



Airborne pine (*Pinus* spp.) pollen in the atmosphere of Perugia (Central Italy): Behaviour of pollination in the two last decades

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Abstract

The phenology of many species, which grow in temperate climate, is principally regulated by the temperature and the plants respond with variations in the beginning, in the duration and in the intensity of the various phenophases towards every climate change. We have analysed the data of *Pinus* pollination in Perugia, Central Italy, during last 2 decades (1982–2001), in a period during which the annual mean temperature significantly increased by about 0.8 °C. The pine pollination started, on average, between the end of March and mid-April and ended in the last days of June, with a mean duration of 65 days. The start dates showed a significant negative correlation with the average air temperature in March and significant trends towards an earlier beginning of pollination by 18 days (–0.9 day/year) and a shorter duration of the pollen season by 10 days (–0.6 day/year) were found over the studied period. Moreover, the trend of the daily pollen counts showed, on average, an almost normal distribution, but the analysis of each yearly trend revealed significant differences correlated with the mean temperature during the pollen season. These observed trends in pine pollination suggest the use of aerobiological monitoring of this airborne pollen as indicator of temperature change in Central Italy over a relatively long period.

1. Introduction

Plants are excellent bio-indicators and, in zones with temperate climate in which the seasons are clearly differentiated, the vegetation synchronises its development with the alternating seasons.

The phenology of many herbaceous and arboreal species which grow in this climate is principally governed by the temperature, even if the availability of water and the photoperiod can influence some phases of growth (Leith, 1974).

Every time there are anomalies and as climate changes, plants respond with variations in the beginning, in the duration and in the intensity of the various phenophases. Thus, changes in phenological phases of some species can be used to record the climatic changes which have occurred in recent decades. In recent years, especially the temperature, has registered a positive trend in many regions of the Northern Hemisphere (van Vliet and de Groot, 2001); the

same trend has concerned Perugia (Central Italy) where increase in the annual mean temperature (about 0.8 °C) in the last 20 years has been registered (Frenguelli, 2001).

In Europe, many data from the International Phenological Gardens revealed, for the last decades, an advance of spring events, a delay in autumn events and a lengthening of the growing season (Ahas et al., 2000; Menzel, 2000; Defila and Clot, 2001). Moreover, aerobiological studies have shown an anticipated beginning of the pollination of alder, hazel and elm in Nordic countries (Jäger et al., 1996), birch in the UK (Emberlin et al., 1997) and grasses in Switzerland (Frei and Leuschner, 2000). In previous studies carried out in Perugia (Frenguelli, 2001; Frenguelli et al., 2001) the analysis over 20 years of the pollination of many arboreal and some herbaceous species has revealed the same trend: for example *Quercus*, *Olea* and *Castanea* showed, on average, an earlier pollination of 0.5 day/year in the period.

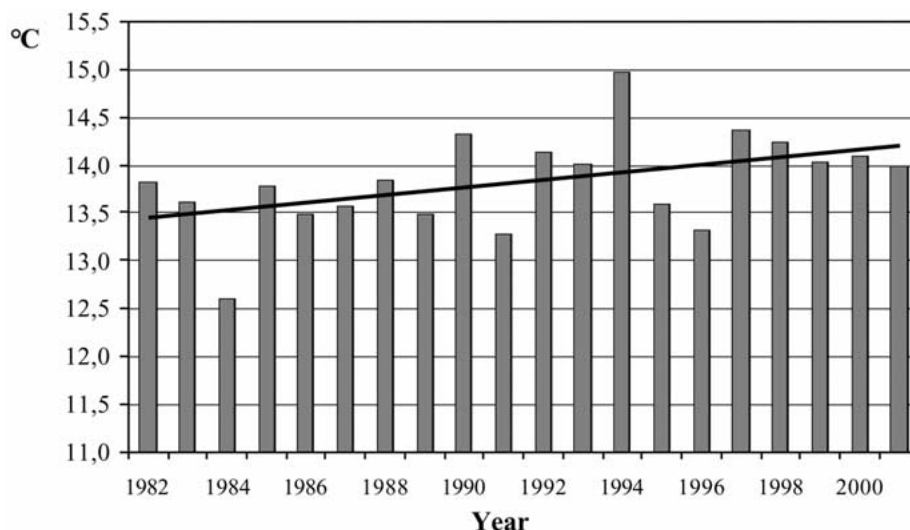


Figure 1. Annual mean temperature over the studied period (trend-line equation: $y = 0.04x - 64.93$; $r^2 = 0.22$; $p = 0.04$).

The aim of this paper is to analyse the pollination of *Pinus* genus in the last two decades, registered by means of aerobiological monitoring in the city of Perugia and to correlate it with the average temperature of preceding periods and during the pollination, in order to stress the possibility of using this species as an indicator of the climatic changes registered in the same years.

2. Materials and methods

Daily pollen counts for *Pinus* were extracted from the data of the aerobiological sampling centre located at the Agricultural Faculty of Perugia University and obtained by a volumetric spore trap (Lanzoni VPPS 2000). The sampling and counting methods have been described elsewhere (Frenguelli et al., 1981) and daily pollen data are expressed as number of pollen grains per cubic meter of air. The most common species sources of *Pinus* pollen type in the Perugia area are: *Pinus halepensis*, *P. sylvestris*, *P. radiata*, *P. nigra*, *P. brutia* and *P. pinea*, growing, above all, in public and private gardens, and along the main roads in the city. Perugia is a hill town overlooking the central valley of the River Tiber (Central Italy) and is characterised by a sub-mediterranean climate.

The beginning of the pollen season, the peak day, the end and duration of the season, and the annual total amount (sum of daily pine-pollen counts) have been calculated for the period 1982–2001. To identify the

date of the beginning of pollination we have used the 5% method considering the date of pollination onset when the daily count reaches the 5% level of the total annual pollen sum (Nilsson and Persson, 1981). The end of the Main Pollination Period (MPP), for each year, was defined as the date when 95% of the annual total was collected (Jäger et al., 1996) and the duration of the MPP was calculated considering, in days, the period when the pollen collected was included between 5% and 95% of the annual total. The peak day was the first occurrence of the highest value in each year.

The temperature data was collected by means of an automatic meteorological station situated next to the pollen trap.

The existence of trends in the studied parameters over the two decades has been analysed after transformation of all pollen data as running means to avoid short term fluctuations (Emberlin et al., 1997). Statistical regression analysis was performed and the connections were evaluated with regression coefficients.

3. Results

The annual mean temperature increased during the 20 studied years by about 0.8 °C with a linear significant trend ($p = 0.04$) (Figure 1). The coldest year was 1984 with a mean temperature of 12.6 °C and the hottest was 1994 with 15.0 °C; 80% of the colder years were

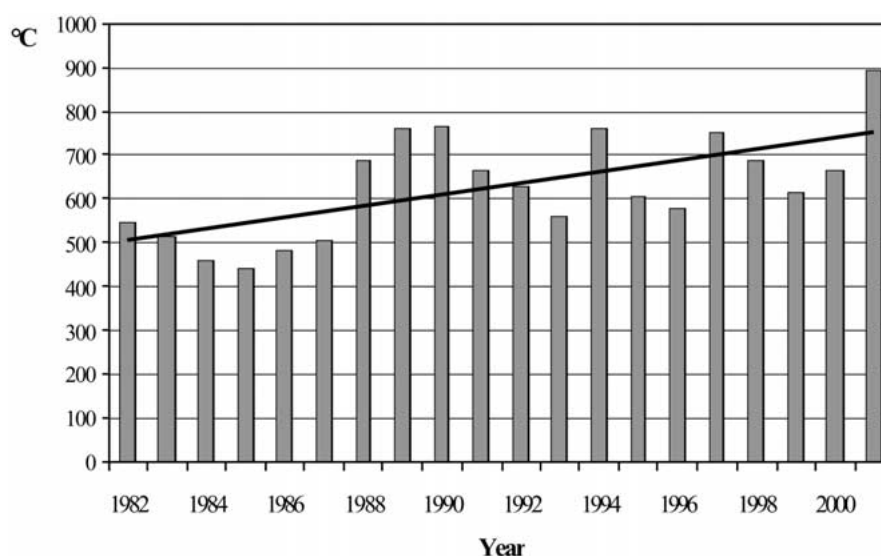


Figure 2. Cumulative daily mean temperature over January–March period (trend-line equation: $y = 12.91x - 25076.5$; $r^2 = 0.39$; $p < 0.01$).

in the first decade. Not all the months contributed equally to this increase and January–March period was one in which the most significant increase occurred (Figure 2).

The dates of the beginning of pollination in the period are reported in Table 1 and it appears clear that there is a marked difference between the years: the earliest pollination was in 2001 and the latest in 1984, with a difference of 41 days. The average date was identified as occurring on 15th April (105 days from the 1st of January) with a standard deviation which was relatively high reaching a value of 11.2. The onset of pollination advanced, over the period, of 18 days, with a linear highly significant mean trend ($p < 0.01$), calculated on a 3 years running mean, of -0.9 day/year (Table 2).

Considering that the release of pine pollen starts between the end of March and the middle of April, we analysed the correlation between the starting dates of pine pollen season and the mean daily temperature in March, which usually precedes the pollination of this *taxon* in Central Italy; it is clearly identifiable the negative trend of the starting dates values responding to rising mean temperature in March, over the 20 studied years (Figure 3).

The duration of the main period of pollination, as indicated in Table 1, also showed a high standard deviation: the shortest duration of 39 days was registered in 1992, while the longest of 86 days in 1988. The trend of the duration, which was also calculated on a 3 years

Table 1. Characteristics of the pine (*Pinus* spp.) pollen seasons in Perugia. For the start, the end and the peak of pollination the dates are reported as days number, from January 1st.

Years	Start dates	End dates	Duration days	Annual sum (pollen/m ³)	Peak Peak	Kurtosis
1982	115	190	75	1601	149	6.45
1983	106	176	70	288	141	6.30
1984	122	196	74	1721	163	-0.90
1985	106	172	66	1844	146	3.00
1986	115	179	64	2187	138	2.00
1987	120	170	50	2082	150	2.32
1988	106	192	86	1251	144	1.87
1989	91	173	82	978	143	1.04
1990	115	169	54	1757	143	2.76
1991	100	179	79	1229	178	0.59
1992	111	150	39	1485	133	4.10
1993	107	167	60	1896	147	1.41
1994	89	157	68	1635	140	6.13
1995	105	169	64	1399	151	3.13
1996	112	163	51	1491	147	5.01
1997	87	155	68	1707	137	5.65
1998	95	174	79	1891	136	4.83
1999	107	163	56	1055	145	1.75
2000	108	155	47	1695	139	3.85
2001	81	153	71	1933	135	3.36
Mean	105	170	65	1556	145	3.23
S.D.	11.2	13.0	12.6	439.6	10.3	2.0

Table 2. Equations, coefficients and significance levels of trends in start, duration and annual sum of pine (*Pinus* spp.) pollination in Perugia over the 20-year studied period.

Parameters	Trend-line equation	Coefficient of trend (R^2)	Significance level	Linear trend day/year
Start of pollination	$y = -0.98x + 2057.4$	0.768	$p < 0.01$	-0.9
Duration of MPP	$y = -0.68x + 1412.3$	0.273	$p = 0.03$	-0.6
Annual sum	$y = 1.97x - 2356.3$	0.002	n.s.	—

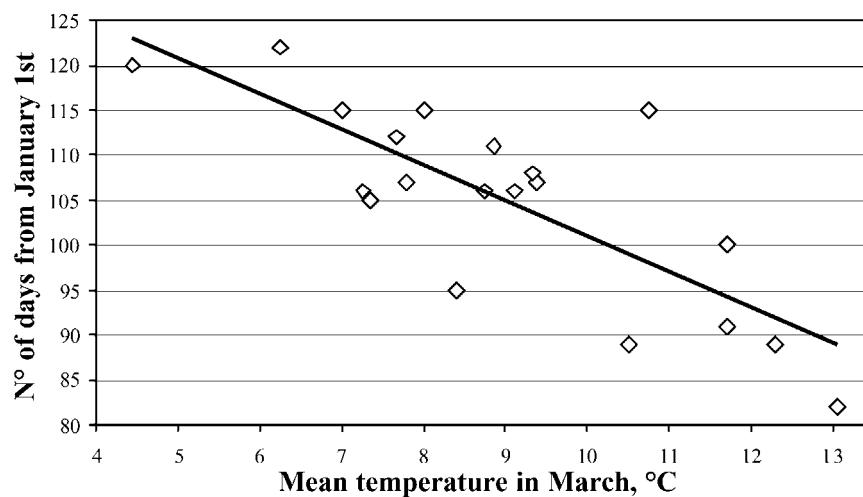


Figure 3. Correlation between starting dates of the *Pinus* spp. pollen season and mean temperature in March, over the 20-year studied period (trend-line equation: $y = -3.93x + 140.40$; $r^2 = 0.61$; $p < 0.01$).

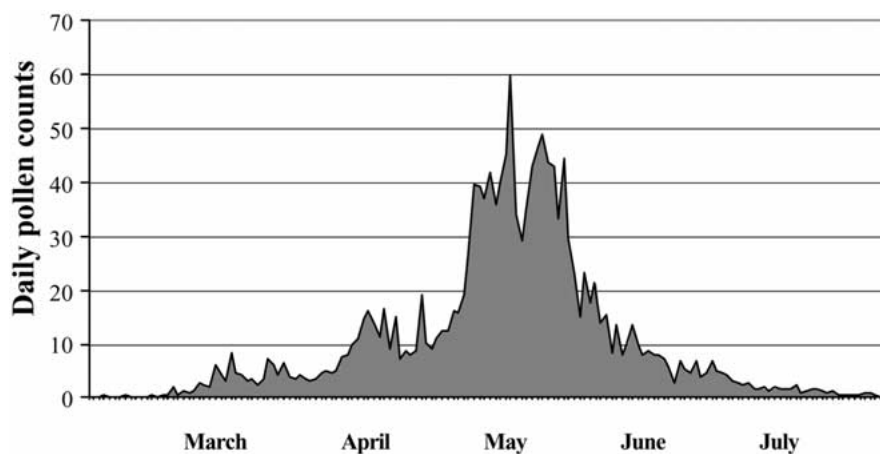


Figure 4. Average of daily pollen counts (pollen/m³) of airborne *Pinus* pollen for the 20-year studied period (1982–2001).

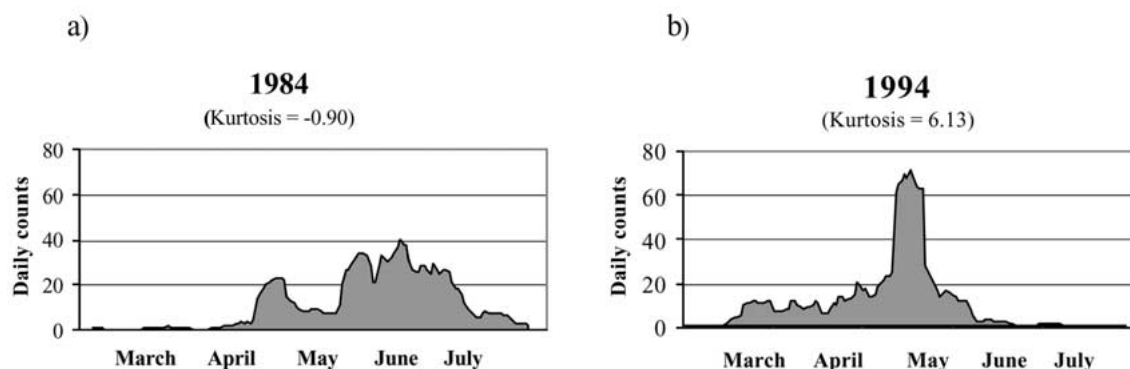


Figure 5. Ten-day running mean curves of daily pollen counts (pollen/m³) of airborne *Pinus* pollen in 1984 and 1994 with kurtosis values.

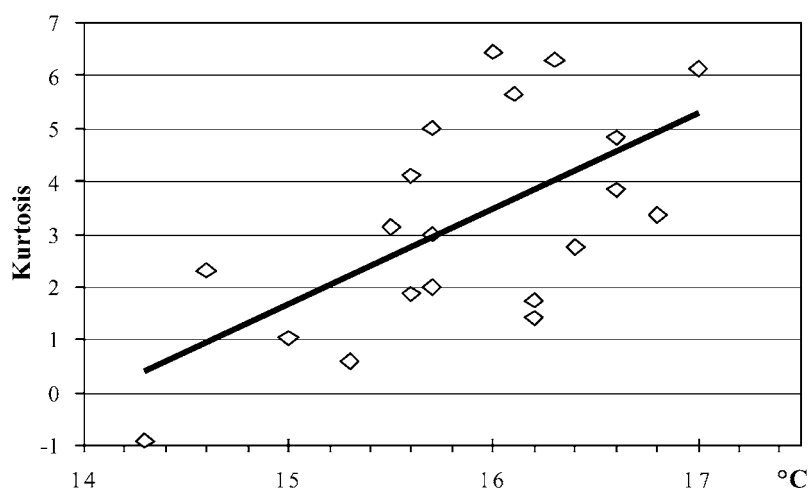


Figure 6. Correlation between the mean temperature during the March–July period and the kurtosis values of *Pinus* spp. daily pollen counts distribution (data expressed as ten-day running mean) over the 20-year studied period (trend-line equation: $y = 1.81x - 25.42$; $r^2 = 0.39$; $p < 0.01$).

running mean, showed a total significant decrease ($p = 0.03$) of 10 days equal to -0.6 day/year. No significant differences were registered about the annual sums (Table 2).

The mean pollination trend (Figure 4) shows an almost normal distribution with a kurtosis value equal to 3.23 (Table 1), but the analysis of each yearly trend showed significant differences as underlined by kurtosis values calculated on the ten-day running means curves of daily counts (Table 1). In the years in which during the pollination the temperature was lower than the mean (i.e. 1984) the pollen was released gradually during the season and therefore there was not an easy identifiable peak and the curve had flatter tops than the normal (Figure 5a). Instead, in the warmer years (i.e. 1994) the presence of pollen in the atmosphere was more concentrated with an excess of

values near the mean and then with a high kurtosis value and a well identifiable peak (Figure 5b).

Figure 6 shows the correlation between the mean temperature over the March–July period and the kurtosis values of daily pollen counts over the same period, for each of the 20 studied years. It appears clearly the positive correlation between these two parameters: higher is the temperature during the pollination period, higher is the kurtosis value, that is the pollination peak is very easily identifiable.

4. Discussion and conclusions

The pollination of *Pinus*, as that of many other *taxa* (i.e. Frenguelli et al., 1991; Norris-Hill, 1998; Clot, 2001), is regulated by the temperature in the imme-

diately preceding months: in Perugia, it is the average temperature of the month of March which has a significant influence on the date of onset. In Northern, Central and Eastern Europe the mean linear trend of springtime phenophases referred to *Pinus sylvestris* is only -0.02 day/year (Menzel, 2000) and Jäger et al. (1996) report also not significant values about the beginning of pollination of the same species as monitored by airborne pollen in the atmosphere of Vienna and of some Nordic countries. But in Central Italy the *Pinus* pollen type monitored is released, other than *P. sylvestris*, above all by other species of the genus *Pinus* as reported in Materials and methods, many of them characteristic of the mediterranean area, thermophilic, less tolerant to low winter temperature, more sensitive to temperature during winter and releasing pollen before *P. sylvestris* such as *P. brutia* and *P. halepensis*.

Thus, in Central Italy, where there are many taxa with anemophilous pollination which are capable of responding significantly to variations in temperature (Frenguelli and Bricchi, 1998), the pollen of *Pinus* seems to be very sensitive to this parameter because, when the temperature increases, it shows not only a significant earlier pollination, but also significant reductions in duration of the main period of pollination and characteristic trend of the pollen presence in the atmosphere.

In the sub-mediterranean climatic belt the behaviour of the *Pinus* pollination could be taken into consideration as bioindicator of the climatic changes and in particular to monitor changes in mean temperature of the air. Above all, in areas where there are no Phenological Gardens, which historically have this role, aerobiological monitoring carried out continuously and with historical series of 15–20 years could be a valid alternative and provide us with statistical significative indications.

The aerobiological monitoring of *Pinus* pollen is moreover very easy in that it is simple to recognise on monitoring slide thanks to its saccate morphological characteristics and therefore it can not be confused with other pollen.

We do not know if in future the temperature of the air will follow this trend or will stagnate or decrease; in any case, we should register future changes in Central Italy using this relatively simple kind of extremely sensitive monitoring, easy to register and less subject to individual interpretation of phenological field surveys.

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