Assessment of heat units models for predicting flowering dates of *Graminaceae* species growing in Northern Sardinia (Italy)

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Abstract

Airborne pollen is responsible for several allergic diseases. Knowledge of pollen season features is important to optimise airborne pollen allergies prevention. The aim of this paper is to assess two heat accumulation methods for predicting peak airborne pollen concentrations (i.e. flowering stage occurrences) in *Graminaceae* species growing in North Sardinia (Italy). The application of degree days models, on a 18-years data-set, has given good results in prediction of peak pollen concentration and has confirmed to be a useful tool in the prevention of allergenic diseases caused by pollen also when used for predicting flowering dates in *Graminaceae* species.

Key words: aerobiology, forecast, *graminaceae*, pollen, threshold temperature

Introduction

Airborne pollen is responsible for several allergic diseases. *Graminaceae* pollen, in particular, represents the most important allergenic pollen widely spread all over the world (Laaidi, 2001). Prediction of the beginning as pollen season is particularly important for optimise the effectiveness of medical treatment in allergic people and in airborne pollen allergies prevention (D'Amato and Spieksma, 1993). Models to predict the date of peak pollen season, in fact, would allow allergist to initiate preventive treatment at the correct moment.

It is well known that timing of phenological events, especially flowering phase, are affected by meteorological factors and, to a large extent, by air temperature. Because airborne pollen concentration pattern is related to the release of pollen from anthers, it reflects flowering phases. As a consequence of this remark forecasting models of phenological phases can be used for predicting dates of pollen season.

In recent years, several studies have been carried out for predicting the features of the pollen season (beginning of pollen release, peak of air pollen concentration, total pollen amount in the atmosphere) for allergenic species. In fact, knowledge of these characteristics in allergenic taxa appear to be crucial in the airborne pollen allergies prevention.

In order to forecast pollen season characteristics mechanicistic and statistical models have been tested. Mechanicistic models are mainly based on the assumed relationship between pollen release from the involved species and biological and meteorological parameters. Because of the complexity of their algorithms mechanicistic model application is limited, whereas the more simple statistical methods are widely applied.

It is well known that the number of days needed for the reproductive cycle of plant decreases at higher temperature. Therefore, degree-day values are often used for predicting flowering phase because they quantify temperature or heat unit accumulation for each day. Critical aspects of degree-day calculation are represented by the selection of an appropriate threshold temperature, the method used to degree-day calculation and the selection of a correct date for starting accumulation.

Previous studies have developed several procedures for estimating degree-days using maximum and minimum air temperature. The main methods used are the triangle method and the sine-wave method and its modifications (Allen, 1976; Baskerville and Emin, 1969; DeGaetano and Knapp, 1993; Yin *et al*., 1995). In addition, some researchers proposed several methodology to determine the most appropriate starting date of degree-day summation in relation to the choice of threshold temperature (Castonguay *et al*., 1984; Oger and Gilbert, 1989; Yang *et al*., 1995).

The aim of this paper is to assess two heat accumulation methods for predicting flowering dates in *Graminaceae* species growing in North Sardinia (Italy).

Material and methods

Data of pollen concentration were monitored for 18 years in a urban area of Northern Sardinia (Italy) using a Burkard seven-day recording volumetric spore trap (1984-2001). Daily maximum and minimum temperatures were recorded during the same period by an automatic weather station.

Degree days were calculated for 15 years (1984-1998) using the daily averaging method and the single triangle method (Zalom *et al.*, 1983) (Fig. 1) from seven starting dates (January 1 and 15, February 1 and 15, March 1 and 15, and April 1), and five lower threshold temperatures (0 °C, 4 °C, 8 °C, 12 °C, and 14 °C).

The standard deviation and the coefficient of variation in degree days and the standard deviation in days were also calculated. The least standard deviation in days was used to determine the best method, the starting date and the threshold temperature value that provide the best estimate of the dates. The 1999-2001 temperature and airborne pollen concentration data were used for testing the models.

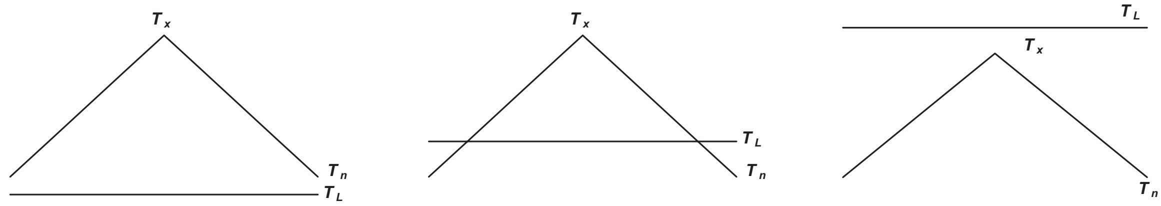

Figure 1. Triangle method temperature curves. T_x= Maximum daily temperature, T_n=Minimum daily temperarure, T_L= Lower threshold temperature

Results and discussion

For *Graminaceae* species different dates of starting pollen season and of peak pollen concentration were observed. Beginning of pollen season in the examined areas was recorded in all years during the first week of May. Pollen concentration peaks were observed during the period from mid-May to first week of June, with a average mean date of May 25 (146 day of the year) (Fig. 2).

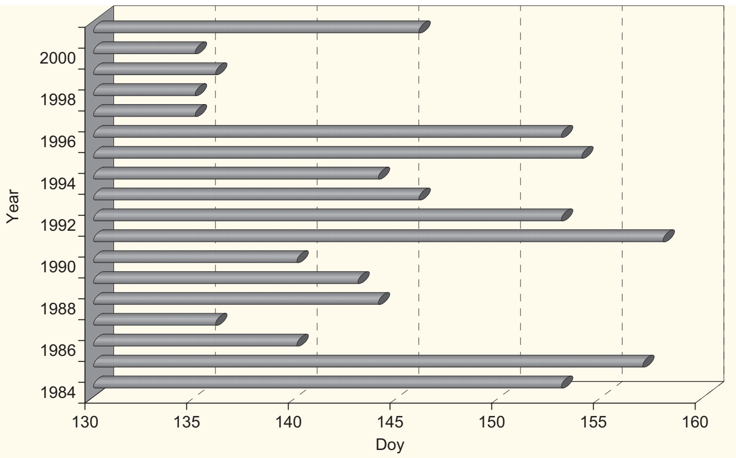

Figure 2. Peak of maximum pollen concentration occurrences, in days, for the years 1984-2001 calculated from January 1

The selection of an appropriate temperature threshold is critical for degree-day model calculations. The statistical threshold temperature value was selected as the temperature which provided the lowest value of the standard deviation in days.
In figure 3, the effects of the five temperature thresholds (ranging from 0 to 14°C) and the seven starting dates of accumulation (varying from January 1 to April 1) on the standard deviation in days using the two methods (single triangle and daily averaging method) are plotted. The minimum standard deviation values were obtained for both methods using a temperature threshold of 0°C and the starting date for heat accumulation April 1.

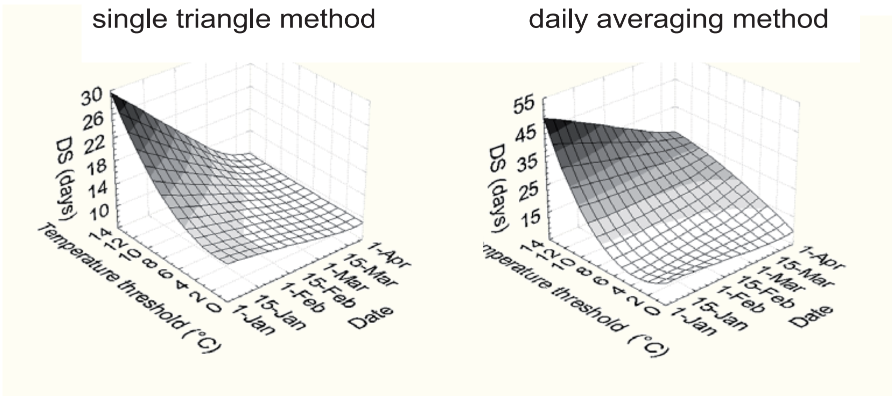

Figure 3. Standard deviation in days (DS) calculated for the two methods using five base temperature values and different starting dates

In general, the best prediction of the peak pollen concentration for *Graminaceae* species is obtained when 0 °C base temperature and April 1 as starting data were used. No differences between the two methods were observed in the statistical parameters using 0 °C as base temperature (average degree day = 849.7; standard deviation in degree day = 133.05; coefficient of variation in degree day = 15.66; standard deviation in day = 8.78). This is due to the mathematical formulation of the single triangle method that provided identical results of the daily averaging method when a lower base temperature equal to 0 °C was used.
The observed dates of peak airborne pollen concentration and the expected dates calculated for the years 1999-2001 using 0 °C as base temperature and April 1 as starting date are shown in table 1. An average an absolute difference of 4.3 days between the predicted and observed dates of peak pollen concentration was observed. This result indicated a good performance of the daily averaging method and single triangle method in predicting the peak of airborne pollen concentration for *Graminaceae* species.

Table 1. Differences between the observed and the predicted peak airborne pollen concentration dates calculated for the years 1999-2001 using daily averaging method

Years	Observed dates	Predicted dates	Differences (days)
1999	16 May	22 May	6
2000	14 May	20 May	6
2001	26 May	25 May	1
Mean			4.3

Conclusions
In this work, the single triangle method and the daily averaging method were applied on time series of 15 years and tested on a 3-years period. The methods provided a good prediction with a mean difference of 4.3 days between the predicted and observed dates of peak pollen concentration.

The results confirm that temperature is one of the main parameters that should be considered in forecasting models. Air temperature affects biochemical and physiological processes related to flowering phase.
The application of forecasting models, based on meteorological parameters, has proved to be a useful tool in the prevention of allergenic diseases caused by pollen also when used for predicting flowering dates in *Graminaceae* species.

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