Influence of heat accumulation on olive tree flowering dates in the Mediterranean region

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Abstract
Airborne pollen data can represent an important source of information on flowering phenology at regional scale. The main aim of this research was to verify whether airborne pollen data of *Olea europaea* L. could be used as indicator of climate change in Mediterranean areas. In this work olive pollen data recorded in the last two decades (1984-2003) in North Sardinia (Italy) were presented. The trend of date of peak pollen concentration was analysed. Finally, relation between trend of air temperature and trend of this parameter was investigated. The results suggested that the onset of flowering phase in *Olea europaea* L. was affected by rising spring temperature.

Key words: Airborne pollen, climate change, *Olea europaea* L, phenology

Introduction

In plant species, living in temperate area, variations in the beginning, in the duration, and in the intensity of the various phenophases, and especially of flowering, are regulated by meteorological factors and, to a large extent, by temperature. As a consequence, plant phenological observation series have been often used to document climatic variability and change (Sparks *et al.*, 2000; Kramer *et al*., 2000; Menzel, 2000; Chmielewski *et al*., 2005). Previous works showed that increasing spring temperature during the past century determined an advance of the timing of flowering in many species at high northern latitudes in Europe and in North America (Schwartz *et al*., 2006; Studer *et al*., 2005).

Airborne pollen concentration pattern is related to the release of pollen from anthers. Then pollen emission data can be considered as an indirect manifestation of the flowering phase that occurs in plant population surrounding the sampling station (Osborne *et al*., 2000; 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 (Newnham, 1999; Orlandi *et al.*, 2005; Emberlin *et al.*, 2002;. Osborne *et al*., 2000; Van Vliet *et al*., 2002).

Olive (*Olea europea* L.) is one of the largest crops in Mediterranean countries, particularly in those areas were the climate is generally warmer. In Sardinia it represents an important economic activity and, in the North of the island, it accounts for 74% of all cultivated fruit species.

The aims of this paper were i) to verify whether there has been a significant change over time of olive season pollen dates recorded in the last two decades in North Sardinia (Italy), and ii) to evaluate whether olive airborne pollen data could be used an as indicator of climate change in Mediterranean areas.

Material and methods

Olive daily pollen concentration data 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 full flowering phase 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) as:

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

Trends of full flowering dates 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.

Results and discussion

The full flowering dates of olive, based on percentages of total pollen emission, showed a significant decreasing trend. The olive dates advanced over the examined period with a linear significant mean trend of 1.3 day/year (Fig. 1).

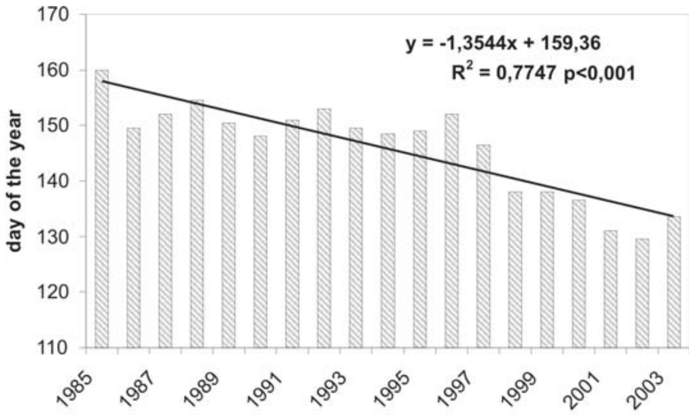

Figure 1 – Full flowering dates of *Olea europaea* at the study site (2-year running means from 1984 to 2003).

The equation which estimate the trend, the coefficient of determination (R^2) and the significance of regression are also indicated.

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 olive full flowering date occurs on average between the middle of May and the middle of June, cumulative °D were calculated from different starting 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).

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

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

n.s. p> 0.05, * p≤ 0.05, ** p≤0.01

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.
These results suggest the hypothesis that during the last two decades phenological trends observed for olive was 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 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 *Olea europaea* in our region. The highest significant relations were observed when cumulative °D were calculated using February 15 and March 1 as starting dates.

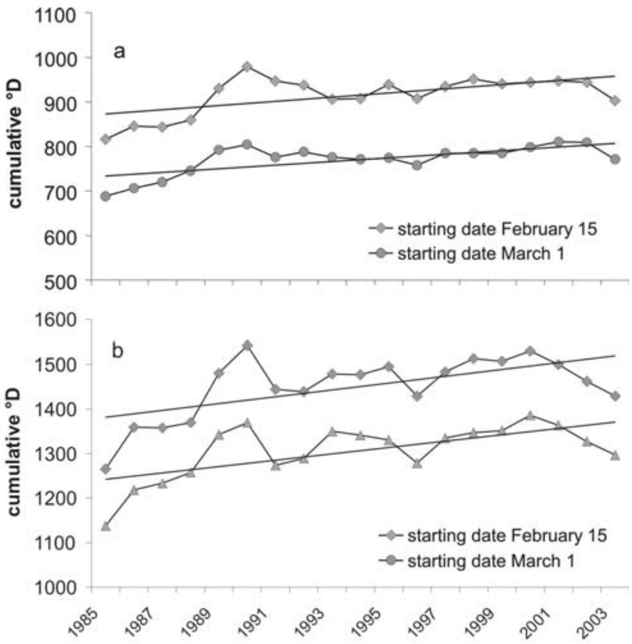

Figure 2. Trends of cumulative degree day (2-year running means from 1984 to 2003) calculated until April 30 (a) and until May 30 (b) and considering two different staring dates.

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

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

n.s. p> 0.05, * p≤ 0.05, ** p≤0.01

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 *Olea europaea* 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 specie.

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