

The influence of climate changes in *Platanus* spp. pollination in Spain and Italy

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Abstract

There is evidence of a significant increase in air temperature in the northern hemisphere over recent decades, with consequent changes for anemophilous pollen. In this work we present the effects of climatic change on *Platanus* spp. pollination in different areas of Italy and Spain, characterized by different climates. In particular, the historical series of pollen monitoring and meteorological data of two Italian stations, Perugia (1982 – 2003) and Torino (1985 – 2003), and two Spanish stations, Santiago de Compostela (1992 – 2003) and Vigo (1994 – 2003), were analysed. The changes recorded in all stations included the timing and behaviour of pollen release. However, no or minimal influence on the total pollen emission was found. Research has linked the changes in phenological events to an increase in temperature, moreover in this study temperature changes are believed to be mainly responsible for the variations recorded in the pollen season of *Platanus*. A previous start of pollination (–0.66; –1.21; days/year) is reported in both Italian stations where the temperatures have significantly increased and a delay of 0.2 – 0.8 days/year in Spanish stations where a different trend of temperature is recorded. Other important data is given regarding the type of discharge of pollen grains during the pollen season. Pollination curves are examined by two statistical shape parameters (kurtosis and skewness) which show that pollen release is more gradual with higher temperatures or faster under colder conditions. A regression analysis links the atmospheric pollen presence to mean air temperature.

Keywords: Climatic changes, pollination, phenology, *Platanus*

The climate of our planet has never been constant so natural ecosystems have succeeded each other over time, adapting to intrinsic levels of climatic variations (Sæther et al., 2000). Research on current climatic changes refers both to natural variations and, more specifically, to human intervention which is accelerating the process (D'Odorico et al., 2002, Menzel & Fabion, 1998). Awareness of this substantial change has grown over the last twenty years during which temperatures have increased, the sea level has risen by about 2 mm per year, and the risk of flooding has increased due to heavier rainfall. Plant ecosystems have undergone changes, synchronizing their growth rhythms with temperature variations. The International Phenological Gardens

has documented over the last 20 years an earlier spring flowering and a delay in autumn flowering caused by the increase of temperature in Europe (Ahas et al., 2000; Menzel, 2000; Defila & Clot, 2001).

The chronology of the phenological phases of plants is a valid bioindicator in order to check if and how ecosystems react to temperature change, but this is only statistically significant if there is sufficient historical data. The phenological phase of flowering can be studied either by checking the inflorescences, or by monitoring their pollen in the atmosphere; this second method is particularly reliable for plants such as gymnosperms and anemophilous angiosperms. For this reason, in countries where pollen

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monitoring is carried out on regular basis for aerobiological studies, there are continuous series of historical data which can be used to study phenological changes. Many papers report the effects of climatic changes on the flowering of plants using the data from pollen monitoring in correlation with temperature data: in northern Europe, early pollination has been reported for *Ulmus*, *Betula*, *Alnus* and *Corylus* (Emberlin et al., 2002; Jäger et al., 1996; Van Vliet et al., 2002); in Italy the most relevant early pollination occurs in spring flowering plants (Frenguelli, 2002; Frenguelli et al., 2002), while for winter flowering plants, for example *Corylus*, there is a delay of the beginning of the pollen season (Frenguelli, 2002; Tedeschini et al., 2003a).

The changes in the flowering season show that within a wide area of distribution of a genus, characterized by different climatic belts, a species can react to the same stimulus in different ways. In this paper, the influence of climatic changes on *Platanus* spp. pollination in Italy and Spain are reported.

Material and methods

The study of *Platanus* spp. (plane tree) pollination period was made by monitoring atmospheric pollen concentrations in four European areas (Figure 1). The periods of monitoring vary between different

stations with 21 and 18 years for the Italian monitoring stations; and 11 and 9 years for Santiago and Vigo, respectively.

One of the Italian monitoring stations (Perugia) has aerobiological monitoring data from 1982 to 2003. Perugia lies in central Italy at an altitude of 443 m a.s.l. and is located approximately at 100 km from the Mediterranean Sea. It is surrounded on the south-west by the valley of the Tiber River and on the north-west by the Trasimeno Lake. It has a mean annual temperature of 13.8°C, a mean maximum temperature of 17.1°C and a mean minimum temperature of 9.2°C. It has a submediterranean climate with an average of 877 mm annual precipitation.

The second Italian monitoring station (Torino) lies in northern Italy at 260 m a.s.l. It is located on a plain crossed by important rivers such as the Po, Dora and Stura. The vegetation is composed mainly of riparian species, such as *Platanus* spp., which is typically cultivated along avenues and in parks. It has a mean annual temperature of 13.5°C, a mean maximum of 17.4°C and a mean minimum of 9.5°C. It has a subcontinental climate with an average of 891 mm annual precipitation. For this monitoring station, the data from 1985 to 2003 was considered.

The other European stations, located in Spain, are in Santiago de Compostela and Vigo. Santiago de Compostela is located in north-west of Spain at 270 m a.s.l. along Ulla river valley, 50 km inland

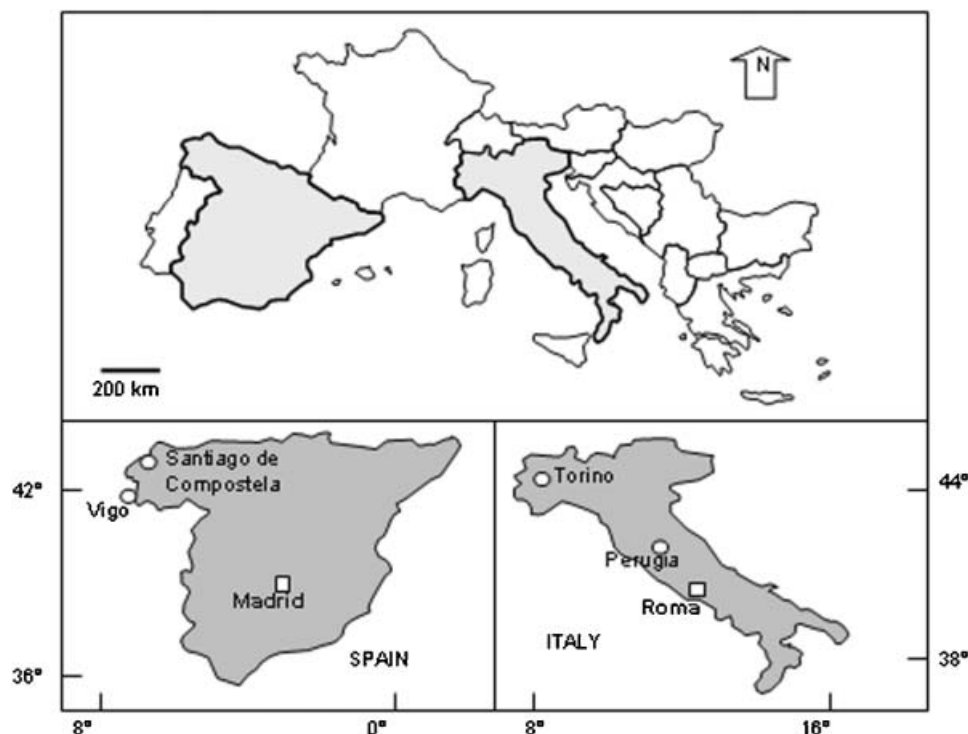


Figure 1. Location of the studied areas in Europe.

from the Atlantic Ocean, with a temperate maritime climate. It has a mean annual temperature of 12.9°C, with mean maximum and minimum temperatures of 17.1°C and 8.8°C respectively, and a total annual precipitation of 1288 mm. For this monitoring station the data from 1992 to 2003 was considered.

The city of Vigo is situated at sea level on the right-hand shore of the Vigo estuary. The valley making up the city has a small drainage system, mainly running north-south and south-west to north-east. Like Santiago, it has a temperate maritime climate, but in this case the influence of the ocean is greater and the mean annual temperature is 14.9°C, the mean maximum is 18.8°C and the mean minimum is 11°C. It has the highest total annual precipitation with 1412 mm. For this monitoring station, the data from 1994 to 2003 was considered.

The species of *Platanus* investigated in Perugia, Santiago de Compostela and Vigo were *P. orientalis* L. and *P. × hybrida* Brot. (= *P. × acerifolia* [Aiton] Willd.) which are the most common species, while in Torino *P. × hybrida* is prevalent, and *P. occidentalis* and *P. orientalis* are rare.

A 7-day pollen trap made by Lanzoni Italy (VPPS 2000), based on the Hirst model pollen trap (Hirst, 1952), was used to monitor airborne pollen in the four stations. These instruments were located at a height of about 15 to 18 m above ground at all stations. In Perugia, the trap was located on the roof of San Pietro Monastery where the Agriculture Faculty is located; in Torino, on the roof of the Mauriziano Hospital; in Santiago de Compostela, on the roof of the Pharmacy Faculty and in Vigo, on the terrace of the town hall. The methods of preparation and analysis of the samples were the same for each station, following Frenguelli et al. (1981). The mean daily values were represented as the number of pollen grains per cubic metre of air (p/m³). The meteorological data used for the study was recorded in Perugia, using an automatic meteorological station, located close to pollen trap. In Torino the data was provided by the airport meteorological

service and in Santiago de Compostela and Vigo by the National Institute of Meteorology.

In this work the main pollination period was considered, discarding the 2.5% initial and final values of the annual pollen counts. This method is considered the best for *Platanus* pollination producing the most significant data (Mullenders, 1974; Emberlin et al., 2002). The following parameters describing pollination were considered: the starting date; the length of the season; the final pollination date; the peak day; the peak value; and the total annual amount (P.I.=pollen index). The behaviour of pollination was examined through the shape statistical parameters: kurtosis and skewness to evaluate the pollen distribution during the pollination period (Frenguelli et al., 2002; Tedeschini et al., 2003b, 2004a).

In this work the daily temperatures data for each station, periods: 1982–2003 (Perugia), 1985–2003 (Torino), 1992–2003 (Santiago de Compostela) and 1994–2003 (Vigo), were compiled to monthly and annual means. These were then smoothed by a 5-year running means for statistical analysis. Five year running means were also calculated for the dates of pollination for statistical analysis.

Results

In the selected areas, the annual mean temperature has significantly increased in recent years. The temperature increased by about 0.08°C per year in Perugia, and by 0.16°C in Torino. The continental area (Santiago) with a warmer climate and little oceanic influence has a similar trend >0.055°C per year. Not all months contributed equally to this increase, as the period from January to June had the most significant increase. March was the month with the highest significant trend in all stations (Table I). In Vigo, which is under oceanic influence, the mean temperature decreased with a significant trend of about 0.26°C per year.

Platanus pollen season starts during March (Figure 2), and we analysed the trends of the

Table I. Slopes and significance levels of the mean temperature year and month trends during the studied period.

Period	Slope (R^2 value)			
	Vigo	Santiago	Perugia	Torino
Year	−0.262*** (0.636)	0.055* (0.333)	0.078*** (0.582)	0.156*** (0.934)
January	−0.214 (0.322)	0.035 (0.028)	−0.004 (0.001)	0.072** (0.187)
February	−0.089 (0.142)	0.097 (0.068)	0.111*** (0.321)	0.191*** (0.598)
March	−0.185** (0.491)	0.119* (0.055)	0.119*** (0.303)	0.184*** (0.640)
April	−0.399** (0.450)	0.029 (0.080)	0.001 (0.000)	0.091*** (0.546)
May	−0.217*** (0.724)	0.080 (0.066)	0.114*** (0.608)	0.195*** (0.839)
June	−0.507*** (0.823)	0.047 (0.061)	0.212*** (0.555)	0.205*** (0.662)

* – $p < 0.1$; ** – $p < 0.05$; *** – $p < 0.001$.

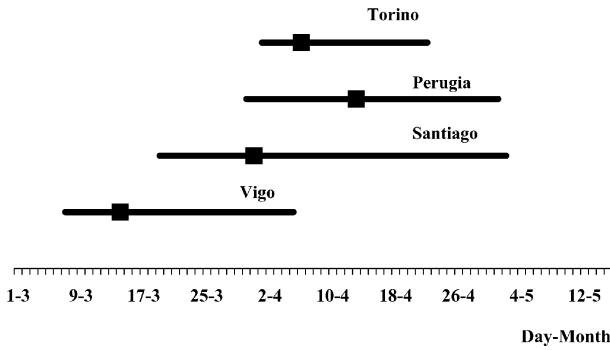


Figure 2. Length average of the *Platanus* pollen season in the studied years. Mean peak value date marked with a point.

parameters which define its pollen season. *Platanus* pollen is usually released earlier into the atmosphere of Vigo, the city with the highest mean annual temperature, and afterwards in Santiago and Perugia which have lower average temperatures. Finally, after several weeks, the corresponding phenomenon occurred in Torino, the city with the coldest climate (Figure 2). The average values of maximum concentration (Figure 2) generally occur in March in Spain and some days later in the coldest Italian stations.

The pollination start date trend has a significant negative slope (Table II) in the Italian areas studied, which indicates that the onset of the pollen season tended to begin progressively earlier and a significant advance of almost 0.66 – 1.21 days per year (Table II). In the warmest Spanish stations, Santiago de Compostela and Vigo, an opposite trend is shown with a delay of 0.2 – 0.8 days/year. The dates of the end of the pollen season and peak values show similar trends. Therefore the length of the pollen season was longer in Italian stations and shorter in Spanish ones.

A statistically significant correlation was found between the start of pollination dates and the

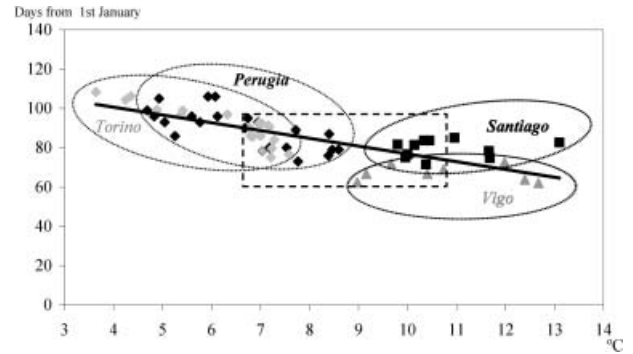


Figure 3. Correlation between starting dates of the *Platanus* pollen season and mean temperature average value of the month in which the release of the pollen takes place [$y = -3.9626x + 116.5$; $R^2 = 0.6332$; $p < 0.000$].

average of the mean temperatures registered during the three months period before flowering (Figure 3). When the temperature of this period is lower *Platanus* flowers later, conversely, when the temperature is warmer the pollination is earlier. It is possible to recognize two populations of points, within the data. These occur at either extreme of the regression line (Figure 3) and correspond to the lower and higher temperature responses.

No significant differences were registered about the total annual sums and the peak value parameters, except for Torino, where a significant decrease of the peak value parameters was registered.

To verify the influence of temperature on the pollen release we analysed the average distribution of the *Platanus* pollen grains in the studied period, and its distribution in the year with the coldest and warmest months (March in Vigo, April in the other places), during which the start of pollination takes place in each locality (Figure 4). Sequentially, the behaviour of pollen curves were evaluated by means of the analysis of the kurtosis and skewness indices in the different climatic areas (Figure 5). Generally, in

Table II. Slopes and significance levels of the trends of the parameters that define the *Platanus* pollen season during the studied years: total annual pollen, start and final date of the pollen season, length of the pollen season, peak value and its date, and skewness and kurtosis values.

Features	Slope (R^2 value)			
	Vigo	Santiago	Perugia	Torino
Total pollen	6.400 (0.013)	4.840 (0.001)	1.350 (0.030)	-47.570 (0.098)
Start date	0.232 (0.025)	0.850** (0.387)	-0.660*** (0.515)	-1.212*** (0.622)
Final date	-0.704 (0.096)	0.670* (0.328)	-0.646*** (0.437)	-0.692*** (0.324)
Length pollen season	-0.936** (0.542)	-0.173 (0.017)	0.401 (0.075)	0.513*** (0.375)
Peak value	9.500 (0.240)	-2.426 (0.009)	-0.390 (0.060)	-21.018*** (0.327)
Date peak	-0.067 (0.001)	1.010* (0.358)	-0.406** (0.182)	-1.019*** (0.502)
Skewness	0.088* (0.421)	-0.042* (0.276)	-0.048*** (0.460)	-0.031 (0.098)
Kurtosis	0.257 (0.276)	-0.164* (0.291)	-0.226*** (0.325)	0.063 (0.052)

* – $p < 0.1$; ** – $p < 0.05$; *** – $p < 0.001$.

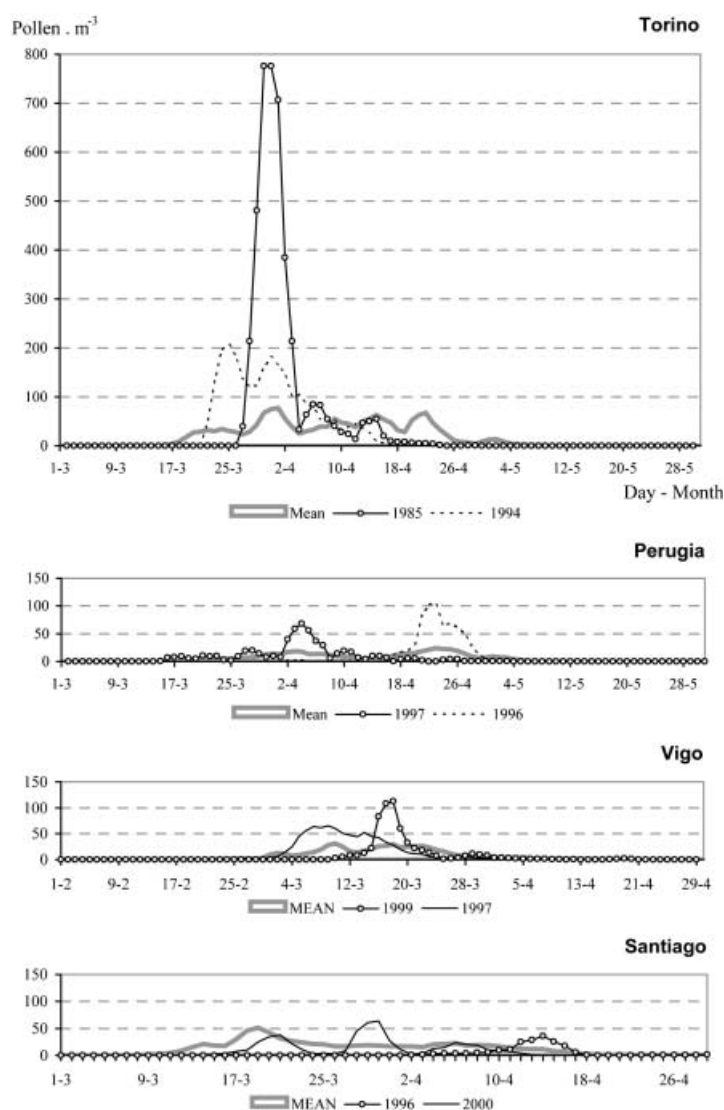


Figure 4. Average of daily pollen counts in the studied period (area) and its distribution in the coldest (line) and the hottest year (pointed line).

the coldest years the pollen was released some days later than the average distribution and skewness and kurtosis parameters assumed higher values. Conversely, in the hottest years where pollination begins earlier, these indices were lower.

The trends of these indices are reported (Table II) and a negative slopes were shown in accordance with the increase of the temperature trend registered in Perugia, Santiago and Torino. An opposite trend of both indices was shown in Vigo where, a significant decrease of temperature occurred in the studied years.

Discussion

Platanus orientalis and *P. × hybrida* are the most common species of the genus *Platanus* present in

the study areas, where they are commonly planted, as in much of Europe especially as road side trees (Tutin, 1964). Plane trees usually flower in March and this phenomenon, as in other species, is affected by the climatic conditions in the months prior to flowering (Frenguelli et al., 1991; Galan et al., 2001). Across Europe, as in the rest of the world, there have been important climatic changes including a general increase of temperature (Houghton et al., 2001). This has also been detected in Italy where the increase is on average 0.12°C per year and has been greatest in the last decade (Walther et al., 2002). This temperature trend has been recorded in the north-west of Spain but has a lower magnitude. In the area furthest from the sea (Santiago de Compostela), a moderate increase of temperature has been registered, moreover in the station along

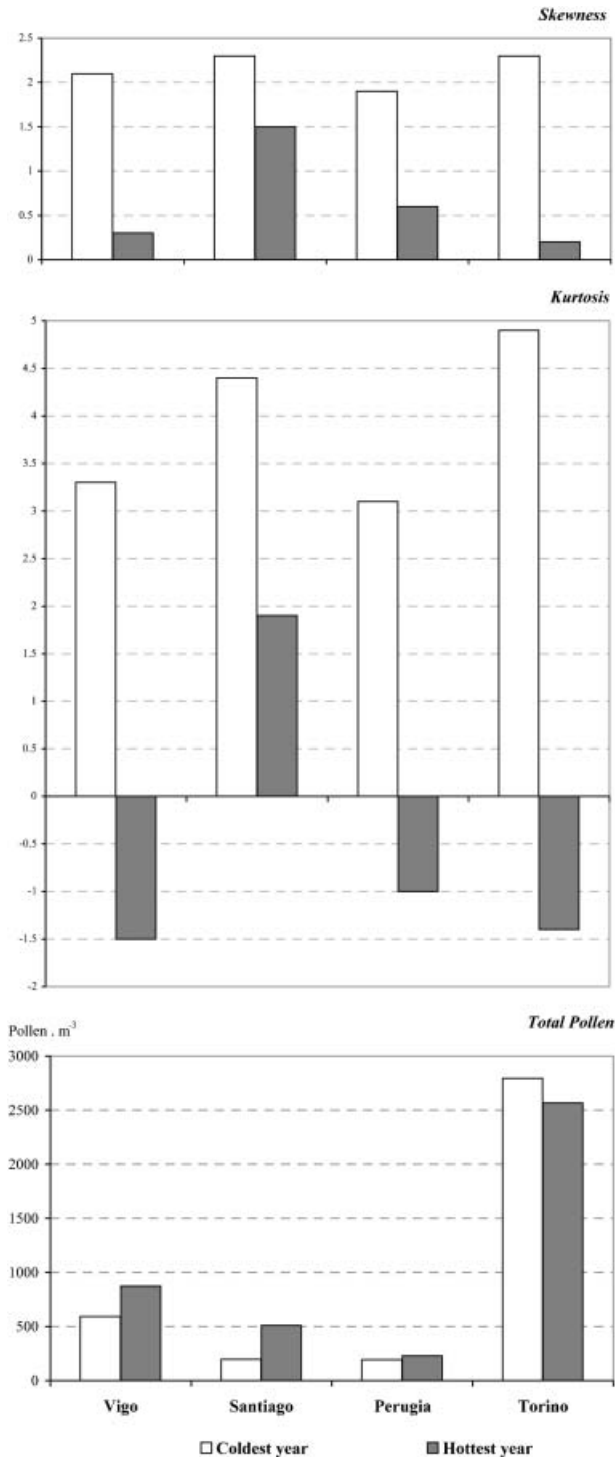


Figure 5. Skewness, kurtosis and total pollen values during the coldest and hottest year.

the oceanic coast (Vigo) the mean annual temperature showed a decrease.

It is well known that a strong and complex relation between air temperature and pollen release is present in many tree species, but the temperature influence is different depending on the species and on the area

where the plants grow (Frenguelli et al., 1997; Spiessma et al., 1989; Rodriguez-Rajo et al., 2003). There is evidence that the actual temperature increases have changed the timing of the season in many herbaceous and arboreal plants. In general, in all continental Europe to the lowest latitudes, these phenological changes have been monitored, such as in the United Kingdom (Emberlin et al., 2002), The Netherlands (Van Vliet et al., 2002), Austria (Jäger et al., 1996), Switzerland (Defila & Clot, 2001), and Italy (Caramiello et al., 2004; Frenguelli et al., 2002; Tedeschini et al., 2004b). However, there is little research reporting an increase of temperature in recent years in the Iberian Peninsula linked to the flowering season of plants.

The results presented in this work show a decrease or only a moderate increase of temperature for the Spanish stations, and they show that the timing of plane flowering reflects the trend of air temperature. As a result, a significant advance of the pollen season in Santiago occurred while a delay of flowering occurred in the coastal city of Vigo where a decrease of temperature has been registered. Both Italian stations showed a significant advance in the start of pollination following the increase of the spring temperature. Moreover we have recorded, that the different trends of temperature also exerted an influence on the behaviour of the pollination. Generally, in the coldest years the start of the *Platanus* pollen season occurred some days later than the average, and in this case the pollen was released quickly, reaching the maximum value in a short time, so in these years, the skewness index is lower (2) indicating a peak closer to the start of the pollen season than in the years with higher temperature. Equally, the kurtosis index in the coldest years is higher (3), with an almost normal distribution of the pollen discharge during the season. Therefore, lower temperatures result in a more rapid release of *Platanus* pollen and the peak value is easily identified.

In years when the temperature was higher, the pollen was released more gradually during the season and therefore the curve had a low asymmetric trend and with a flatter top than normal (the skewness and kurtosis indices assume lower values).

Only the total annual amount of pollen released in the atmosphere shows no significant variation linked to temperature increase. This is in contrast with the studies conducted in other species where some indications of increased pollen production are linked to temperature (i.e. Emberlin et al., 1997). Our results on the *Platanus* Pollen Index parameter agree with another study conducted in the Spanish area, where it has been shown that other environmental factors such as water availability and the chilling

requirement during the winter months can influence the amount of pollination (Cariñanos et al., 2004).

Therefore, from our data it seems that the temperature is tending to increase in the coldest areas and decrease in the warmest ones so that the flowering time of *Platanus* season in Italy and in Spain is getting closer. If this temperature trend continues in the future, the scenario for the *Platanus* pollen season may be as suggested by the bold line in Figure 3. The pollination behaviour of *Platanus* may change as a consequence of the adaptation to this new situation. This could lead to modification of the pollen calendar with effects on human health, but could also modify the function of genera in ecosystems, jeopardising the natural balance.

The limits of this work are represented by the different lengths of historical series considered. The lower number of years of monitoring data for the Spanish stations could have contributed to an underestimate of the significance of some results. Monitoring of pollen should be continued because this paper essentially demonstrates again that pollination of anemophilous plants should be taken into consideration as a bioindicator of the effects of climatic changes. Moreover, in the areas where there are no historical series of phenological data, aerobiological monitoring has been carried out continuously over many years, and statistical significant indications of climatic trends could be provided.

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