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Airborne pollen trends in the Iberian Peninsula

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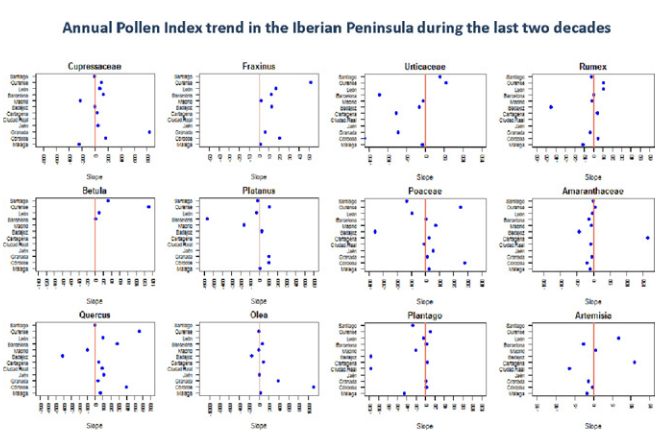
HIGHLIGHTS

- We studied the airborne pollen of 12 anemophilous taxa in the Iberian Peninsula.
- We show variations in flowering intensity over the last two decades.
- Results revealed differences in the distribution and flowering intensity.
- A negative correlation was observed between airborne pollen and winter NAO index
- Changes in rainfall pattern play a key role as driver of climate change effects.

GRAPHICAL ABSTRACT



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ABSTRACT

Airborne pollen monitoring is an effective tool for studying the reproductive phenology of anemophilous plants, an important bioindicator of plant behavior. Recent decades have revealed a trend towards rising airborne pollen concentrations in Europe, attributing these trends to an increase in anthropogenic CO_2 emissions and temperature. However, the lack of water availability in southern Europe may prompt a trend towards lower flowering intensity, especially in herbaceous plants. Here we show variations in flowering intensity by analyzing the Annual

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Pollen Index (API) of 12 anemophilous taxa across 12 locations in the Iberian Peninsula, over the last two decades, and detecting the influence of the North Atlantic Oscillation (NAO). Results revealed differences in the distribution and flowering intensity of anemophilous species. A negative correlation was observed between airborne pollen concentrations and winter averages of the NAO index. This study confirms that changes in rainfall in the Mediterranean region, attributed to climate change, have an important impact on the phenology of plants.

1. Introduction

Changes in climate can have different effects on ecosystems and species (Walther, 2010). Variations in species distribution have been observed over recent decades in response not only to global warming but also to habitat fragmentation and changes in land use (Heap et al., 2014). The last assessment report by the Intergovernmental Panel on Climate Change (IPCC, 2014) notes that each of the last three decades has consecutively been the warmest on record and that the first decade of the 21st century was the warmest on instrumental record in terms of the Earth's overall mean surface temperature. The report concludes that global warming over the last few decades is prompting phenological changes in plants and animals. Species may respond to climate change through a varying degree of genotypic and phenotypic plasticity (Hedhly et al., 2009). However, variations in temperature and the high degree of plant plasticity suggest that genetic variations between populations may be insignificant in relation to changes in reproductive phenology (Chuine and Belmonte, 2004).

A number of authors report a generalized advance in flowering (Cook et al., 2012) as well as greater flowering intensity (Ziello et al., 2012). Research has highlighted the major contribution of rainfall and photoperiod to plant phenology, and various papers have paid special attention to changes in precipitation and water availability as a major driver of climate change in the Mediterranean area (Peñuelas et al., 2004).

In southern Europe, a generalized advance has been reported in flowering, especially in woody species blooming in early spring (García-Mozo et al., 2010a, 2010b). However, it becomes more difficult to define a model in autumn, probably due to a greater annual regional oscillations (Gordo and Sanz, 2005).

Today, airborne pollen monitoring is regarded as an effective tool for studying the reproductive phenology of anemophilous plant species, especially as a bioindicator of their behavior in areas where there are variations in pollen concentrations. Research over the last few years has revealed a trend towards rising airborne pollen concentrations (Ziello et al., 2012; Fernandez-Llamazares et al., 2014), especially for tree species flowering in winter and early spring. Some authors have analyzed variations in the Annual Pollen Index (API) with a view to charting trends in flowering intensity, attributing these trends to an increase in anthropogenic CO_2 emissions (Rogers et al., 2006). Abrupt changes in species distribution have also been ascribed to human activity (Cariñanos and Casares-Porcel, 2011; Oteros et al., 2013b; Velasco-Jiménez et al., 2013). Ziello et al. (2012) report increased flowering intensity over the last few decades for a range of species across Europe, observing more pronounced trends in urban than in rural or semi-rural areas, and also stronger trends in Northern Europe. In Southern Europe, by contrast, lack of water availability may prompt a trend towards lower flowering intensity, especially in herbaceous plants (Alcázar et al., 2009; Recio et al., 2009). Rainfall is governed in part by the influence of the North Atlantic Oscillation (NAO) (Gallego et al., 2005), and research points to a link between the timing and/or intensity of flowering and different phases of the NAO in Europe, and especially in Northern Europe (Smith et al., 2009; Stach et al., 2008).

The main goal of this paper was to investigate variations in flowering intensity by analyzing the Annual Pollen Index (API) of 12 anemophilous taxa across 12 locations in the Iberian Peninsula and charting trends over the last two decades. A secondary aim was to detect the possible influence of the NAO index on flowering intensity.

2. Material and methods

2.1. Study areas and pollen data

This study focused on the Iberian Peninsula. Airborne pollen concentrations were obtained from the *Spanish Aerobiology Network* (REA) www.uco.es/rea database. Pollen data from 12 monitoring stations, which have data for the 20 year period (1994 to 2013), have been considered (Fig. 1). Airborne pollen data were collected using a Hirst-type volumetric spore-trap, based on the impaction process (Hirst, 1952). This device allows continuous monitoring of the atmosphere and enables daily concentrations (daily average of pollen grains per cubic meter of air) or even hourly data. Data were obtained by REA members following a standardized procedure outlined in the *Management and Quality Manual* (Galán et al., 2007), which complies to the minimum requirements described by the European Aerobiology Society's (EAS) Working Group on Quality Control (Galán et al., 2014). REA members are involved in performing external quality control exercises, both at national (Oteros et al., 2013a) and European level (Galán et al., 2014).

This paper examined flowering intensity in anemophilous plants, taking the parameter Annual Pollen Index (API) as the sum of daily pollen concentration during the year. Due to the fact that pollen grains from several taxa are stenopalynous and share certain features under light microscope, airborne pollen grains were classified into pollen

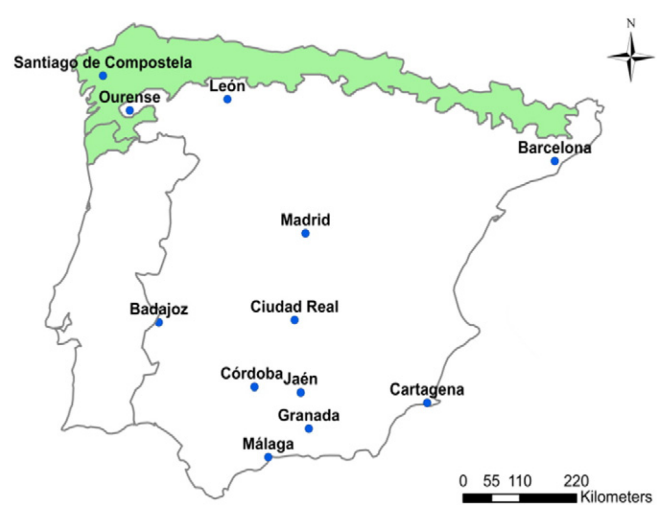

Fig. 1. Location of airborne pollen monitoring sites in the Iberian Peninsula. Green for Eurosiberian region and white for Mediterranean region. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)