

Cumulative temperatures for prediction of the beginning of ash (*Fraxinus excelsior* L.) pollen season

Annie Gérard Peeters

Section of Agro- and Biometeorology, Swiss Meteorological Institute, Krähbühlstrasse 58, Zurich, CH-8044, Switzerland

Received 18 November 1997; received in revised form 18 May 1998; accepted 20 May 1998

Abstract

The aim of this study is the analysis of the meteorological conditions leading to the release of ash pollen in order to predict the beginning of the pollen season in Zurich, Switzerland. For 12 years over a period of 14 consecutive years, it appears that ash pollen release begins when the cumulated mean daily temperatures starting on January 1 reach 220.7°C, admitting a variation of $\pm 30^\circ\text{C}$ that more or less corresponds to 3 consecutive days at 10°C. © 1998 Elsevier Science Ireland Ltd. All rights reserved.

Keywords: Ash pollen; Cumulated temperatures

1. Introduction

The ash tree (*Fraxinus*) belongs to the olive family and is widespread in central and northern Europe. It is also widely used as an ornamental tree in the Mediterranean area (Candau et al., 1994). Within the *Oleaceae* family, olive tree (*Olea europaea*) pollen is considered the most allergenic pollen in the Mediterranean area (Bousquet et al., 1985; D'Amato et al., 1988; D'Amato and Lobefalo, 1989; D'Amato and Spiesksma, 1993; Gonzalez Minero and Candau Fernandez-Menasque, 1996) as well as in the most southern part of Switzerland (the Tessin region). There, in Locarno, 54% of pollen allergic symptoms are due to this pollen (Gilardi et al., 1994). Cross-reactions between the different genera of the *Oleaceae* family have been observed in Europe (Bousquet et al., 1985; D'Amato and Lobefalo, 1989; Macchia et al., 1991). *Fraxinus* pollen has so many allergens in common with *Olea* that it may be that patients allergic to *Olea* pollen in the Mediterranean area react to *Fraxinus* pollen when travelling to central and northern Europe during April and May (D'Amato et al., 1988).

In Switzerland, for a long time *Fraxinus* pollen has been considered as secondarily allergenic pollen (Helbling et al., 1985). Spring allergic symptoms have been rather attributed to birch (*Betula* spp.) pollen which has always been considered as highly allergenic and which is released in the atmosphere at the same period of the year as the *Fraxinus* pollen (Helbling et al., 1985; Guerin et al., 1990; Leuschner, 1991; D'Amato and Spiesksma, 1993; Guerrier, 1993). But, in 1991 *Fraxinus* pollen count was especially high in the region of Zurich and moreover pollen grains had appeared 16 days before those of birch tree. Since then it has been recognised that the *Fraxinus* allergenicity had been underestimated in Zurich (Schmid et al., 1992; Schmid-Grendelmeier et al., 1994) as well as in France (Lelong et al., 1992). In the Tessin region, the ash pollen season always begins before the birch pollen season and 36% of positive reactions (skin prick test) are due to this pollen.

Ash pollen has been consequently included in the list of major allergenic pollen together with grass (*Poaceae*), birch and mugwort (*Artemisia*) pollen (Wüthrich and Peeters, 1991; Peeters et al., 1994;

Wüthrich et al., 1994, 1995; Frei et al., 1995; Wüthrich, 1995). This also reflects the opinion of other European researchers (D'Amato and Spiesksma, 1993).

One of the most important aims of aerobiology is the prediction of the date on which pollen causing allergic reactions appears. This may be a pretty difficult task since the variation of the date can be very large (see below). Therefore, in Switzerland research is now focused on the determination, as precisely as possible, of the beginning of the pollen season for the most important types of pollen: hazel (*Corylus*) (Frei, 1995), grass and, in this work, ash pollen. One of the first results of these works has been to demonstrate the great importance of local factors such as altitude, orientation and vegetation in addition to the meteorological factors that lead to pollination.

2. Material

2.1. Meteorological data

The Swiss Meteorological Institute (SMI) in Zurich has provided meteorological data. Data come from the automatic network and have been published in the Annals of the Swiss Meteorological Institute, 1983–1997 (Annalen der Schweizerischen Meteorologischen Anstalt, 1983).

2.2. Palynology

A Hirst-type volumetric pollen and spore trap (Burkard) was placed from 1984 until March 1993 on the roof of a building in Zurich. The building was situated at an altitude of circa 450 m.a.s.l. and approximately 50 m above ground level. In March 1993 the trap was been transferred to the roof of the Swiss Meteorological Institute (556 m.a.s.l.), 15 m above ground level.

Conventional methods, as described in Peeters and Zoller (1988), have been used for trap preparation and results analysis (such as slide evaluation). Pollen concentrations are expressed as the number of pollen grains per day/m³. Pollen data come from the Swiss work group for aerobiology for the years 1984–1992. Since 1993, data have come from the SMI.

2.3. Mathematical considerations

Only temperatures above or equal to 0°C have been taken into account in the calculation of cumulative sums; negative temperatures have been considered as equal to 0°.

3. Method

3.1. Required concentrations and superior limit

The first step of this study was the determination of the pollen concentration that would be appropriate for the prediction of the beginning of ash pollen season. The date at which this concentration is reached is going to become the superior limit for cumulative sums of mean daily temperatures.

Traditionally, the starting date for cumulative sums is the 1st of January. This date has been chosen in this work. In a second step the validity of this choice will be tested.

Daily concentrations of at least one, ten, 30, 50 and 100 pollen grains per cubic meter of air were tested (Table 1). The difference between the highest and lowest sum of cumulative temperatures reaches 100.2°C in the case of the very first pollen grain release and 103.1°C for a daily concentration of at least ten ash pollen grains per cubic meter of air. This difference amounts to 153.1, 152.2 and 159.4°C for respective daily concentrations of at least 30, 50 and 100 pollen grains. A minimal difference between extremes should ensure a greater precision in predicting the beginning of the pollen season. Therefore, the date of the very first pollen grain release has been kept as the superior limit.

3.2. Starting date for cumulated temperatures (inferior limit)

The second step was the determination of the date since which daily mean temperatures should be cumulated. The 1st of November, December, January and February were tested (Table 2), and it turned out that the 1st of January was the most favourable date to start cumulative sums. Beginning with this date allows the smallest difference between the extremes of cumulative temperatures.

4. Results

4.1. Beginning of the pollen season

In Zurich, between 1984 and 1997, the earliest release of *Fraxinus* pollen was observed in 1990 on the 26th of February and the latest happened 50 days later in 1987 on the 16th of April (Fig. 1).

Since 1989, the release of ash pollen seems to happen earlier in the year (i.e. in March and even at the end of February in 1990). In 1994, 1995 and 1997, it occurred during the first 10 days of March and from 1991 to 1993 during the second ten-day period of March.

Table 1
Sums of mean daily temperatures at Zurich from 1st January

	<i>Fraxinus</i>											
	First pollen		>Ten grains		>30 grains		>50 grains		>100 grains		Maximum	
	Date	t°	Date	t°	Date	t°	Date	t°	Date	t°	Date	t°
Year												
1984	14.04.	219.4	15.4.	232.3	21.4.	277.6	21.4.	277.6	21.4.	277.6	24.4.	322.4
1985	02.4.	224.3	09.4.	298.5	19.4.	363.6	20.4.	376.7	20.4.	376.7	20.4.	376.7
1986	08.4.	214.1	17.4.	251.3	21.4.	273.3	21.4.	273.3	25.4.	304.6	01.5.	362.5
1987	16.4.	249.1	16.4.	249.1	18.4.	276.4	18.4.	276.4	23.4.	328.5	24.4.	343.3
1988	26.3.	254.8	02.4.	286.2	16.4.	404.0	16.4.	404.0	18.4.	429.6	19.4.	445.2
1989	13.3.	236.6	16.3.	256.6	27.3.	336.2	27.3.	336.2	27.3.	336.2	31.3.	398.4
1990	26.2.	232.4	06.3.	261.4	08.3.	279.9	11.3.	311.7	11.3.	311.7	19.3.	391.7
1991	11.3.	202.3	11.3.	202.3	17.3.	251.8	17.3.	251.8	28.3.	329.9	10.4.	424.7
1992	17.3.	217.9	17.3.	217.9	21.3.	250.9	11.4.	354.8	12.4.	365.5	21.4.	429.5
1993	19.3.	249.0	19.3.	249.0	11.4.	383.3	13.4.	397.0	17.4.	430.0	17.4.	430.0
1994	04.3.	207.1	11.3.	273.4	15.3.	309.8	18.3.	326.2	22.3.	359.6	30.3.	448.5
1995	08.3.	225.1	25.3.	305.4	03.4.	345.6	03.4.	345.6	05.4.	375.3	21.4.	491.6
1996	26.3.	154.6	12.4.	237.5	16.4.	260.0	16.4.	260.0	17.4.	270.6	21.4.	328.5
1997	05.3.	202.5	05.3.	202.5	12.3.	254.5	12.3.	254.5	17.3.	300.8	18.3.	311.9
Mean		220.7		251.7		304.8		317.6		342.6		393.2
Minimum		154.6		202.3		250.9		251.8		270.6		311.6
Maximum		254.8		305.4		404.0		404.0		430.0		491.6
Difference		100.2		103.1		153.1		152.2		159.4		179.7

Sums of mean daily temperatures cumulated from the 1st of January to the date of the very first pollen release (2nd column), resp. to the date when a concentration of at least 10, 30, 50, or 100 (next columns) pollen grains per cubic meter of air is reached. In the last column, temperatures are cumulated up to the peak day. Mean, minimum and maximum values, as well as the difference between the extremes are indicated at the bottom of the table.

Except for 1996, phenological observations have revealed an early beginning of flowering since 1988 (Defila, 1994).

In 1996, respective concentrations of two and four grains per cubic meter of air were observed on March 26 and 28. Between the 26th and 29th of March only a few isolated ash pollen grains were reported from other stations in Switzerland, i.e. (from west to east) in Neuchatel (on the 28th of March), Bern (28th), Lucerne (29th) and Constance lake (26th and 28th). South of the Alps, in the Tessin region, the first pollen grains were trapped on the 25th of March in Locarno and on the 27th in Lugano. A strong south, southwest airflow may be the explanation for this sporadic presence of 'foreign' ash tree pollen north of the Alps. Long-range pollen transport has already been observed over Switzerland: sweet chestnut pollen was measured in a high valley region (St. Moritz, Haute-Engadine) and was backtracked to origin from a southern valley (Bergell) over the Maloja pass (Peeters and Zoller, 1988).

In the time span of 14 years covered by this study, the comparison between birch and ash tree pollen shows that ash pollen generally appears 2 or 3 days later than the birch pollen. However, in 1988, ash pollen appeared 17 days before birch pollen, and in 1991, 1992 and 1996 20 days before (see Table 3). These

observations reveal that the meteorological factors responsible for the release of ash or birch pollen into the atmosphere are different.

4.2. Pollen concentration

During this study, it appeared that between the release of the first pollen grains and a daily concentration of 30 grains, the average time span extends to 13 days. Once the concentration amounts to 30 pollen grains, it only takes 5 days to reach or exceed a daily concentration of 100 grains. These 5 days can be reduced to 3, if the calculation does not take into account the years 1991 and 1992, when 11 and 22 days were needed to reach these amounts.

The daily concentrations of ash pollen in the air remain above 100 pollen grains per cubic meter for a period of 10–20 days in Zurich.

The annual totals vary from 615 for the smallest amount in 1984 to 9680 for the highest in 1990 (Fig. 2). In contrast to other types of pollen such as hazel, there is no noticeable trend towards increasing or decreasing amounts of ash pollen (Frei, 1995).

4.3. Temperatures

From 1984 to 1997, the mean of the sums of daily

Table 2
Sums of mean daily temperatures cumulated from the 1st of November, December (of the preceding year), January and February to the date of the very first *Fraxinus* pollen release

	Cumulated daily average temperatures >0°C			
	T Nov. → 1 P.	T Dec. → 1 P.	T Jan. → 1 P.	T Feb. → 1 P.
Date of first pollen				
14.04.	400.0	297.2	219.4	178.0
02.04.	474.5	294.7	224.3	203.4
08.04.	407.5	334.2	214.1	164.8
16.04.	486.2	322.8	249.1	233.0
26.03.	501.4	351.2	254.8	147.7
13.03.	435.6	329.1	236.6	186.4
26.02.	438.8	342.8	232.4	175.1
11.03.	373.0	241.7	202.3	130.1
17.03.	372.7	255.4	217.9	187.1
19.03.	489.0	298.5	249.0	106.4
04.03.	414.4	336.5	207.1	108.1
08.03.	579.5	346.7	255.1	163.6
26.03.	319.0	204.8	154.6	131.5
05.03.	398.7	251.7	202.5	184.0
Mean	435.02	300.52	220.66	164.23
Minimum	319.00	204.80	154.60	106.40
Maximum	579.50	351.20	254.80	233.00
Difference	260.50	146.40	100.20	126.60

Mean, minimum and maximum values, as well as the difference between the extremes are indicated at the bottom of the table.

mean temperatures cumulated from the 1st of January to the first release of *Fraxinus* pollen reaches 220.7°C.

In 12 years out of 14, the cumulated temperatures corresponding to the start of pollination ranged from 190.7 to 250.7°C, showing a variation of $\pm 30^\circ\text{C}$ around the mean cumulated temperature. In 1988, the cumulated temperature exceeded the upper limit by only 4.1°C. As for 1996, the very first pollen grain was trapped when the cumulative temperature only reached 154.6°C. But, as seen before, this first grain as well as a few others could be 'foreign' pollen grains transported by wind. The second appearance of pollen was recorded some 15 days later, with a cumulative temperature of 237.5°C, which would fit perfectly well into our theory.

Therefore, assuming a fictive daily maximum temperature of 10°C, it is possible to predict the start of the *Fraxinus* pollination season with a precision of ± 3 days. Higher temperatures may be explained by precipitation occurring just before the date of the expected pollen release. When precipitation occurs, no pollen is released, while the cumulative sum of temperatures keeps on increasing, therefore generating variations in the results.

5. Discussion

To consider the very first appearance of ash pollen as the beginning of the pollination season does not correspond exactly to the reality, since relatively long-lasting

periods of precipitation may occur between the appearance of the very first pollen grain into the air and the next ones (i.e. the real start of the pollination season). However, the presence of even very little pollen can be the obvious signal that ash trees located at favourable or protected places are flowering. In Zurich, at the lake level (406 m.a.s.l.) ash trees blossom earlier than those located in the vicinity of the trap. The threshold of 167 pollen grains per cubic meter of air at which hay fever symptoms are observed (Horak et al., 1980) is probably

Table 3
Date of the appearance of the very first pollen grain of *Fraxinus* and *Betula* in Zurich, and the difference between the two dates

Year	Release of the very first pollen		
	<i>Fraxinus</i>	<i>Betula</i>	Difference (days)
1984	14.04.	13.04.	−1
1985	02.04.	03.04.	+1
1986	08.04.	15.04.	+7
1987	16.04.	06.04.	−10
1988	26.03.	12.04.	+17
1989	13.03.	27.03.	+14
1990	26.02.	11.03.	+13
1991	11.03.	31.03.	+20
1992	17.03.	06.04.	+20
1993	19.03.	23.03.	+4
1994	04.03.	21.03.	+17
1995	08.03.	26.03.	+18
1996	26.03.	15.04.	+20
1997	05.03.	14.03.	+9

Date of appearance of the very first pollen of Fraxinus in Zurich in air

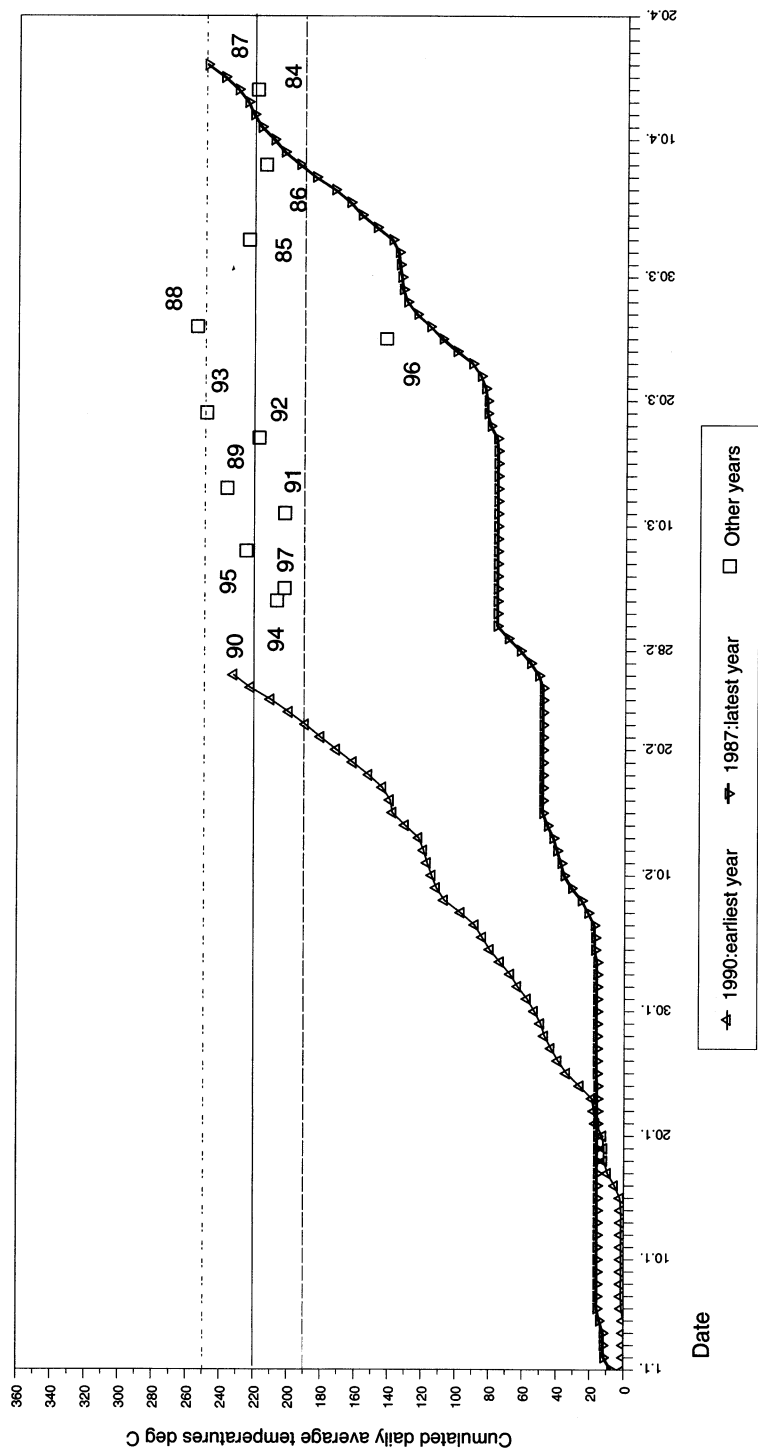


Fig. 1. Sums of cumulated mean daily temperatures (1990 and 1987) and date of appearance of the very first *Fraxinus* pollen in Zurich (other years).

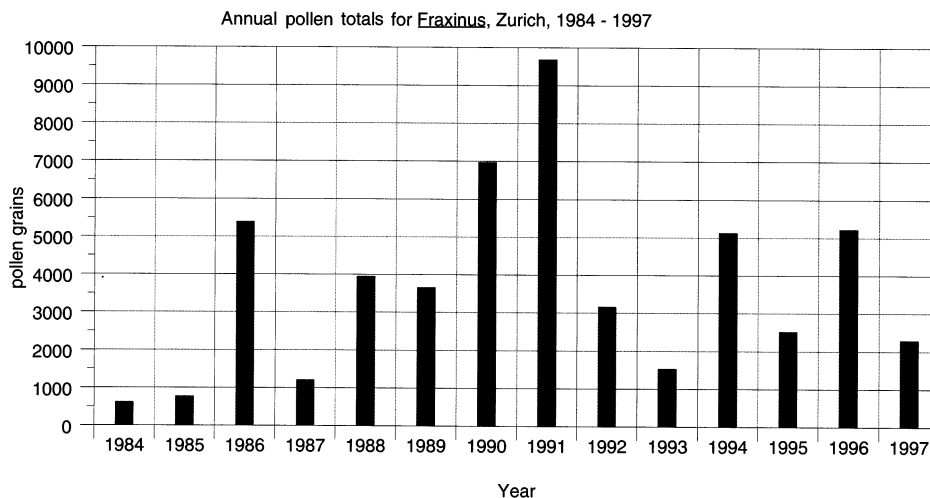


Fig. 2. Annual total of *Fraxinus* pollen in Zurich, 1984–1997.

exceeded at lake level, when at the altitude of the SMI (556 m.a.s.l.) flowers are still closed and no pollen has yet been monitored.

6. Conclusions

The method chosen to study the case of Zurich, based on cumulated temperatures, very simply allows prediction of the beginning of the ash pollen season. The same approach has been used for predicting the birch pollen season but it failed because other factors had to be taken into consideration. Researches on that approach are still continuing. Moreover the determination of the required concentration and starting date for calculation of cumulative sums of mean daily temperatures has to be adapted to every single type of pollen. The different types do not react in the same way to meteorological factors. The location of the trap as well as microclimatic elements may influence the results.

References

- Annalen der Schweizerischen Meteorologischen Anstalt, 1983–1997.
- Bousquet J, Guérin B, Hewitt B, Lim B, Michel F-B. Allergy in the Mediterranean area. III: Cross-reactivity among *Oleaceae* pollens. *Clin Allergy* 1985;15:439–48.
- Candau P, Gonzalez Minero F, Romero F. Aeropalynology of *Fraxinus* (Ash) in an urban area of southwestern Spain. *Aerobiologia* 1994;10:47–51.
- D'Amato G, Lobefalo G. Allergenic pollens in the southern Mediterranean area. *J Allergy Clin Immunol* 1989;83:116–22.
- D'Amato G, Spieksma FTM. Pollenallergie in Europa. *Allergologie* 1993;16:430–3.
- D'Amato G, Mullins J, Noland N, Spieksma FTM, Wachters R. City spore concentrations in the European Economic Community (EEC). VII. *Oleaceae* (*Fraxinus*, *Ligustrum*, *Olea*). *Clin Allergy* 1988;18:541–7.
- Defila C. Phänologische Beobachtungen in der Schweiz in Jahr 1993. *Schweiz Z Forstwes* 1994;145(5):333–8.
- Frei T. Einfluss der mittlere Tagestemperatur auf die Haselpollenfreisetzung in Zürich. *Präv-Rehab* 1995;8:59–63.
- Frei T, Torricelli R, Peeters AG, Wüthrich B. The relationship between airborne pollen distribution and the frequency of specific pollen sensitization at two climatically different locations in Switzerland. *Aerobiologia* 1995;11:269–73.
- Gilardi S, Torricelli R, Peeters AG. Pollinosen im Kanton Tessin. Eine prospektive Studie in Locarno 1990–1993. *Schweiz Med Wschr* 1994;124:1841–7.
- Gonzalez Minero FJ, Candau Fernandez-Menasque P. Prediction of the beginning of the olive full pollen season in southwest Spain. *Aerobiologia* 1996;12:91–6.
- Guerin B, Wüthrich B, Peeters AG, Choquet PH. Allergie aux pollens d'arbre. *Méd Hyg* 1990;48:1089–96.
- Guerrier G. Les pollinoses aux arbres chez les enfants dans la région lyonnaise. 'Il ne faut pas que l'herbe cache la forêt'. *Rev Fr Allergol* 1993;33:221–5.
- Helbling A, Leuschner B, Wüthrich B. Pollinosis. IV: Welche Pollen sollen in der Allergie-Praxis getestet werden? *Schweiz Med Wschr* 1985;115:1150–9.
- Horak F, Hussarek M, Jäger S, Skoda-Türk R. Die Bestimmung der Aggressivität allergisierender Pollenarten. *Klin Wschr* 1980;75:532–8.
- Lelong M, Castelain MC, Sulmont G. Existe-t-il en France, une pollinose au frêne? *Rev Fr Allergol* 1992;32:41–2.
- Leuschner RM. Comparison of airborne pollen levels in Switzerland at four recording stations (Davos, Lucerne, Nyon and Basle) during 1989. *Int J Biometeo* 1991;35:71–5.
- Macchia L, Caiffa MF, D'Amato GD, Tursi A. Allergenic significance of *Oleaceae* pollen. In: D'Amato G, Spieksma FTM, Bonini S, editors. *Allergenic Pollen and Pollinosis in Europe*. Oxford: Blackwell, 1991:87–93.
- Peeters AG, Zoller H. Long-range transport of *Castanea sativa* pollen. *Grana* 1988;27:203–7.
- Peeters AG, Frei T, Wüthrich B. Vergleich des Pollenflugs und der Pollinose-Häufigkeit an zwei klimatisch verschiedenen Standorten in der Schweiz (Zürich und Locarno). *Allergologie* 1994;17:501–4.
- Schmid P, Peeters AG, Wüthrich B. L'allergie aux pollens de frêne existe, nous l'avons rencontrée. *Rev Fr Allergol* 1992;32:139–40.

- Schmid-Grendelmeier P, Peeters AG, Wahl R, Wüthrich B. Zur Bedeutung der Eschenpollenallergie. *Allergologie* 1994;17:535–42.
- Wüthrich B. Pollenallergie. Aktuelles zur Epidemiologie, Pathogenese, Diagnostik und Therapie. *Dtsch Ärzteblatt* 1995;92:809–14.
- Wüthrich B, Peeters AG. Allergenic pollen and pollinosis in Switzerland. In: D'Amato G, Spieksma FTM, Bonini S, editors. *Allergenic Pollen and Pollinosis in Europe*. Oxford: Blackwell, 1991:197–202.
- Wüthrich B, Peeters AG, Schindler C, Brändli O, the Sapaldia Team. Prevalence of atopy, hay fever and asthma in eight areas of Switzerland (Sapaldia Study). *Allergy Clin Immunol News*, Suppl 2, 1994.
- Sapaldia Team, Wüthrich B, Schindler C, Leuenberger P, Ackermann-Liebrig U. Prevalence of atopy and pollinosis in the adult population of Switzerland (Sapaldia Study). *Int Arch Allergy Immunol* 1995;106:149–56.