P 1.3 METEOROLOGICAL PATTERN AND AIRBORNE POLLEN CONCENTRATION TRENDS IN THE MEDITERRANEAN REGION

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1. INTRODUCTION

Timing of phenological events, especially flowering phase, are affected by meteorological factors and, to a large extent, by air temperature. Thus, climatic warming may cause changes in the onset of various phenophases and should be visible in long term phenological observation. As a consequence plant phenological observation series were often used, to document climatic variability and change (Sparks *et al.*, 2000; Kramer *et al*., 2000; Defila and Clot, 2001; Menzel, 2000; Chmielewski *et al*., 2005). In the last century, global and annual mean air temperatures have increased by 0.3-0.6 °C (IPCC, 1998). In recent years a large number of research articles reported that rising spring temperatures during the past century have affected the onset of plant spring phenological phases, especially flowering. This was well documented for many species at high northern latitudes in Europe and in North America (Schwartz *et al*., 2006; Schwartz, 1999; Beaubien and Freeland, 2000; Studer *et al*., 2005)

Airborne pollen data can represent an important source of information on flowering phenology at regional scale. Airborne pollen concentration pattern is related to the release of pollen from anthers and it reflects flowering phases of plant population surrounding the sampling station (Osborne *et al*., 2000; Jato *et al*, 2002; Van Vliet *et al*., 2002). As a consequence, in recent years, several studies suggested that airborne pollen data could be considered as a possible indicator of the responses of plants to climate change (Clot, 2003; Newnham, 1999; Orlandi *et al.*, 2005; Emberlin *et a.l*, 2002;. Osborne *et al*., 2000; Van Vliet *et al*., 2002).

The aims of this paper were i) to analyse pollen data of three families recorded in the last two decades in North Sardinia (Italy) in order to verify whether there has been a significant change over time of season pollen dates, and ii) to examine the trend over the time of heat summations of preceding period of pollen season to evaluate whether airborne pollen data could be used as indicator of climate change in Mediterranean areas.

2. MATERIALS AND METHODS

Daily pollen concentration data for three families (*Oleaceae*, *Graminaceae*, and *Pinaceae*) were measured for 20 years (1984-2003) in a urban area of northern Sardinia (Italy) using a Burkard seven-day recording volumetric spore trap. Daily pollen data were expressed as number of pollen grains per cubic meter of air. The date of the full flowering phase for each families was defined as the day when the cumulated daily pollen values reached the 50 % of the total annual pollen concentration. Daily maximum (T_{max}) and minimum (T_{min}) temperature values were recorded during the same period by an automatic weather station.

Cumulative Degree days (°D) were calculated, for each year, from different starting dates until two fixed dates (April 30 and May 30) using the daily averaging method (Zalom *et al*., 1983) with a 0°C threshold temperature (T_s):

$$°D = \sum_{d=1}^{d=n} \left[\left(T_{\max} + T_{\min} \right) / 2 \right] - T_s$$

Trends of full flowering dates for each family

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and of °D accumulation over the two decades were analyzed. Two-years running means were calculated. A linear regression model was used for the trend analysis.

Dates of full flowering stage were related to cumulative degree day, calculated for the periods preceding flowering phases, by a linear regression analysis.

3. RESULTS AND DISCUSSION

The full flowering dates, based on percentages of total pollen emission, showed a significant decreasing trend for all three families examined. The dates advanced over the examined period with a linear significant mean trend of 1.3, 1.3, and 1.5 day/year respectively for *Oleaceae*, *Graminaceae*, and *Pinaceae* families (Fig. 1).

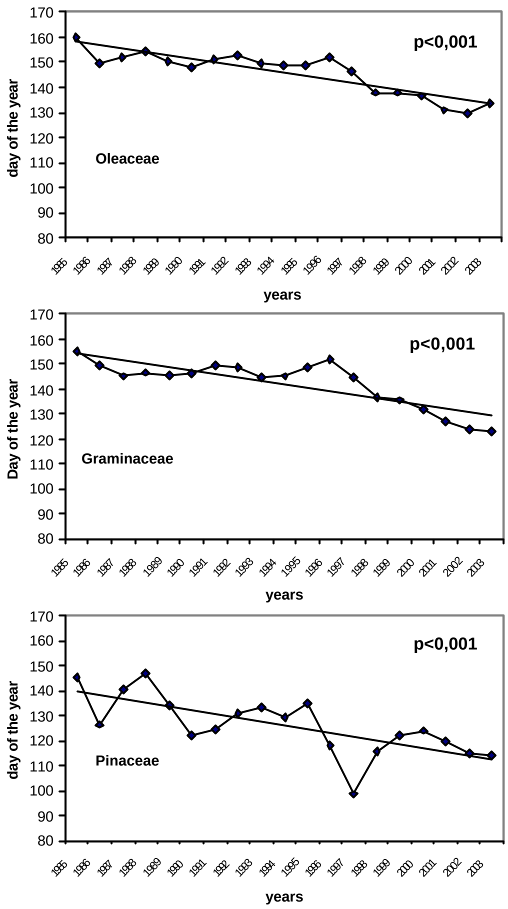

Figure 1 – Full flowering dates of *Oleaceae*, *Graminaceae*, and *Pinaceae* families (2-year running means from 1984 to 2003).

These results are in accordance with those found by other authors who observed a trend towards earlier beginning of pollination for many species in Europe (Frenguelli *et al.*, 2002; Osborne *et al.*, 2000; Clot, 2003).

Because the full flowering dates started between the middle of April and the beginning of June for Pinaceae family, between the beginning of May and the beginning of June for Graminaceae family, and between the middle of May and the middle of June for Oleaceae family, cumulative °D were calculated from different staring dates until April 30 and May 30.

The time trend of the cumulative °D values, calculated for all different periods, showed a significant increase during the 20 studied years (Table 1). This tendency was particular evident for spring temperature (Fig 2). The most significant increases were observed, in fact, when February 15 and March 1 were used as starting date for calculation.

Table 1 – Level of significance of thermal summation (degree days) trends for the different starting and ending dates.

Ending date	Starting date				
	Jan 1	Jan 15	Feb 1	Feb 15	Mar 1
April 30	*	*	*	**	**
May 30	*	*	**	**	**

* p≤ 0.05, ** p≤0.01

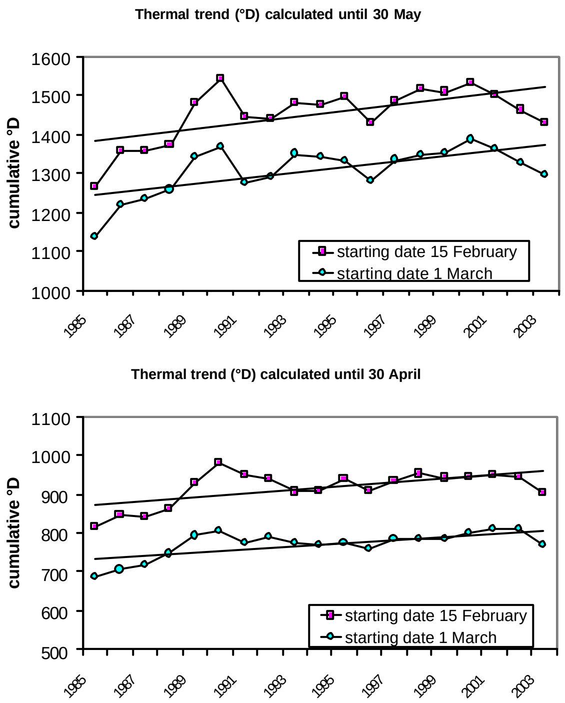

Figure 2 – Trend of cumulative degree day (2-year running means from 1984 to 2003).

These results suggest the hypothesis that during the last two decades phenological trends observed for the three families examined were probably linked to temperature values recorded during the periods preceding the flowering dates. The negative trend of the starting dates values could be a response to rising spring temperature.

This assumption was confirmed by the results of linear regression analysis of full flowering dates for each family on the °D cumulated until both April 30 and May 30 (Table 2).

Negative relations between dates of full flowering and cumulative degree day were observed. The inverse relations were clearly identifiable for February-April and February-May periods, which precede pollination of families examined in our region. Relative to *Oleaceae* family the highest significant relations were observed when cumulative °D were calculated using February 15 and March 1 as starting dates. For *Graminaceae* family values of p< 0.01 were observed when accumulation started from March 1. Relative to *Pinaceae* family dates of full flowering were significantly related to cumulative °D for all periods examined.

Table 2 – Level of significance of linear regression of dates of full flowering on cumulative degree days calculated for the different starting and ending dates.

Familiy	Ending date April 30				
	Starting date				
	Jan 1	Jan 15	Feb 1	Feb 15	Mar 1
Oleaceae	ns	ns	ns	**	**
Graminaceae	ns	ns	ns	ns	**
Pinaceae	**	**	*	**	*

Familiy	Ending date May 30				
	Starting date				
	Jan 1	Jan 15	Feb 1	Feb 15	Mar 1
Oleaceae	ns	ns	*	**	**
Graminaceae	ns	ns	ns	ns	*
Pinaceae	*	*	*	*	*

* p≤ 0.05, ** p≤0.01

4.CONCLUSIONS

In conclusion, our results seem to confirm, as reported by other authors, that the course of temperature between February and April affects in large measure the timing of spring phenological phases (Chmielewski and Rotzer, 2001; Chmielewski *et al*., 2005).

Airborne pollen of the examined families is sensitive to spring thermal variation and could be taken into consideration as bioindicator of changes in air temperature. In addition measurements of airborne pollen may be a complement of existing direct phenological observations and provide valuable information about the impacts of climate change on flowering phases of this group of species.

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