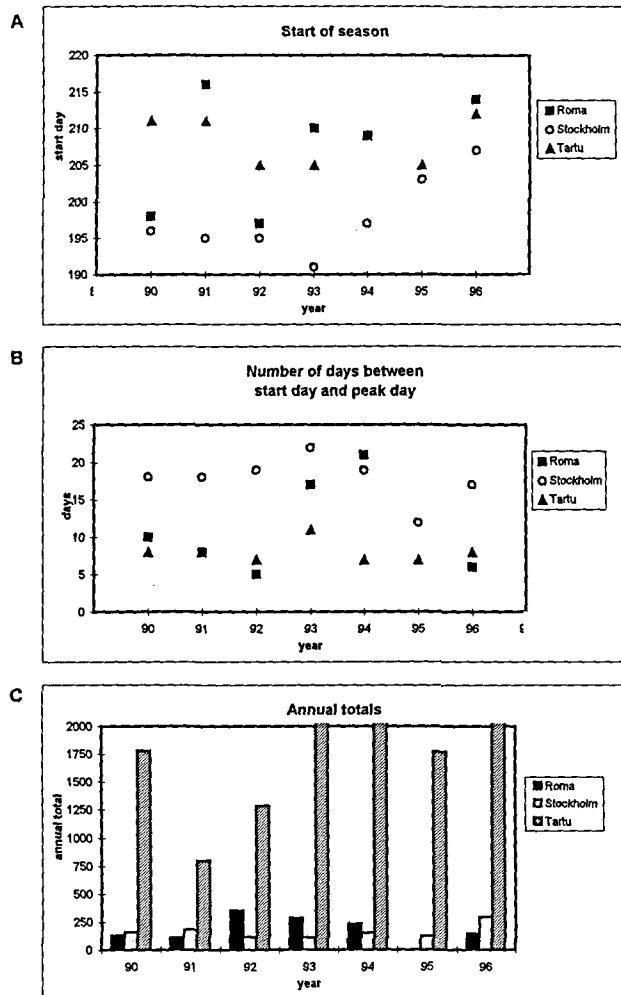


Fig. 4A-C. Artemisia. (A) Beginning of pollen season. (B) Number of days from start day to peak day. (C) Annual totals.

Gotland was as high or higher than that in Stockholm during the investigated years (1990-1992). In the present study, which is based on data from the same three years and three additional years (1993, 1994 and 1996) it is clear that the highest birch pollen concentration can alternate between Stockholm and Roma.

The bedrock on Gotland is mainly limestone, unlike the mainland of Sweden, and the calcareous soil promotes a different flora. A different composition of grass species, and consequent differences in the periods of flowering, can in part explain that the grass pollen season starts earlier in Roma compared to Stockholm despite the growing season is generally a week later. The bedrock in the Baltic countries is also mainly limestone.

The periods of flowering of different grass species vary and the weather conditions during the flowering of a certain species can have a great influence on the annual pollen total, and affect the time of peak day. The pollen season of birch is more limited in time than that of grasses, and the grass pollen season - stretching over a longer period of time - is more influenced by the weather conditions: therefore one

expects a greater variation for the grasses in the period of pollen presence and in pollen concentrations between the sites and years. In this study especially the peak days and the end of season for the grasses differed between the sites. Therefore it is even more remarkable that the time of the peak day for grass pollen corresponded to the time of start day and occurred the same relative order – first Roma then Stockholm – in a way that neither birch nor mugwort did in this study.

The reason for the very high concentration of *Artemisia* pollen in Tartu is unknown. The longer time between start and peak day for mugwort in Tartu, may be due to the high concentration and the definition of the pollen season; 90% of a high annual total means a later start to the season. A second explanation can be that the late start is a consequence of the resolution of the measurement, the smaller analysed area of the random field method makes it more difficult to detect the small amounts of the early season mugwort pollen. A third explanation is based on the phenology of mugwort. The start of pollen seasons depends mainly on the flowering of local and regional plants. Flowering of mugwort is a photoperiodically triggered process and depends on the lengthening of dark periods after the summer solstice. The dark periods lengthen more rapidly at higher latitudes and therefore, as Stockholm is situated further north than Roma and Tartu, the flowering starts in Stockholm earlier than in the other two places.

The differences in annual total and peak value between Tartu and the two other sites, Stockholm and Roma, may be caused by the differences in the density of plants, or the time of mowing of grass and herbs in relation to the time of their pollination. One other important difference is the influence of the large inland area surrounding to Tartu, a situation that contrast to the coastal area of Stockholm and Roma.

CONCLUSIONS

1. The amounts of birch, grass and mugwort pollen in the air are much higher in Tartu than in Stockholm and Roma.
2. The birch pollen season starts at about the same time in Stockholm and Roma, and earlier than in Tartu.
3. The birch pollen season ends later in Stockholm, i.e. the season is prolonged.
4. The time of peak day for grass pollen corresponds to the time of start day and occurs earlier in Roma than in Stockholm.

5. The grass pollen season ends later in Stockholm.
6. The mugwort flowering season starts earlier in Stockholm than at the other sites.
7. Information concerning the earlier start of birch and mugwort pollen season in Stockholm might to predict the start of the season in Tartu. Also the late end of birch pollen season in Stockholm might explain if there is a sudden occurrence of birch pollen in Tartu outside the season. For further conclusions, detailed analysis, particularly of dominant wind directions, would be required. However, this is outside the scope of this work.

ACKNOWLEDGEMENTS

Financial support for this study was received from the Swedish Council for Work Life Research, the Swedish Foundation for Health Care Sciences and Allergy Research, the Swedish Asthma and Allergy Association, the Hesselman Foundation, and the Karolinska Institute.

REFERENCES

- Ekström, U., Jacobson, R., Mattsen, M. & Porsne, T. 1988. Ölands och Gotlands växtvärld. En ekologisk och kulturhistorisk flora. – Natur Kultur, Stockholm.
- Hage-Hamsten, M. van, Johansson, S. G. O. & Zetterström, O. 1987. Predominance of mite allergy over allergy to pollens and animal danders in a farming population. – *Clin Allergy* 17: 417–423.
- Hirst, J. M. 1952. An automatic volumetric spore trap. – *Ann Appl. Biol.* 36: 257–265.
- Hjelmroos, M. 1992. Evidence of long-distance transport of *Betula* pollen. – *Grana* 30: 215–228.
- Hjelmroos, M. & van Hage-Hamsten, M. 1993. Birch pollen dispersal on the Baltic island, Gotland. – *Grana Suppl.* 2: 75–79.
- Jögi, R., Janson, C. Björnsson, E., Boman, G. & Björkstén, B. 1996. The prevalence of asthmatic respiratory symptoms among adults in Estonian and Swedish university cities. – *Allergy* 51: 331–336.
- Käpylä, M. & Penttinen, A. 1981. An evaluation of the microscopical counting methods of the tape in Hirst-Burkard pollen and spore trap. – *Grana* 20: 131–141.
- Nilsson, S. & Persson, S. 1981. Tree pollen spectra in the Stockholm region (Sweden), 1973–1980. – *Grana* 20: 179–182.
- Riikjäär, M. A., Julge, K., Vasar, M., Bråbäck, L., Knutsson, A. & Björkstén, B. 1995. The prevalence of atopic sensitisation and respiratory symptoms among Estonian schoolchildren. – *Clin. Exp. Allergy* 25: 1198–1204.
- Wallin, J.-E., Segerström, U., Rosenhall, L., Bergman, E. & Hjelmroos, M. 1991. Allergic symptoms caused by long-distance transported birch pollen. – *Grana* 30: 265–268.