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Grana

Publication details, including instructions for authors and subscription information:

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

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Available online: 05 Nov 2010

To cite this article: Margrét Hallsdóttir (1999): Birch pollen abundance in Reykjavík, Iceland, *Grana*, 38:6, 368-373

To link to this article: <http://dx.doi.org/10.1080/00173130050136163>

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Birch pollen abundance in Reykjavík, Iceland

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Hallsdóttir, M. 1999. Birch pollen abundance in Reykjavík, Iceland. – Grana 38: 368–373. ISSN 0017-3134.

A ten-year birch pollen record for Reykjavík, Iceland, has been analyzed with respect to fluctuations in the annual pollen sum, the starting date, and the duration of the birch pollen season. A three-year cycle is observed for the annual birch pollen sum, which could be of value in predicting the severity of the next birch pollen season. The annual birch pollen sum is regressed on six climatic variables, only one of which turned out to be statistically significant. The number of days with temperatures above +7.5°C in the year of inflorescence initiation shows a significant correlation with the annual birch pollen sum of the following flowering year ($P=0.009$). For the starting date of the birch pollen season the accumulated thermal sum on May 15 is shown to have the best predictive value, estimating it to within one week. The mean duration of the birch pollen season in southwestern Iceland is 17 days, starting May 29 and ending June 14.

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(Manuscript accepted 17 December 1999)

The daily airborne pollen concentration has been recorded in Reykjavík, Iceland, using a Burkard Seven-day Recording Volumetric Spore Trap for a period of ten years, 1988–1997, operating 4 to 5 months every summer from May to September. The pollen season starts in early May with crowberry (*Empetrum nigrum*) and willow (*Salix* spp.), followed later by aspen (poplar; *Populus trichocarpa*) and with birch (*Betula pubescens*) pollen appearing at the end of May. Sorrel (*Rumex* spp.) flowers in June as do some grass species (Poaceae), both with peaks in July. A second peak of grass-pollen is seen in some years during the middle of August. The pollen season tails off in September with grass-pollen as almost the only pollen type left in the air.

Grass pollen is the major cause of hay fever in Iceland, but in a recent survey on atopic allergy amongst urban population in Iceland 20–44 years of age, 3% were positive to birch allergen in a skin prick test (Gíslason et al. 1995). In spite of the low annual birch pollen sum in Iceland, compared with the more densely wooded countries on mainland Europe, individuals sensitive to birch pollen do, nevertheless, react in most years, and particularly in the years of relatively high birch pollen sums (D. Gíslason 1998: pers. comm.). Because of this it would be of value to develop a method to predict the intensity of the coming birch pollen season.

In the present study the importance of several climatic parameters and indices are considered and their predictive value evaluated by the use of regression analysis. In addition a method based on accumulated thermal sums (Bergþórsson 1985, 1987) is developed, by which the starting date of the birch pollen season in southwest Iceland can be empirically predicted with an accuracy of one week.

Physiography

Geographical position and environmental description

Reykjavík (64°08'N, 21°54'W), the capital of Iceland, is situated on a small peninsula which stretches NW into the Bay of Faxaflói (Fig. 1). The bedrock is mostly compiled of Quaternary basaltic lava, eroded by Late Pleistocene glaciers, and partly covered by tills and marine sediments. Aeolian andosol and peat are the most prominent soil types.

Vegetation

By definition the lowland of Iceland is within the subalpine birch woodland, although only 1.5% of the total land area is covered by birch woodland at present. The vegetation in the vicinity of the Reykjavík trap is mainly grassland and private gardens with birch (*Betula pubescens*), aspen (*Populus trichocarpa*), rowan (*Sorbus aucuparia*) and willow (*Salix* spp.) cultivated as ornamental or sheltering trees and shrubs. Most of the grassland is mown regularly several times during the summertime but some parts of it only once or mostly twice. The Öskjuhlíð recreation area, in the neighborhood, has several species of conifers (i.e. *Pinus uncinata* and *Picea sitchensis*), although birch is the most abundant tree species (Sigurðsson & Loftsson 1993).

Climate

The climate can be characterized as cold-temperate oceanic. The maritime influence from a westerly branch of the North Atlantic Current results in mild winters (mean temperature January –0.5°C) and cool summers (mean temperature July +10.6°C). Here and in the following climatic averages refer to the normal period 1961–1990 (Icelandic Meteor-



Fig. 1. Map of Reykjavík showing the location of the pollen sampling station at the Meteorological Office near Öskjuhlíð.

ological Office 1990, 1992). The annual mean temperature is $+4.3^{\circ}\text{C}$. The average growth period is 124 days per year (Ragnarsson 1977) of which 13 have temperatures above $+15^{\circ}\text{C}$. The annual precipitation of 799 mm falls mainly during autumn and winter with a maximum in October (86 mm). The spring and summer are the drier periods of the year with a minimum in May (44 mm). The number of days with precipitation above 0.1 mm is 221 per year. The mean number of days with frost is 122, and these occur between October 1st and May 10th, while total snow cover is observed on average for 55 days a year. The number of sunshine hours per year is around 1268. As the country lies in the track of the Icelandic low across the North Atlantic, the weather can change very abruptly and consequently it is very windy. In Reykjavík the weather is on average calm only 12.4 days (3.4%) of the year.

MATERIAL AND METHODS

A Hirst trap was replaced by a seven-day Burkard Volumetric Spore and Pollen Trap after the first four weeks of the 1988 pollen season had elapsed, and from that time the Burkard trap has been run for the sampling. The trap is situated in the instrument-yard of the Icelandic Meteorological Office in Reykjavík at an altitude of 52 m a.s.l. The height of the trap orifice is about 2 m above ground level.

A Melinex tape coated with Pavatol was used in the trap, and glycerine jelly was used as mounting material. Microscopic analyses were performed at 500x magnification, counting twelve transverse traverses evenly spread over the slide 4 mm apart. The pollen concentration is expressed as the sum of the average number per cubic metre of air for 24-h periods.

Some climatic parameters, that were *a priori* considered to exert the strongest influence on the annual fluctuations and starting dates for airborne pollen, were selected for regression analysis. These included the thermal sum of the daily mean temperature during the growing season, where the daily mean has been converted as to compensate for the difference in day-length at high latitudes (Bergþórsson 1985, 1987). The number of days with temperatures above $+7.5^{\circ}\text{C}$, which has been used as a criterion for the growing conditions of birch (Ragnarsson 1977) was also included.

In order to study the existence of cyclic fluctuation patterns in the annual sums, the 10-year average of the annual sums was calculated. A year was defined "high" if its annual sum was higher than the

average and, in the same way, a year was defined "low" if its annual sum was lower than the average.

The starting date and duration of an airborne pollen season has been defined differently by several authors (e.g. Mullenders 1974, Lejoly-Gabriel 1978, Nilsson & Persson 1981, Spieksma et al. 1995). For this study the four different methods referred to above were employed and compared for their usefulness in the peripheral situation experienced in Iceland.

RESULTS AND DISCUSSION

Intensity of the birch pollen season

Year-to-year fluctuations in the annual sum of birch pollen vary greatly, the range being 26 to 543 pollen grains per m^3 , as shown in Fig. 2. From this figure a three-year cycle can be discerned, with the sharpest peaks in 1991, 1994 and 1997. The annual sum for the year 1988 must be viewed with some caution or even suspicion, because of a malfunction in the Hirst pollen trap during the first week of the birch pollen season, which most probably resulted in a minimum value for that year. In addition, the measurements of the 1988 birch pollen season were not performed at exactly the same place as the later ones. The Hirst trap was located on the roof of the Meteorological Office, with the orifice 9 m above ground level, and not in the instrument-yard as later on. For this reason also, 1988 is not strictly comparable. The autocorrelation of the annual sums of birch pollen was calculated as a simple regression on the sum of birch pollen in the two preceding years. This resulted in the equation $y = 0.007x^2 - 1.195x + 597.43$, where x is the sum of birch pollen in the two preceding years and y is the annual sum of birch pollen for the year in question (Fig. 3). This regression explains 55.1% of the variance in the annual birch pollen sum and is statistically significant ($P < 0.05$).

From elsewhere in northern Europe a two-year cycle has been described for birch (Nilsson & Persson 1981, Ramfjord 1991, Spieksma et al. 1995) and several other deciduous tree species (Atkinson & Larsson 1990, Jäger et al. 1991). Pollen monitoring in Stockholm for the period 1977–1986 indicated a three-year cycle in *Pinus* (Atkinson & Larsson 1990), which is the only report known to the author of a three-year cycle in an arboreal species.

It is remarkable that the years with high birch pollen sums

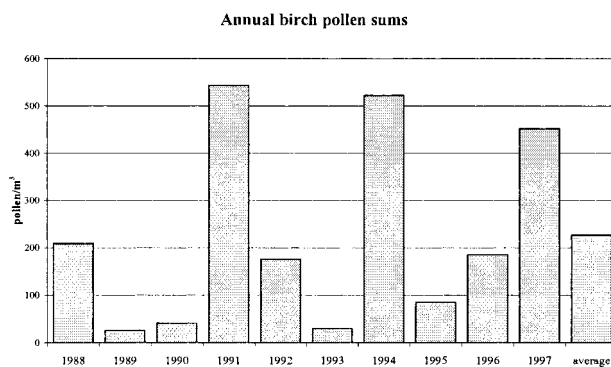


Fig. 2. Annual birch pollen sums plotted for each year together with the average for the 10-year period.

Table I. Selected climatic parameters for May – June in the period 1988–1997 and the average values 1961–1990.

Year/period	Mean temperature °C		Mean duration of bright sunshine hrs		Mean precipitation mm		Mean number of days with precipitation >0.1 mm		Number of days with temperature below zero	
	May	June	May	June	May	June	May	June	May	June
1988	7.5	8.2	202.3	72.2	98	51.2	20	23	0	0
1989	4.8	8.7	191.4	181.8	126	40.3	26	18	3	0
1990	7.2	9.8	140.4	186.4	75.2	43.9	19	20	0	0
1991	6.8	9.4	109.3	295	119.7	14.3	28	6	0	0
1992	5.8	7.8	132.4	148.6	75.7	79.6	18	21	7	0
1993	5.4	9.1	202.7	136.4	65.5	33.3	17	15	5	0
1994	6.9	8	211.9	209.5	67	46.8	20	17	0	0
1995	6.7	9	216	109.8	20.7	38.1	14	23	2	0
1996	7.2	9.8	202.9	154.7	48.4	55.3	18	16	2	0
1997	6	8.4	213.5	240.4	14.1	16.1	10	10	4	1
average 1961–1990	6.3	9	192	161.3	43.8	50	16.6	17.4	3.6	0.1

in Stockholm and London: 1989, 1990, and particularly 1993, according to Spieksma et al. (1995), are all years of extremely low values in Iceland. The Icelandic birch population is clearly not in phase with the population on the continent of Europe, which may suggest a more climatic than genetic controlling mechanism for these oscillations.

As emphasized by Jäger et al. (1991) in respect of patterns of annual pollen fluctuations, one must be aware of the fact that there are at least two factors influencing the magnitude of the annual sums, i.e. pollen production and the actual weather condition during anthesis. A significant climatic index in this respect is the thermal sum of the year of inflorescence initiation, i.e. the year before anthesis, as shown by Hicks et al. (1994) and Dahl & Strandhede (1996). The low pollen sums in Iceland for the years 1989 and 1993 seem natural and plausible, when the weather conditions during the birch pollen season of those two years are considered (Table I). In the year 1990, on the contrary, we cannot blame the weather, as that year was relatively warm, dry and sunny, and the pollen dispersal conditions during June must be considered as good. In this case the low

thermal sum of the year of inflorescence initiation (i.e. 1989, Table II) may explain the low pollen sum in 1990. The years 1990 and 1993 have in common a relatively low thermal sum at the end of September in the year of inflorescence initiation (1989 and 1992), or <1400 thermal units (Table II) while the forerunner of 1989 was an intermediate one with 1548 thermal units.

Using multiple regression, the annual birch pollen sum during one flowering season (the dependent variable) was regressed on three climatic parameters from Table I (temperature, sunshine hours, precipitation in May), and two climatic indices from Table II (the thermal sum at the end of September the preceding year and the number of growth days the preceding year) as the independent variables. Only one of these, the last mentioned one, was shown to be statistically significant. The main reason for this might be the low degree of freedom, as only ten years of data were available.

The average growth period (number of days with temperatures above 7.5°C) is one of three parameters taken into consideration, when estimating growing conditions for birch in Iceland (Ragnarsson 1977). Growth days in the year of inflorescence initiation when regressed alone

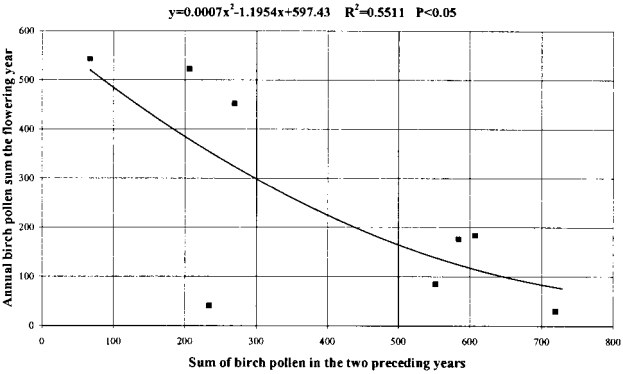


Fig. 3. The auto-correlative relationship between the annual sum of registered airborne birch pollen in Reykjavik during the period 1988–1997 and the accumulated sum of total birch pollen in the two preceding years.

Table II. Two climatic indices of the years of inflorescence initiation in the period 1987–1996.

Year	Number of growth days	Thermal sum up to Sept 30
1987	137	1700
1988	121	1548
1989	101	1329
1990	135	1637
1991	122	1779
1992	107	1372
1993	129	1505
1994	107	1555
1995	122	1506
1996	142	1786

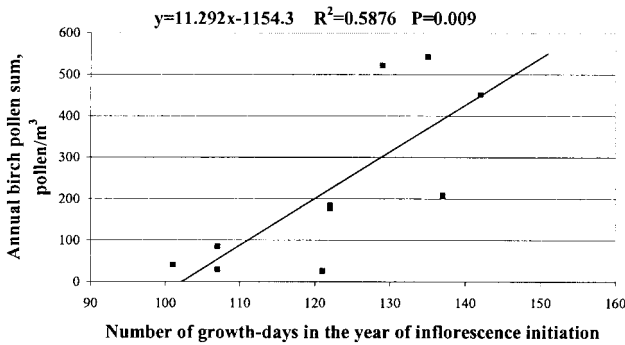


Fig. 4. The relationship between the annual sums of registered airborne birch pollen in Reykjavik during the period 1988–1997 and the number of growth days during the year of inflorescence initiation.

on the intensity of the pollen season in the following year, was shown to be significant ($P=0.009$, Fig. 4) and thus having some predictive value.

Frost days during the start of the growth period of a tree species have been assumed to damage the inflorescence and cause low pollen sums (Andersen 1991). The spring of 1997 was one with high annual birch pollen in Iceland. Even so there were four days during the start of the growth period, when the temperature fell below zero (Table I), which indicates that frost days do not necessarily result in low annual pollen sums. However, it is possible that the frost was not hard enough to cause damage. From the columns listing the number of days in May and June with temperatures below zero, in Table I, it is obvious that frost days occur both in years with high (in 1997) and low (in 1989) birch pollen sums. Thus frost days in May or June, even those reaching -5°C during the period 1988–97, does not seem to affect the pollen sum of the coming season. Possibly the Icelandic birch population, through millennia in a harsh climate, has developed a better frost-resistant provenances than elsewhere in Europe.

The aim of this paper was primarily to describe the cyclic nature of annual birch pollen production in Iceland and to come nearer to its causes. The empirical result is that years with high birch pollen sums ($400\text{--}600\text{ pollen grains/m}^3$) are to be expected every third year, with the next one in the year 2000. The thermal conditions of the previous year certainly influence the pollen production of the year in question, and the rough estimate of this, the number of growth days, showed to have a predictive value. Yet, in the case of adverse weather conditions for pollen dispersal during the pollen season, the annual pollen sum may be even lower than predicted.

Starting date and duration of the pollen season

When the different methods described in the literature, for determining the starting date and duration of the birch pollen season are compared, the method of Lejoly-Gabriel (1978) seemed to best fit a subjective judgment (*cf.* Fig. 5) on the starting and end date of the birch pollen season in Iceland. This method defines the starting date as the day

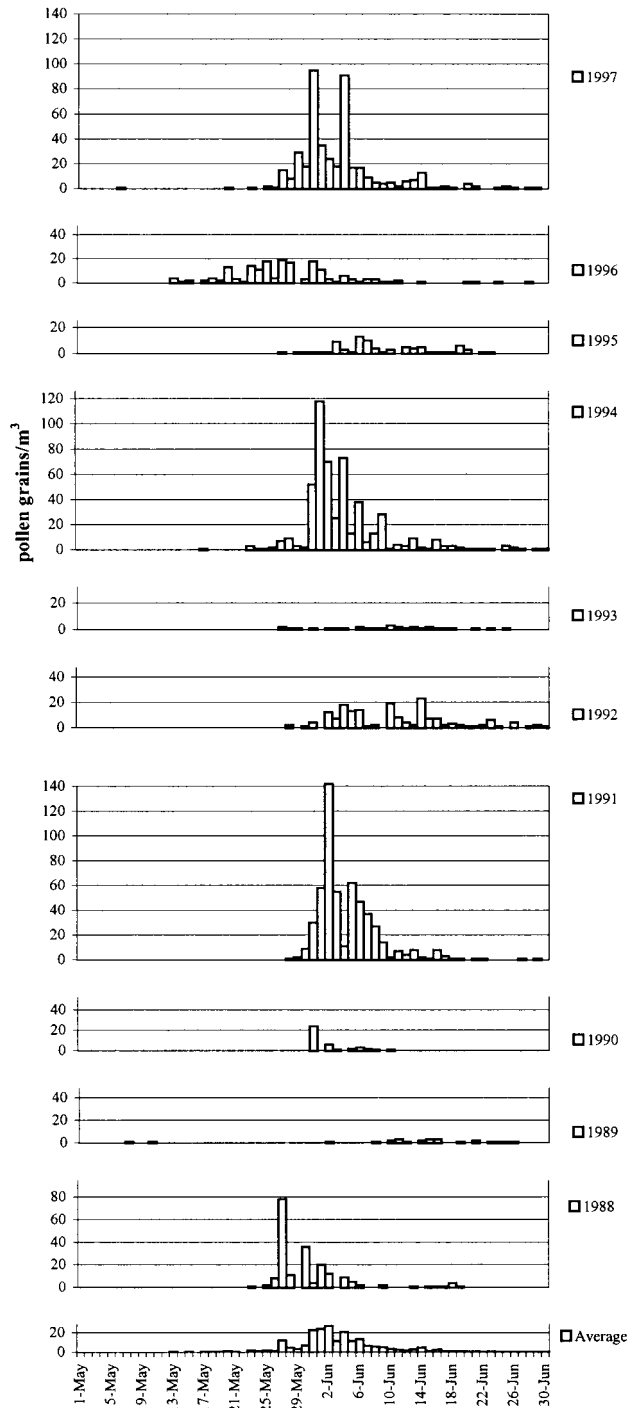


Fig. 5. Daily birch pollen count in Reykjavik, plotted for the period May – June each year, and the 10-year average.

when the sum of pollen counts reaches 5% of the annual total, provided that this particular day contributes at least 1% itself, or the first day on which output equals or exceeds 1% after the 5% level has been reached, and the end date on the last day with more than 1% of the total preceded by 2 days with a joint total of at least 3%. The 90% range used by Nilsson & Persson (1981) was shown to give too long a

Table III. Starting date of the birch pollen season in Reykjavík by four different definitions.

Year	Lejoly–Gabriel 1978	Nilsson & Persson 1981	Mullenders 1974	Spieksma et al. 1995
1988	May 26	May 27	May 26	May 26
1989	June 2	May 10	May 10	June 14
1990	May 31	May 31	May 31	May 31
1991	May 31	May 31	May 31	May 30
1992	June 2	June 2	June 2	May 31
1993	May 27	May 28	May 27	June 10
1994	May 30	May 29	May 31	May 26
1995	May 31	June 1	June 2	June 3
1996	May 17	May 18	May 19	May 15
1997	May 28	May 28	May 28	May 27

season for 1989, which was extremely low in the birch pollen. A good consistency was found between the definitions of the starting date (Table III) by Mullender (1974) and by Nilsson & Persson (1981), as was to be expected. The modification by Spieksma et al. (1995), on the other hand, was less usable, especially when years with very low pollen sums and no clear maxima, like in 1989 and 1993 (Fig. 5), are considered.

In Fig. 6 the different timing of the birch pollen season

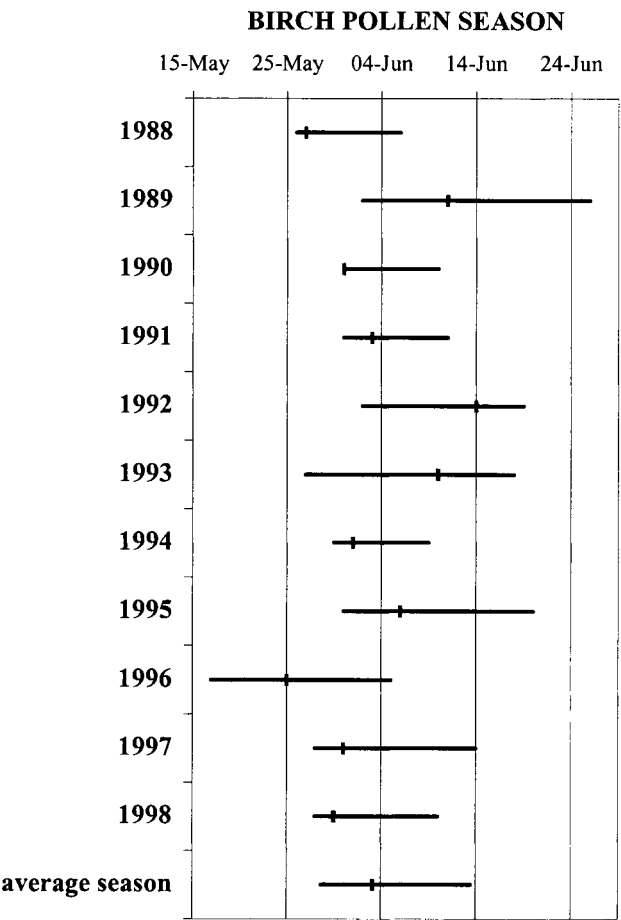


Fig. 6. The duration of the birch pollen season 1988–1997 and the 10-year average season as defined by Lejoly-Gabriel (1978). The mark indicates the birch pollen maximum.

and its maximum within the year is shown, together with the average duration of the season based on 10 years of data. It is clear that the birch pollen season is short in Iceland; the average duration is 17 days, with the range from 11 to 25 days. The variation in the starting date is small, falling within a 17-day period, from May 17 to June 2, compared with the European mainland, where the starting date differs by some tens of days from year to year (Spieksma et al.1995).

The most reliable parameter, when considering a possible application in forecasting the starting date of the coming birch pollen season, seems to be the accumulated thermal sum prior to anthesis. On May 15 the thermal sum has reached some critical value that indicates the timing of the start of the coming season fairly well, or within a period of one week ($2\sigma = \pm 3.4$ days), see Fig. 7.

CONCLUSIONS

From the above study of airborne birch pollen counts from ten consecutive seasons in Reykjavík, Iceland, the following can be drawn:

- 1. A periodicity of three years is to be seen in the intensity of the birch pollen season. A season of high total annual

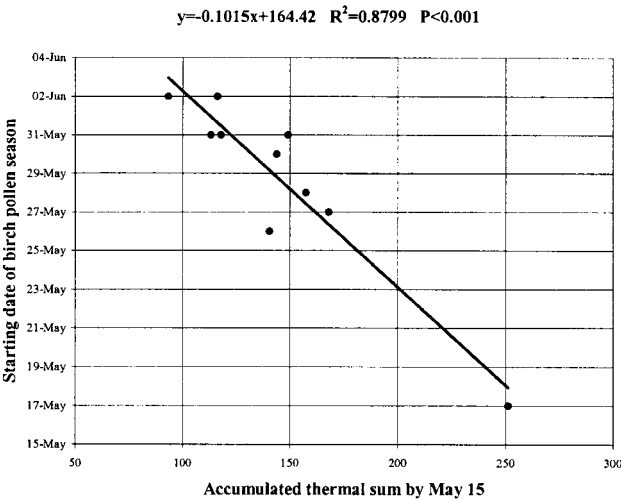


Fig. 7. The relationship between the onset of the birch pollen season and the accumulated thermal sum on May 15, during the period 1988–1997.

- pollen counts is followed by two seasons of low total pollen.
- The parameter, which correlated best with the total annual pollen count, was the length of the growth period in the preceding year.
 - Frost days during spring (never below -5°C in the period 1988–1997) do not seem to affect pollen productivity. However, cumulative factors, as for instance the combination of frozen soil and transpiration on sunny days in spring may cause damage to the inflorescence of birch and result in low annual pollen sum.
 - The duration of the birch pollen season in Reykjavík is on average 17 days, beginning in the end of May and tailing off in the middle of June.
 - By May 15 the onset of the birch pollen season can be forecasted with an accuracy of one week, and its severity can be qualitatively predicted on the basis of its three-year periodicity.
- ACKNOWLEDGEMENTS**
- The Science Institute of the University of Iceland, the Icelandic Meteorological Office, the SIBS Association, the Icelandic Ministry of Environment, the City Council of Reykjavík, the Icelandic Research Council, and the Research Fund of the University of Iceland, are all thanked for working facilities and financial support during the period 1988 to 1996. Dr. Sheila Hicks at the University of Oulu is gratefully thanked for her improvements to the text.
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