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Impact of 2003 heat waves on aerobiological indices of allergenic herbaceous family pollen season in Tuscany (Italy)

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Abstract The aim of this study was to assess the current aerobiological situation and to investigate the influence of the hot and dry summer 2003 on pollen season (onset, end and duration of the pollen season, peak pollen day and value, total seasonal amount of pollen grains) of herbaceous family as Poaceae, Urticaceae and Compositeae. Heat wave of 2003 influenced the phenology of the main pollen families in Tuscany: the high temperatures occurred during 2003 affected pollen season of different family with different responses. This study confirms the role that the climate has on the flora species and in particular on herbaceous species phenology and the high variability of the pollination among different places, during extreme events. In general, high spring temperature induces an advance of the flowering period and a release of higher pollen quantity of Urticaceae and Poaceae; however, exceptional weather conditions

(i.e., summer 2003) could exert an opposite effect, resulting in an impairment of flowering of Urticaceae during autumn. Compositeae species produced a low amount of pollen in 2003, even if the peak value was higher than the average in some stations.

Keywords Aerobiological parameters · Heat wave · Allergy · Pollen

1 Introduction

An exceptional heat wave affected Europe in summer 2003. In a large area of the continent, mean summer temperatures exceeded the 1961–1990 mean of about 3 °C (Schar et al. 2004; Della Marta et al. 2007). In Italy, a period of extreme excessively high temperatures was registered and an excess of mortality was noted, especially in the generally cooler northwestern cities (Michelozzi et al. 2005). In a study focused on temperature and indices of heat wave carried on in Tuscany region, Central Italy, Bartolini et al. (2008) highlighted the extreme temperatures observed in Tuscany too, when mean Tmax and Tmin registered clearly appear as an outlier in respect to the period 1955–2008. According to international literature, the climate is changing and at an increasing rate. Global average temperature has increased by more than 0.7 °C over the past 100 years (IPCC 2007; WHO 2012). In particular, the mean temperature was higher than normal from May month; the mean value of June

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2003 was 4.4, 3.9 and 5.6 °C higher than the average value (1955–2008), respectively, in Pistoia, Lucca, Peretola meteorological station (Fig. 1a, b, c). The high temperatures recorded were also accompanied by low precipitation in the period June–August, in each city under study (Fig. 2).

In addition to global warming, extreme weather events, such as heat waves, heavy precipitation and thunderstorms, are also predicted to increase over the next few decades (della Marta et al. 2007).

Climate change is affecting natural allergens in several ways. The total amount of pollen observed in the air is growing, probably due to the interaction between changing land use, temperature and CO₂ concentrations (Confalonieri 2007; Menne et al. 2008; Shea et al. 2008). A review of previous literature has demonstrated the lacking of studies about the influence of extreme events and pollen season of allergenic

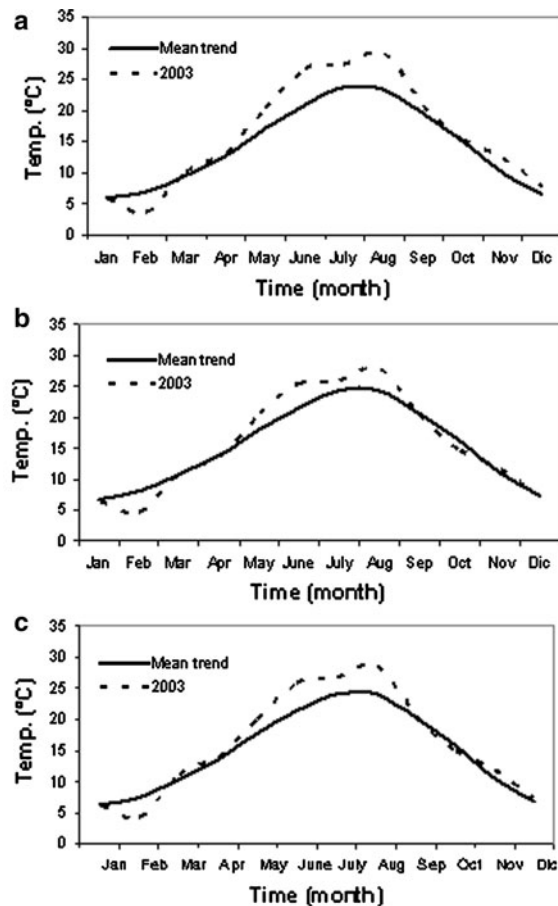


Fig. 1 Comparison between trend of mean monthly temperature and of 2003 observed in Pistoia (a), Lucca (b) and Peretola (c) station

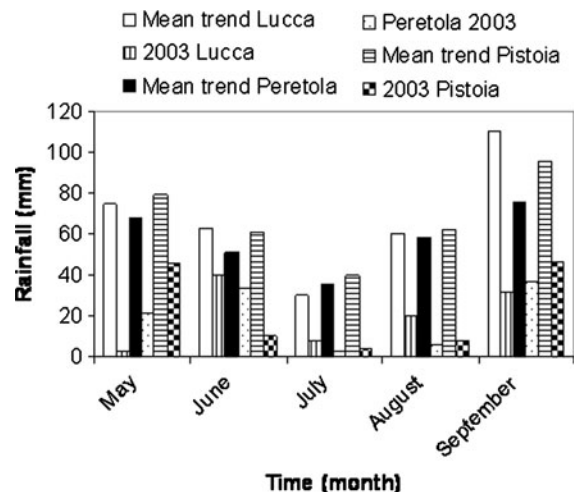


Fig. 2 Comparison between summer period trend of mean monthly rainfall and 2003 observed in Lucca, Peretola and Pistoia station

plant. However, the influence of extreme events, such as the heat waves, on pollen season should be taken into consideration in the future.

Epidemiologic studies showed a pollen sensitization rate in the population around 15 % in adults and 5–10 % in children in Italy. Among them, the 64.6 % and the 36.7 % of the population are sensitized to *Poaceae* and *Urticaceae* pollen, respectively (Negrini and Arobba 1992). Similar prevalence has been found in Tuscany where the *Poaceae* and *Urticaceae* are the most important herbaceous families responsible for respiratory allergy (Arrigoni et al. 1995).

Regarding *Compositae*, the main allergenic species of this family are *Artemisia spp.* and *Ambrosia spp.* The sensitization to *Ambrosia* is high in the north and low in the rest of the country; the only study performed in central Italy showed prevalence of 5.9 % among atopic children (Verini et al. 2001).

Poaceae family has about 600 genera and some 9,000–10,000 or more species while *Urticaceae* family counts about 2,600 species, grouped into 54–79 genera; the most important in Tuscany are *Parietaria* and *Urtica*. The flowers of these herbaceous plants are usually hermaphroditic, and pollination is always anemophilous. However, in the case of the *Urticaceae* family, pollen dispersion involves an explosive mechanism. *Urticaceae* stamens are normally bent, but when temperature and humidity are

suitable, they rise to the upright position and release their pollen grains (Galán et al. 2000). In Tuscany, the flowering season is generally from April to August for *Poaceae* and from late March to late October with two distinct phases (spring-summer and autumn) for *Urticaceae* family. *Urticaceae* plants showed a reduction of pollen production during the second flowering season.

Compositae family has about 1,600 genera and more than 23,000 species. The most important allergenic species are *Ambrosia*, *Taraxacum*, *Chamomilla* and *Artemisia*. The flowers are usually hermaphroditic and pollination is anemophilous; each plant could produce a large amount of pollen. In Tuscany *Artemisia* flowers late in the summer, the peak being in August–September. In Italy, *Ambrosia* spp. occurs prevalently in north–north-eastern regions, where sensitization rate is high (Asero 2012). Because of the small diameter of pollen grains, it is often involved in episodes of long-range transport (Cecchi et al. 2007).

The aim of this study was to assess and to investigate the influence of the hot and dry summer 2003 on pollen season (onset, end and duration of the pollen season, peak pollen day and value, total seasonal amount of pollen grains) of *Poaceae*, *Urticaceae* and *Compositae* in Tuscany.

2 Materials and methods

Daily pollen concentration data were collected by pollen traps located in four Tuscany stations: Florence ($\Lambda = 11^{\circ}11'E$; $\Phi = 43^{\circ}47'N$), Pistoia ($\Lambda = 10^{\circ}55'E$; $\Phi = 43^{\circ}56'N$), Montecatini ($\Lambda = 10^{\circ}46'E$; $\Phi = 43^{\circ}53'N$) and Lido di Camaiore ($\Lambda = 10^{\circ}13'E$; $\Phi = 43^{\circ}53'N$) (Fig. 3). Florence is located about 50 m a.s.l. in the bottom of a closed valley at the foot of the Apennines and it extends along the plain in SE–NW direction. It is crossed by the Arno river and is surrounded by hills on the south and mountains on the north, which rise to almost 1,000 m. The city has a semi-continental Mediterranean climate, with cold winters and hot summers. The coldest month is January, with an average temperature of about 6 °C. The warmest months are July and August, with an average temperature of 24 °C.

Pistoia is 67 m a.s.l. and has a Mediterranean climate influenced by the nearby hills and the

Apennine Mountains. The coldest month is January, with an average temperature of about 5.8 °C. The warmest month is July, with an average temperature of 23.7 °C.

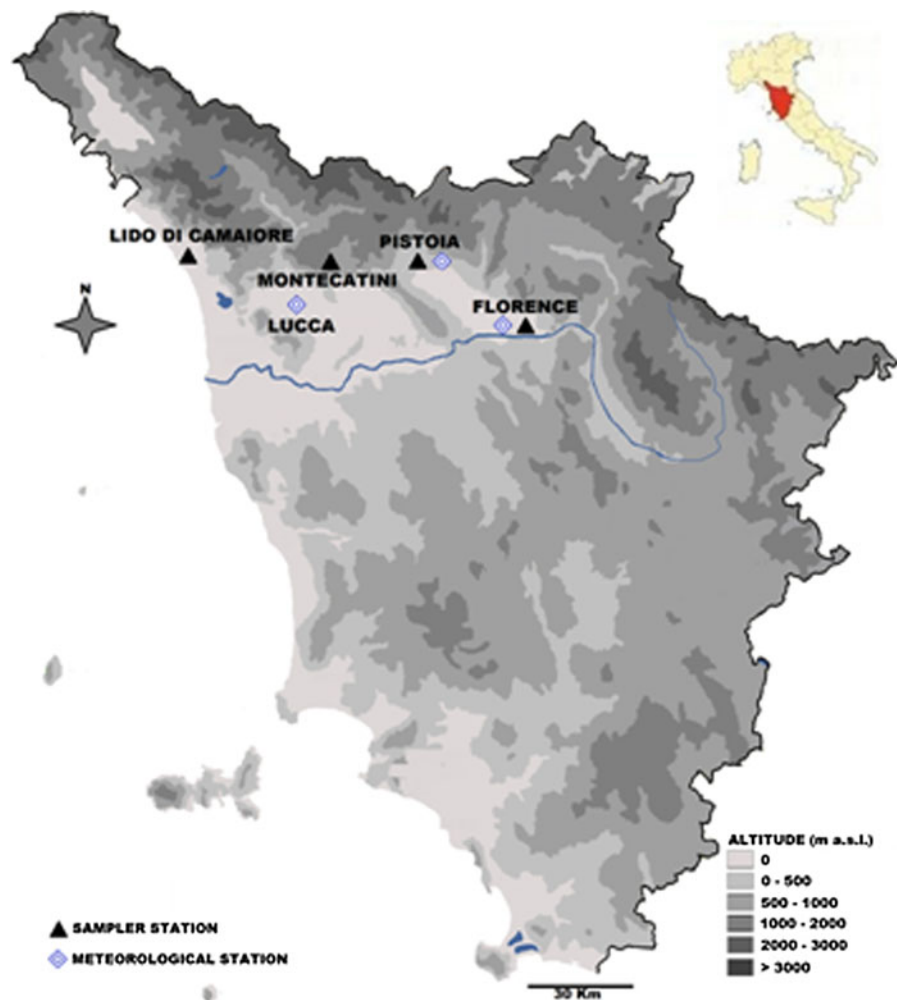
Montecatini is a city located in the province of Pistoia. The coldest month is January, with an average temperature of 6.3 °C. The warmest month is July, with an average temperature of 24.3 °C. Lido di Camaiore is a town, located in the province of Lucca, close to the sea. The climate is influenced by the Tirrenian Sea with temperate winters and summers. The coldest month is January, with an average temperature of about 8 °C. The warmest month is July, with an average temperature of about 23 °C. The daily maximum and minimum air temperatures (1955–2008) and daily rainfall (1955–2007) were collected by standard meteorological stations located in the four stations. Data were provided by Hydrographic Institute of Pisa. Maximum and minimum daily temperature and daily rainfall data were used to obtain the average temperature and cumulate rainfall during summer season (June–September).

2.1 Aerobiological monitoring

The length of time series of aerobiological data is not homogeneous in the four locations. Pistoia has the longest dataset (data recorded from 1995 to 2008), Montecatini from 1996 to 2007, Florence from 1999 to 2008 and Lido di Camaiore from 2000 to 2008. Years with uncompleted data were removed from the dataset.

Airborne pollens were collected with a Lanzoni VPPS 2000 (Lanzoni s.r.l., via Michelino, 93b Bologna Italy) that applies the principle initially proposed by Hirst (Hirst 1952). The instruments are volumetric samplers located at 15–20 m of height above ground level far away from walls and protection. Daily data obtained from the sampler were read following the standard method (UNI11108:2004) recommended by the AIA (Italian Association of Aerobiology). The method used for counting pollen was in accordance with the guidelines described by National Council of Research Institute of Atmospheric and Ocean Science (Mandrioli 1990). Data were provided by “*Articolazione Funzionale di Aerobiologia-ARPAT, Pistoia*” and are expressed as mean daily concentration of pollen grains in the atmosphere in cubic meter of air (p/m^3).

Fig. 3 Tuscany map with pollen samplers and meteorological stations



2.2 Analysis

The analysis is conducted taking into consideration the main pollen indices applied in aerobiological analysis (Grewlinga et al. 2012; Torrigiani et al. 2007; Jato et al. 2006). The following aerobiological indices were calculated using a Microsoft Office Excel software: Seasonal Index (SI) (total amount of pollen grains detected during flowering season), Main Pollen Season (MPS), Start (SD) and End (ED) of MPS, Peak Pollen Value (PV) (the annual maximum value of daily pollen concentration) and Peak Pollen Day (PD) (the day when the peak pollen value occurs). The MPS is defined as the period of the year during which it is possible to detect the great part of the pollen produced during the whole season by a specific genus (or family) of plants. It identifies, with more accuracy, the flowering season. Several authors (Nilsson and

Persson 1981; Andersen 1991; Emberlin et al. 1993; Spieksma and Nikkels 1998; Giner et al. 2002) identify the MPS as the period which includes a fixed percentage (in general ranging between 90 and 99 %) of the total annual pollen grain count.

In this study, we adopted the 95 % of the total amount of pollen grain detected during a whole pollen season for calculating the SD and ED of pollen season and consequently the duration of MPS. For each year, the MPS was determined taking the 95 % of the total annual pollen concentration recorded, using cumulative values (Pathirane 1975). SD and ED dates were set to correspond to the days when the 2.5 and 97.5 % of the total concentration were found (Rizzi et al. 2004). SI was calculated as the annual sum of the number of daily pollen grains per cubic meter of air (p/m^3).

The aerobiological indices were analyzed for the herbaceous family: *Urticaceae*, *Poaceae* and

Compositae. In particular, the aerobiological parameters as SI, SD, PD, PV, ED and MPS were analyzed to evaluate the impact of the heat wave in summer 2003. Box plots graph was utilized to represent the results of the analysis. In the graph, the box plots show first and third percentile, median, minimum and maximum value.

3 Results

The trends of the pollen indices in the four stations are summarized in Table 1, showing the indices of *Compositae* and *Urticaceae* families are significantly

Table 1 Seasonal pollen index (SD), start day (SD), end day (ED), peak day (PD) and main pollen season (MPS) of different family in 2003 compared with the whole pollen data set in all station and classified according to the percentile, min and max value

	Compositae	Poaceae	Urticaceae
SI			
Firenze	–	=	–
Pistoia	–	+	–
MontecatiniT	–	na	na
Lido di camoire	–	=	=
SD			
Firenze	–	+	=
Pistoia	=	+	=
MontecatiniT	–	na	na
Lido di camoire	=	+	+
ED			
Firenze	++	–	=
Pistoia	+	–	=
MontecatiniT	=	na	na
Lido di camoire	–	–	–
PD			
Firenze	=	–	=
Pistoia	=	–	–
MontecatiniT	++	na	na
Lido di camoire	+	=	–
MPS			
Firenze	++	–	=
Pistoia	+	–	=
MontecatiniT	+	na	na
Lido di camoire	=	–	–

2003 value is > max: ++; Max > 2003 value > third percentile: +First percentile < 2003 value < third percentile; = <2003 value < First percentile > 2003 value > min; –2003 value; –na:no available

different in Lido di Camaiore although the temperature and precipitation trends (Figs. 1 and 2) are similar respect the data of the others station.

Poaceae SI resulted above third percentile in Pistoia while it was close to median values in Florence and Lido di Camaiore. PV increased in Florence and Pistoia above the average value, while decreased in Lido di Camaiore (15 p/m³ below the average) (Fig. 6a). The MPS in the three locations under study was shorter than the MPS average values calculated for each series. In 2003, MPS was 85 days in Pistoia, 88 days in Florence and 139 in Lido di Camaiore, respectively, 58, 44, 20 days shorter compared to the calculated mean. SD was delayed in Florence, Lido di Camaiore and Pistoia: the value was over the third percentile (Fig. 4) while ED was in advance and close to the first percentile. PD was close to the median of the series but in Florence, where it was equal to the minimum value.

Urticaceae, SI showed a marked reduction in Pistoia, Florence and Lido di Camaiore, where it falls in the first percentile. In Lido di Camaiore, the minimum values of SI were recorded in 2003.

Urticaceae PV reduced in Florence, Pistoia and Lido di Camaiore while MPS, SD and ED did not show any significant changes and trends of pollen index were different in each station. In Pistoia and Lido di Camaiore, PD occurred earlier than the average. The second peak of flowering of *Urticaceae*, usually higher than the first, was actually lower (Fig. 6b) in Lido di Camaiore in summer 2003. The ED and MPS were below the minimum.

Regarding the family of *Compositae*, the higher temperatures of summer 2003 were associated with a reduction of SI index, which was close to or lower than

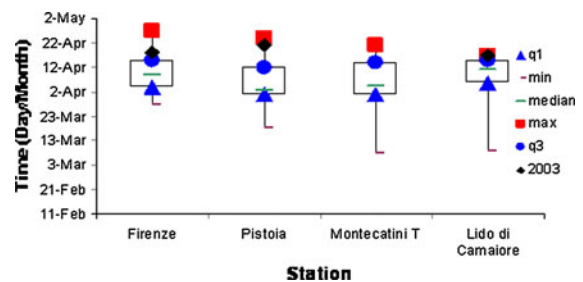


Fig. 4 Start day index of the Poaceae pollen 2003 season. The year 2003 (diamonds) is compared with the whole pollen data set. Box plots show the min, max and median value first and third percentiles

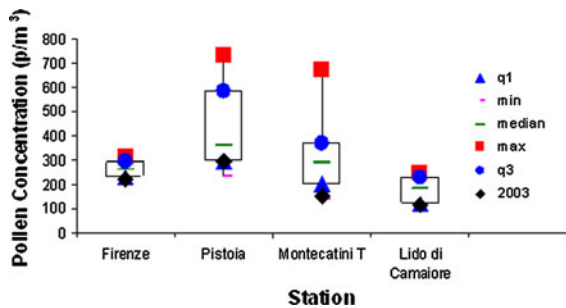


Fig. 5 Seasonal pollen index of the Compositae pollen 2003 season. The year 2003 (diamonds) is compared with the whole pollen data set. Box plots show the min, max and median value first and third percentiles

the first percentile (Fig. 5). SD was advanced in Florence and Montecatini; ED was delayed in all stations but in Lido di Camaiore and Montecatini. As a consequence, MPS value was close to or higher than third percentile in Florence, Pistoia and Montecatini while in Lido di Camaiore was close to the first percentile.

4 Discussion and conclusions

In Tuscany, the flowering season of *Urticaceae* is characterized by a long period (which starts in April–May and ends in October) with two main

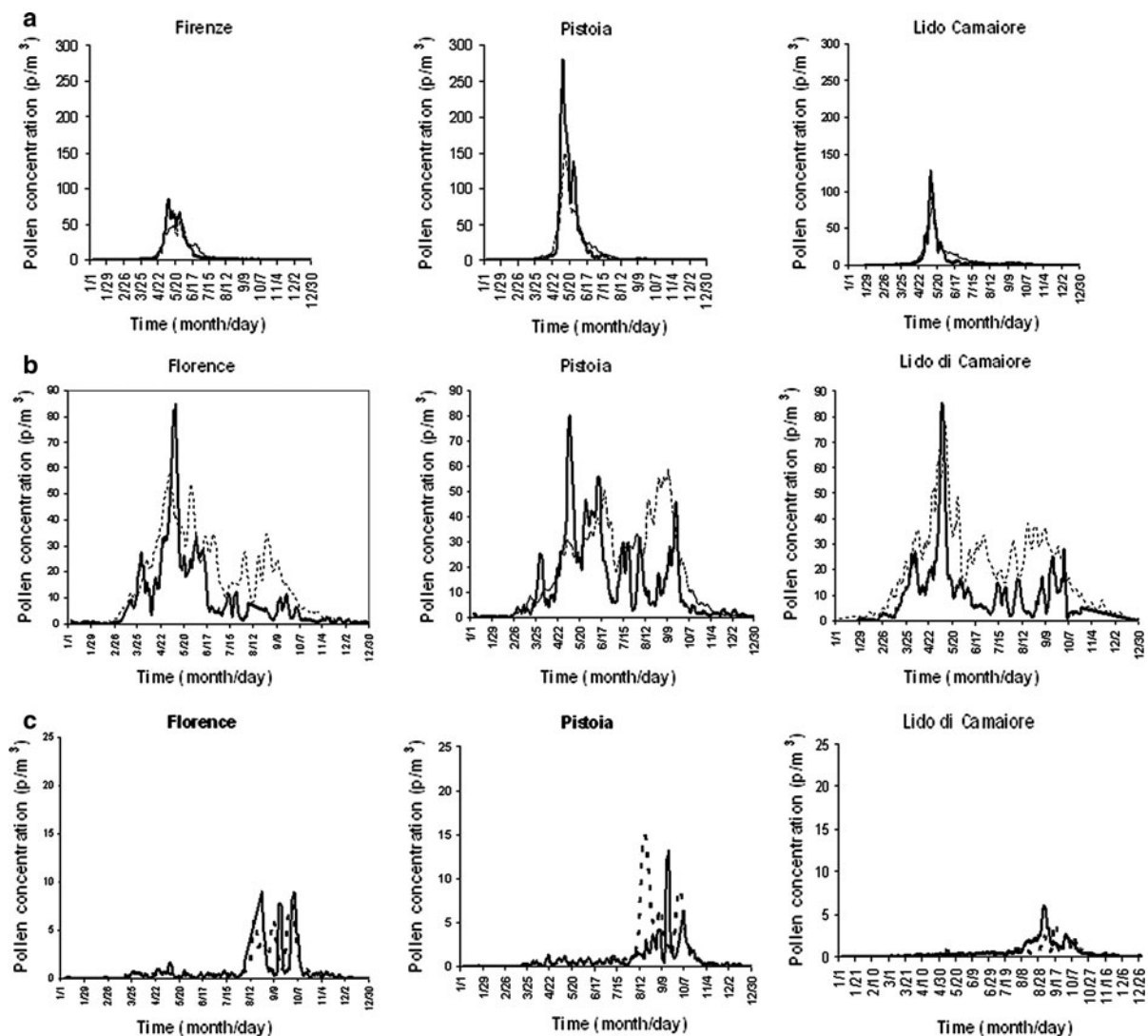


Fig. 6 Daily pollen concentration, between average and 2003, of Poaceae (a) Urticaceae (b) and Compositae (c), in Florence Pistoia and Lido di Camaiore

phases: the first in spring-summer and the second in autumn. *Urticaceae* can develop flower and release the pollen in atmosphere when the temperature and water conditions are favorable, except for the winter period (Galán et al. 2000). In particular, the analysis of our dataset underlines a reduction in *Urticaceae* pollen production during the second flowering season (Fig. 6b). This aspect is at the end of heat wave when the temperature is close to the average value, but the precipitation is lower with respect to the average seasonal value (Fig. 2).

In general, high spring temperature induces an advance of the flowering period and a release of higher amount of pollen of *Urticaceae* and *Poaceae*; however, exceptional weather conditions (i.e., summer 2003) can exert an opposite effect, resulting in an impairment of flowering of *Urticaceae* during autumn. The 2003 heat wave and, in general, the high temperatures affected pollen season of both *Urticaceae* and *Poaceae* with different responses. Strong reduction in MPS, advance of ED and high PV in *Poaceae* and strong decrease in SI, advance of PD and high PV in *Urticaceae* were recorded in the spring period instead of Autumn in Pistoia (Fig. 6b). Furthermore, delay of SD and advance of ED in *Poaceae* was found in all stations associated with a reduction of MPS but not in *Urticaceae* (SD delayed and ED advanced only in Lido di Camaiore). These aspects highlight the differences in term of behavior between *Urticaceae* and *Poaceae* under different climate pressure (i.e. extreme events) respect to average condition.

Compositae species produced a low amount of pollen in 2003, even if the peak value was higher than the average in some stations (Fig. 6c). The duration of these weeds' pollen season was shorter than the normal. In an earlier study, Gehrig (2006) described this observation and found it was due to the drought.

Present study confirms the role of climate and of extreme events in particular, on *Urticaceae*, *Poaceae*, *Compositae* phenology and on the variability of the pollination in different locations. Previous studies suggested that the grass flowering season varies from year to year depending on local weather conditions, mainly in terms of an advance or delay of phenophases (Puppi Branzi and Zanotti 1992). Moreover, environmental factors such as rainfall, temperature and solar radiation are responsible for the major year-on-year variations (Sanchez-Mesa et al. 2005; Cenci and Ceschia 2000).

The heat wave of the summer 2003 affected the pollen production and their distribution remarkably. However, results cannot be generalized: the biologic characteristics of the plant and the local climatic condition and, in particular, precipitation and temperature trends recorded during the extreme event, influence phenology. The extreme temperatures and the drought can affect the pollen season making prediction of the possible consequences on plant pollen production very difficult.

Aerobiological networks are operating in many parts of the world, and modern atmospheric composition models are able to forecast of pollen distribution (WHO 2012). This information, if adequately disseminated, allows allergic population to adjust outdoor activities and, possibly, use of pre-emptive medication in the short-term. Further studies addressed to improve our knowledge on the impact of heat waves on allergenic plant phenology and pollen production are needed, in order to refine the aerobiological forecast under extreme weather conditions.

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