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Potential sources of airborne *Alternaria* spp. spores in South-west Spain

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HIGHLIGHTS

- Counts of *Alternaria* spores and analysis of habitats
- Study of air mass transport and meteorological data
- Analysis of back-trajectories of *Alternaria* in Spain

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ABSTRACT

Fungi belonging to the genus of *Alternaria* are recognised as being significant plant pathogens, and *Alternaria* allergens are one of the most important causes of respiratory allergic diseases in Europe. This study aims to provide a detailed and original analysis of *Alternaria* transport dynamics in Badajoz, SW Spain. This was achieved by examining daily mean and hourly observations of airborne *Alternaria* spores recorded during days with high airborne concentrations of *Alternaria* spores (>100 s m^{-3}) from 2009 to 2011, as well as four inventory maps of major *Alternaria* habitats, the overall synoptic weather situation and analysis of air mass transport using Hybrid Single Particle Lagrangian Integrated Trajectory model and geographic information systems. Land use calculated within a radius of 100 km from Badajoz shows that crops and grasslands are potentially the most important local sources of airborne *Alternaria* spores recorded at the site. The results of back trajectory analysis show that, during the examined four episodes, the two main directions where *Alternaria* source areas were located were: (1) SW–W; and (2) NW–NE. Regional scale and long distance transport could therefore supplement the airborne catch recorded at Badajoz with *Alternaria* conidia originating from sources such as crops and orchards situated in other parts of the Iberian Peninsula.

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1. Introduction

Fungi belonging to the genus of *Alternaria* are recognised as being significant plant pathogens. The majority of *Alternaria* species are secondary invaders. They are rarely considered to be virulent pathogens but can still produce considerable economic losses worldwide (Rotem, 1994). Predictions of airborne *Alternaria* spores can be used to optimize fungicide applications in cereals (Aira et al., 2013) and aid in the fight against phytopathogens in crops such as cotton (Bashan et al., 1991) and potato (Escuredo et al., 2011). In addition, *Alternaria* spp. (hereafter *Alternaria*) allergens are one of the most important causes of respiratory allergic diseases in Europe (D'Amato et al., 1997) and globally (Denning et al., 2006), with the standardised sensitization rate to *Alternaria* allergens in Europe being reported as 8.9% (Heinzerling et al., 2009). It has been shown that patients sensitized to *Alternaria alternata* were more frequently affected by asthma compared to the patients who were not sensitized to this aeroallergen (Bartra et al., 2009). Studies on the paediatric population have also shown that, in children, the prevalence of *A. alternata* sensitization is significantly higher (Bartra et al., 2009), *Alternaria* spores may be an important cause of allergic rhinoconjunctivitis (Andersson et al., 2003) and airborne fungal spores, including *Alternaria*, may provoke or exacerbate asthma attacks (Atkinson et al., 2006). Models of spatial and temporal variations in airborne *Alternaria* fungal spore concentrations may therefore also serve as an early warning to sensitized allergy-sufferers (Aira et al., 2013).

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The conidia of *Alternaria* species may be dispersed by rain splash, but the main dispersal mechanism is passively via air currents (Aylor, 1990; McCartney et al., 1993). A number of studies have examined the long distance transport (LDT) of airborne pollen grains and attempted to identify their sources, e.g.: *Ambrosia* spp. (Stach et al., 2007; Smith et al., 2008; Sikoparija et al., 2009, 2013), *Betula* spp. (Skjøth et al., 2007, 2009), *Quercus* spp. (Hernández-Ceballos et al., 2011b), *Olea* spp. (Hernández-Ceballos et al., 2011a; Fernández-Rodríguez et al., 2014), and Poaceae (Smith et al., 2005). On the other hand, similar studies for airborne fungal spores are less common, e.g.: *Ganoderma* spp. in the UK (Sadyś et al., 2014a) and *Alternaria* in the UK and Denmark (Skjøth et al., 2012; Sadyś et al., 2014b).

The present study aims to connect atmospheric concentrations of *Alternaria* spores recorded in Badajoz, Spain, to different types of agricultural land in the surrounding areas by examining air mass transport. This will be achieved by using daily mean and hourly observations of airborne *Alternaria* spores recorded at Badajoz during days with high airborne concentrations of *Alternaria* spores (>100 s m^{-3}) from 2009 to 2011, as well as four inventory maps of major *Alternaria* habitats, the overall synoptic weather situation and analysis of air mass transport using HYSPLIT and geographic information systems. Some general aerobiological studies on airborne *Alternaria* spores have previously been published with data from the study area (Maya-Manzano et al., 2012; Aira et al., 2013), but this is the first detailed analysis of atmospheric transport of *Alternaria* spores in Badajoz. The results of this study are valuable because they can be used for identifying and mapping sources of airborne *Alternaria* spores in the region. This information can be used to prepare source inventories for dispersion modelling, in a similar way that sources of *Ambrosia* pollen were first identified (Stach et al., 2007; Sikoparija et al., 2009, 2013; Smith et al., 2009) and later mapped (Skjøth et al., 2010; Thibaudon et al., 2014; Karrer et al., 2015). The output from such models can be used for several applications, including the production of bulletins aimed at health care professionals and the allergic population, or to provide information about the potential spread of plant pathogens in agriculture, or both.

2. Material and methods

2.1. Sampling site and inventory of potential Alternaria spore sources

Badajoz is the largest city (1470 km^2) in the agricultural province of Extremadura region, in South-West Spain, with a population of 151,565 (NSI, 2015). Badajoz is located 184 m above sea level and only about 2 km away from the border with Portugal (Fig. 1a). Around the city of Badajoz there are irrigated crops (e.g. fruit, corn, tomato, rice), olive trees, more distant holm-oak trees and extensive grazing (Fig. 1b).

Major *Alternaria* habitats were identified using the Corine Land Cover 2000 (CLC 2000) dataset for the studied area (EC. European Commission, 2005). Seinfeld and Pandis (2006) proposed the following classification for the dispersal of aerosols in the air: (a) micro-scale (up to 100 m), (b) urban-local scale (100 m–10 km), (c) regional or meso-scale (10 km–1000 km), and (d) synoptic or global scale (of more than 1000 km). These classifications are now commonly applied in the aerosol sciences. Although, a more detailed classification proposed by Orlanski (1975) separates the mesoscale into 2–20 km, 20–200 km, and 2000–1000 km. In this study, we examine regional/meso-scale atmospheric transport. The radius of 100 km distance from Badajoz was chosen following Avolio et al. (2008) who suggested that (for pollen sized particles) the typical transport distance is in the range of 30–100 km. The inventory maps were gridded using the CLC 2000 projection by aggregating the grid cells to 5 km × 5 km using similar procedures as Skjøth et al. (2012) and Sadyś et al. (2014b). This procedure enables an easy comparison of the density of habitats at regional and national scales described in previously published studies.

Alternaria species frequently attack cultivated cereals (Table 1). Four habitats where *Alternaria* conidia are known to be present in this area were selected for this study: (1) crops; (2) grasslands and pastures; (3) orchards; (4) vineyards (Table 1). Maps representing each of these four habitats were produced. Firstly, a habitat map showing the distribution of crops in Spain was prepared upon a joint extraction of the: (a) non-irrigated arable land (code 211), (b) permanently irrigated

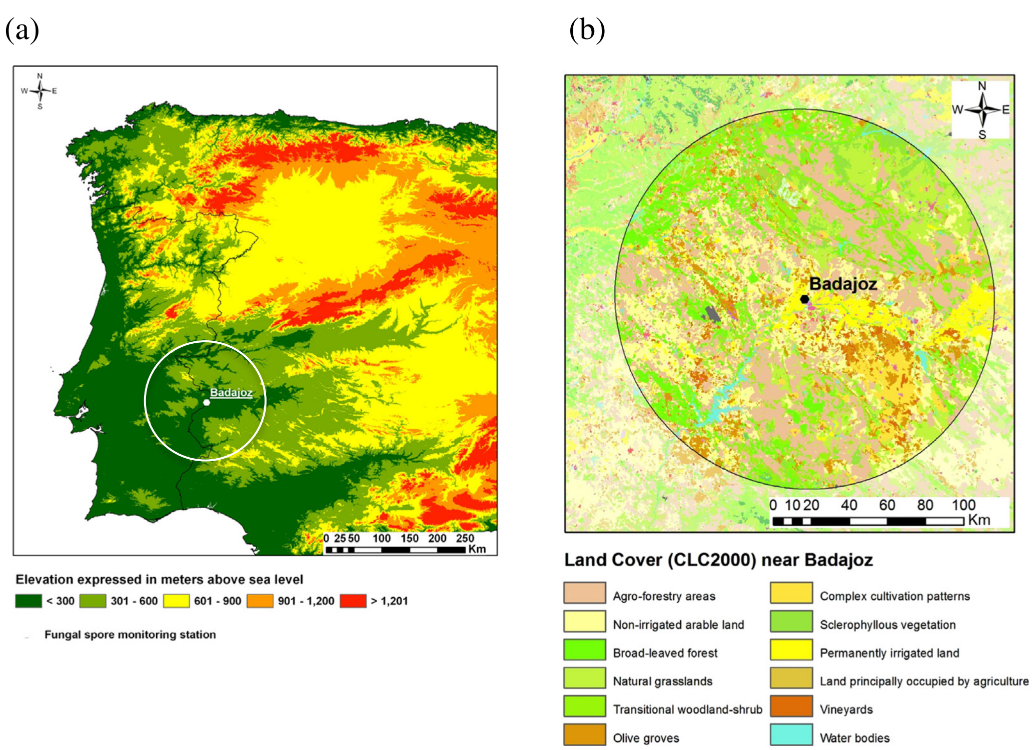

Fig. 1. Site of the study in Badajoz, Spain: (a) hypsometric map; (b) land use within a 100 km radius of the city.