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Climatic change in Mediterranean area and pollen monitoring

Abstract

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The weather conditions directly influence pollination by determining time of onset of flowering, the number of pollen grains produced, and by controlling the amount of pollen that is discharged into the air from day to day. The climate in the Mediterranean is mild and wet during the winter and hot and dry during summer. In this area plant physiology is controlled by temperature, but some plants flower when water is available or as day length increases in spring or decreases in summer. Some species respond to a combination of these environmental parameters which interact with both the initial steps of the flower initiation and the speed of the flower development.

In the last decades, it has been an evidence of a significant increase of air temperature with consequent changes on the airborne presence of anemophilous pollen. The changes recorded involve, above all, the timing in which occur the pollination, the peak date, the behaviour of pollen release, whereas any significant influence on the total pollen emission is found. Many studies carried out on long time series of airborne pollen counts have shown an earlier start of pollination in spring flowering trees, such as *Platanus, Quercus, Betula, Pinus, Olea*. For taxa flowering in winter, such as *Corylus, Alnus* and *Ulmus*, this trend is not linear and could even be delayed by autumn higher temperatures which determine insufficient chilling accumulation and later start of the season. On the contrary of areas of central and northern Europe, in the Mediterranean area more or less stable trends of weeds or grasses have been observed, with a slight tendency to advance or delay of the onset of pollination, depending on the species. There is also evidence that the length of the pollen season could show significant variations: in general, in the warmest years the pollination is shorter that in the years with lower temperature; in some cases it is also extended, especially in late flowering species or species which start to growth once there is sufficient water availability.

Changes in the parameters which characterize the presence of airborne pollen in the atmosphere of Mediterranean areas appear to be a relatively considerable response to climate change although there are both species and regional differences in the examined models.

Key words: pollination, temperatrue, aerobiology.

Introduction

The life cycle of plants is influenced both by endogenous genetic factors of the species and by environmental signals which control the time of the vegetative and reproductive

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growth (Hopkins & Hüner 2008). The weather conditions directly influence pollination by determining time of onset of flowering, the number of pollen grains produced, and by controlling the amount of pollen that is discharged into the air from day to day (Galan & Dominguez-Viches 2012).

There is a great evidence that the climate has changed during the last decades showing a continuous rising of temperature, sometimes accompanied, such as in Mediterranean regions, by a different trend of annual precipitation (Diffenbaugh & al. 2007; Guiot & al. 2010; Kelly & al. 2012). Historical data bases on the pollen content in the air evidence how the climate change is affecting different species in different geographical areas.

Results

Trend of temperature - Global average temperature has increased by more 0.7°C over the past 100 years and the IPCC (Intergovernmental Panel on Climate Change) projects that the average global surface air temperatures in the present century are likely to be between 1.8 and 4.0°C warmer that in 1980-1999 (Hertig & al. 2010).

Over the past 100 years in Europe, the temperature has increased 0.95°C; this increase took place mainly in spring and in summer while no significant variation was recorded during autumn and winter period. In Spain, rises in temperatures have been higher that in the rest of Europe. Spain shows an increase of 1.5°C over the last 100 years and temperatures are forecast to rise steadily by 0.4°C a decade in winter and by 0.7°C in summer (Cariñanos & al. 2004; Diffenbaugh & al. 2007; Galan & Dominguez-Viches 2012).

In Greece also, air temperature has been increasing during the last decades, in particular, the temperature increase has been manifested in minimum and mean annual values, whereas no systematic changes in other meteorological factors have been observed during the same period (Damialis & al. 2007).

Italy showed a clear and significant trend to an increase of the annual mean temperature, mainly due to the spring and summer temperature arises. The mean annual temperature is 1.8°C higher in the last years compared with that registered in the previous century. In Perugia (central Italy), June, August and April showed the highest increases with 0.152°C, 0.088°C and 0.085°C/year respectively, that are 4.5°, 3.0° and 2.6°C in the last three decades.

Trend in rainfall - The Mediterranean area receives almost all of their precipitation during its winter season and may go anywhere from 4 to 6 months during the summer without having any significant precipitation (Kelly & al. 2012).

The observed trend in the last five decades shows a large season cycle, ranging from a substantial drying in winter to a wetting trend in autumn (not significant). The winter observed rainfall trend is significant with an almost 10 mm/month reduction, or about 17% of the total winter season rainfall. In Spain the reduction of 11% than average has been detected (Kelly & al. 2012).

Extreme daily rainfall increases in spite of the fact that total rainfall generally decreases. There is the existence of a substantial change in the rainfall distribution in the Mediterranean region: the reduction is associated with fewer rainy days.

In Perugia, central Italy, the annual rainfall did not undergo a significant change, with an average of 780 mm/year, but it showed an evident fluctuation, with a minimum value of 563 mm in 1985 and a maximum of 1126 mm in 2004.

Which consequences on pollen season? Timing of pollen season - There is strong evidence from various studies that observed higher temperatures due to climate change are associated with an earlier start of plant flowering above all in spring (Frenguelli 2002).

Concerning the starting date there are several studies and in general the analyses show a clear correlation with the temperature in the pre-season and the starting date of the season. The variations observed among different Mediterranean areas in the onset of pollen season in the winter or spring flowering trees, could be explained by differences in the thermal requirements needed for flowering as consequence of the climatic conditions recorded during the previous period of flowering. The timing of spring flowering species pollen seasons is known to depend mostly on a non-linear balance between the winter chilling required to break dormancy, and spring temperatures. An increase of temperatures after the chilling period allows the plants to overcome the heat required blooming (Frenguelli & al. 2002; Jato & al. 2013; Rodriguez-Rajo & al. 2003a) .

Many aerobiological studies have shown an anticipated beginning of the pollination above all of tree, such as cypress, birch, oak, pine, hornbeam plane, olive and chestnut which showed, on average, an earlier pollination of 0.5-0.9 day/year in the last decades, with some differences depending on region (Caimmi & al. 2012; Clot 2003; Clot & al. 2012; Damialis & al. 2007; Galan & al. 2005; Rodriguez-Rajo & al. 2003b; Sin & al. 2008).

In Italy, the dates of the beginning of pollination and the trend in the 30 years considered for the most representative *taxa* monitored show a marked shift to an earlier season, above all those with spring pollination, with an yearly trend between -0.9 days per year for *Pinus*, and -0.25 days per year, for *Salix*. The trend is positive, but not significant, for the taxa with winter flowering such as *Alnus*, *Corylus* and *Ulmus,* revealing, however, a slight delay in the beginning of pollination in the last years. The trend for summer pollinating taxa, such as *Artemisia*, is smaller and statistically not significant (Cristofori & al. 2010; Frenguelli 2002; Negrini & al. 2011; Orlandi & al. 2005).

The observed trend for grasses is in contrast with those reported from Central and North-Europe, where this *taxon* shows only a limited shift (Clot 2003; Frenguelli & al. 2008; Jato & al. 2009; Smith & al. 2009).

In southern Spain, main results show an advance in the start and peak of grass pollen season and an increase in the annual Pollen Index and in severity of the season (days > 25 pollen grain/m^3) (Galan & Dominguez-Viches 2012). The grass pollen season in Italy is typically mid-April to late July and the start dates showed a marked trend to an earlier beginning of the season (-0.5 day/year), as well as an earlier end and incidence of peak day (Frenguelli 2002; Cristofori & al. 2010).

In Greece, such as in other Balkan peninsula areas, in contrast to what is observed in western and northern European and others Mediterranean regions, no shift to an earlier onset of flowering are observed, except for *Parietaria* which showed an earlier, longer, and more pronounced flowering (Bajin & al. 2013; Damialis & al. 2007; Fotiou & al. 2011).

Regarding the family of *Compositae*, being its pollination above all under the control of photoperiod, do not present significative changes in the start of pollination as a consequence of climate change, but the total pollen production, the amount discharged in the atmosphere, date of peak and duration could be associated with the weather conditions, above all to drought (Frenguelli 2002; Cariñanos & al. 2004).

Length of the season - A clear trend for end dates of the pollen seasons has not been found: earlier, later and not significant changes were documented, depending on the pollen species. The same variability is seen for the length of the pollen season, although for some species there is limited evidence that the length of the pollen season has increased (Beggs 2004).

However, the trend of the duration of the seasons showed a significant decrease. Some taxa such as *Cupressus*, *Pinus, Gramineae*, *Olea* and *Castanea*, in the warmest years had a pollination which was shorter by 6-12 days, therefore finishing the pollen season in fewer days than in the years with lower temperature (Frenguelli & al. 2002; Tedeschini & al. 2003; Frenguelli & al. 2004).

There are no significant variations for the other *taxa*, such as *Alnus* and *Salix*, but it is important to note that the *Urticaceae* registered, in the 2 decades in many Mediterranean regions (Spain, Italy, Greece, Israel) an average increase of 20 days of the pollen season due to both an earlier start (16 days) and a prolonging of the season (4 days) (Frenguelli 2002; Beggs 2004; Cariñanos & al. 2004; Fotiou & al. 2011).

Pollen Index (P.I. = annual total pollen emission) - If changes in the timing of the pollen season can be in a large part attributed to changes in temperature, the influences on pollen abundance are more complex and it is difficult to attribute the observed changes to climate warming.

Different tendencies in the annual total quantity were noted for different pollen types and sites. In addition of the weather-related parameters, other factors, such as land use, forest fires, agricultural practices, could be the cause for changes in the pollen index (Beggs 2004; Cecchi & al. 2010).

Temperature affects plant's reproductive effort: increased reproductive output in terms of flower and pollen production under higher temperature regimes have been observed in some *taxa*, such in Greece and Italy (Frenguelli 2002; Damialis & al. 2007).

A tendency towards an increase of pollen load can be observed in some tree pollens at some places and not at others (Clot 2003). Weeds show the same locally varying results and, on the contrary of central and northern Europe, in Mediterranean areas stable trends of grasses have been observed in the most stations (Ridolo & al. 2007; Jato & al. 2009; Natali & al. 2013).

In many long studies of some pollen counts, both the annual P. I. and daily peak levels increased over 2-3 decade period. In some stations, the total yearly pollen counts for *Parietaria* increased significantly in the last decades, however in the same study, grasses and mugwort pollen counts did not show any significant upward trends (Cecchi & al. 2010; Fotiou & al. 2011).

A trend towards higher values was recorded in the case of *Ambrosia*, but in this case the increase can be considered due to a natural increase of the presence and diffusion of *Ambrosia* in the territory, as alien species widespread in North Italy, South France and North Balkans (Cecchi & al. 2010; Cristofori & al. 2010; Clot & al. 2012).

Distribution of the airborne pollen - Every year has its own characteristic course, with variable periods of high and low airborne pollen concentrations, sometime with multiple peaks or with a single peak.

In the years in which during the pollination the temperature is lower than the mean, the pollen is released gradually during the season and therefore there is not an easy identifiable peak and the curve has flatter tops than the normal and it is more or less symmetric. Instead, in the warmer years the presence of pollen in the atmosphere is more concentrated with an excess of values near the mean and therefore a well identifiable peak and the mass of the distribution is concentrated on the left of the figure (Frenguelli & al. 2002).

The test of Asymmetry Index shows that the shape of the emission distribution curves in different years changes as a consequence of the pattern of emission of pollen and its dispersal in the atmosphere, and correlation with the mean temperature during the pollination period is recorded: positive figures are noted in the warmer years while negative figures are registered in the years in which, during the pollination, the temperature is lower than the mean. This could explain the tendency to reach the peak concentration earlier over the years (Frenguelli & al. 2004).

A clear and significant trend ($p<0.001$ and $p<0.001$ respectively), towards an earlier start of the season results in earlier peak days in *Pinus* and *Castanea*: the trend line shows a shift to a 5-10 days earlier season, while a weakest trend ($p<0.06$) towards earlier peak days was observed for *Cupressaceae* (Frenguelli & al. 2002; Jato & al. 2013).

Response to climatic conditions in arid areas of Mediterranean - Temperature seems to be the parameter that has the greatest effect on the presence of many tree pollen in the atmosphere, but in regions marked by a severe drought, such in the south of Spain or Italy, the highest tree pollen levels (plane, oak) are recorded in the years with sufficient rainfall in the winter-early spring months, together with moderate temperatures. The peak concentrations are reached earlier or later according to the rainfall regime.

Water stress caused by irregular rainfall distribution, affects normal development of plants, but some species are able to adjust their cycles to availability of water.

The response is different depending on the arboreal or herbaceous character of the species. The plants behave differently depending on the conditions prior to and during their respective flowering periods (Cariñanos & al. 2004; Galan & Dominguez-Viches 2012).

Platanus spp. – The highest plane tree pollen levels are recorded in the years with sufficient rainfall in the winter-early spring months together with moderate temperature.

Quercus spp. - The rainfall regime influences the pollen season characteristics: one the drought ceases, oak pollen starts to recover the normal value of P.I. and the peak concentrations are reached earlier or later according to the rainfall regime. But the temperature has been also mentioned as an important parameter influencing oak pollination.

Olea europaea L. – It shows the similar trend of oak.

Grasses –Flowering is more intense if rainfall occurs in the 4-week period prior the flowering and rainfall in June prolongs flowering and as a result grass count could be until three time higher than those of years without rainfall in this month.

Parietaria spp. – No correlation is normally detected between principal period of pollination and temperature and rainfall, but maximum concentrations are recorded in years with a certain amount of rainfall prior to and during flowering.

Artemisia spp. – The maximum levels of mugwort pollen are collected in rainy periods, but torrential rainfall does not favour this or other species.

In general, the flowering of tree species is more affected by the conditions in the months prior to flowering. Thus, very low minimum temperatures may affect both the water availability and the accumulation of the required number of hours of heat to break dormancy. Important as the amount of rainfall, is the distribution of rainfall throughout the year, since a regular rainfall regime ensures a recovery of water availability.

Moreover, herbaceous species present the most immediate response to weather conditions. A more intense flowering has been observed in herbaceous species if rainfall occurs in the 2-4 week period prior to flowering. In case of rainfall during their principal pollination period, then this is prolonged. High temperatures seem to favour flowering of species adapted to arid conditions, that show on the contrary stress during prolonged periods of droughts.

Conclusions

Plants are excellent bio-indicators and, in zones with temperate climate such as the Mediterranean area in which the seasons are clearly differentiated, the vegetation synchronises its development with the alternating seasons (Frenguelli 2012).

The phenology of many herbaceous and arboreal species which grow in this climate is principally governed by the temperature, even if the availability of water and the photoperiod can influence some phases of growth. Every time there are anomalies and as climate changes, plants respond with variations in the beginning, in the duration and in the intensity of the various phenophases (Menzel 2000).

Taking into consideration that the temperature increase registered the last decades took place mainly in March-July period, there is a logical conclusion that the main significant changes concern species flowering in spring that are more affected by warming that species flowering later in the year for which photoperiod, other than temperature, controls the timing of flowering .

Changes in the timing of pollination, in particular an advance of the flowering period, have been clearly shown for woody plants, and partially for grasses and weeds. Cypress, plane, oak, birch, pine, olive and chestnut seem to be very sensitive to this parameter because, when the temperature increases, they show not only a significant earlier pollination, but also significant reductions in duration of the main period of pollination and characteristic trend of the pollen presence in the atmosphere (Clot & al. 2012; Galan & al. 2005; Sin & al. 2008; Tedeschini & al. 2006).

The total amount of pollen is more or less constant except for some species in some areas where a significant upward trend is observed.

Concerning the amount of vernalization necessary to fulfil the dormancy, the long-term stability of autumn and winter temperatures does not influence significantly the trend of pollination of species flowering in the first months of year, such as hazel, alder, elm, etc. (Frenguelli & al. 2004).

In warmer and dry regions where temperature does not represent a limiting factor for the growth, the water availability can influence the pollination more than temperature (Cariñanos & al. 2004). In these regions, common in Mediterranean area, an earlier pollination is not always observed as a consequence of increase in the temperature while it is evident a dependence on the water availability which influences the total pollen counts (Galan & Dominguez-Viches 2012).

The evidence suggests that changes in phenology, pollen production and geographic distribution of plants have been occurring in recent decades, and that nature of the changes may be region-specific and species-specific (Menzel 2000).

In the climate scenarios it is foreseen that the temperature will increase further in the coming decades and this predicted future increase in temperature will probably affect both the flowering of plants and the dispersion of pollen in the air (Hertig & al. 2010; Frenguelli 2012).

We should register the influence of any changes on the phenological phases of the plants using the aerobiological monitoring, easy to carry out and not subject to individual interpretation of phenological field surveys.

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