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ORIGINAL ARTICLE

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The effect of meteorological factors on the daily variation of airborne fungal spores in Granada (southern Spain)

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Abstract A study was made of the link between climatic factors and the daily content of certain fungal spores in the atmosphere of the city of Granada in 1994. Sampling was carried out with a Burkard 7-day-recording spore trap. The spores analysed corresponded to the taxa *Alternaria*, *Ustilago* and *Cladosporium*, with two morphologically different spore types in the latter genus, *cladosporioides* and *herbarum.* These spores were selected both for their allergenic capacity and for the high level of their presence in the atmosphere, particularly during the spring and autumn. The spores of *Cladosporium* were the most abundant (93.82% of the total spores identified). The Spearman correlation coefficients between the spore concentrations studied and the meteorological parameters show different indices depending on the taxon being analysed. *Alternaria* and *Cladosporium* are significantly correlated with temperature and hours of sunlight, while *Ustilago* shows positive correlation indices with relative humidity and negative indices with wind speed.

Key words Airborne spore · *Alternaria* · *Cladosporium* · *Ustilago* · Meteorological parameters · Spearman's correlation coefficients · Granada (S. Spain)

Introduction

Aerobiological studies being carried out in the city of Granada, included the sampling of certain fungal spores that constitute high levels of airborne biotic particles in the city (Sabariego 1997) and have been cited by numerous authors as causing severe allergic reactions in sensitive people. *Alternaria* and *Cladosporium* have been identified as the most abundant and frequent airborne allergens in several cities in the Iberian Peninsula (Infante et al. 1988; González Minero et al. 1993; Fernández González et al. 1993; Munuera Giner and Carrión García 1995; Herrero et al. 1996) and their allergenic capacity has been reported by numerous authors (Budd 1986; Vijay et al. 1991; Srivastava and Wadhwani 1992; Caretta 1992; Martínez et al. 1994). Since the sporulation process and spore dispersion of fungi are greatly dependent on the climatic conditions in each area, many authors have correlated meteorological parameters with the presence and prevalence of airborne spores in the atmospheres of climatically different locations. (Hawke and Meadows 1989; Cadman 1991; Hasnain 1993; Hjelmroos 1993; Munuera Giner and Carrión García 1995; Herrero et al. 1996; Méndez et al. 1997). In this paper we use Spearman's correlation coefficient to analyse the effect of certain variables – temperature, sunlight, relative humidity, rainfall and wind speed – on the atmospheric levels of *Alternaria*, *Cladosporium* and *Ustilago* spores in Granada.

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Materials and methods

Methods

Sampling was carried out in 1994, using a Burkard volumetric 7-day-recording spore trap (Hirst 1952) located approximately 23 m above ground level on the roof of the Faculty of Sciences at the University of Granada. The trap functioned continuously, sucking in air at a rate of 10 l/min, with the fungal spores being trapped on a Melinex strip coated with adhesive. Following the methodology proposed by Domínguez et al. (1991) for the Spanish Aerobiology Network, the daily preparations were analysed by optical microscope (40× magnification), with two longitudinal sweeps per slide. The data used correspond to the mean daily values expressed as the number of spores per cubic metre m^3 of air.

Fungal spores belonging to the taxa *Alternaria*, *Cladosporium* and *Ustilago* were identified and counted. The *Cladosporium* spores were divided into two types, *cladosporioides* and *herbarum*, on the basis of their morphological characteristics (Mediavilla 1995). The relationship between the mean daily spore concentrations and mean daily values for maximum, mean and minimum temperature, relative humidity, hours of sunlight, rainfall and wind speed was explored by Spearman's rank correlation coefficient method.

In order to obtain a predictive model with minimal error to indicate the daily behaviour of the different genera, linear and polynomial regressions were carried out, together with multivariant regressions between the spore data and meteorological parameters.

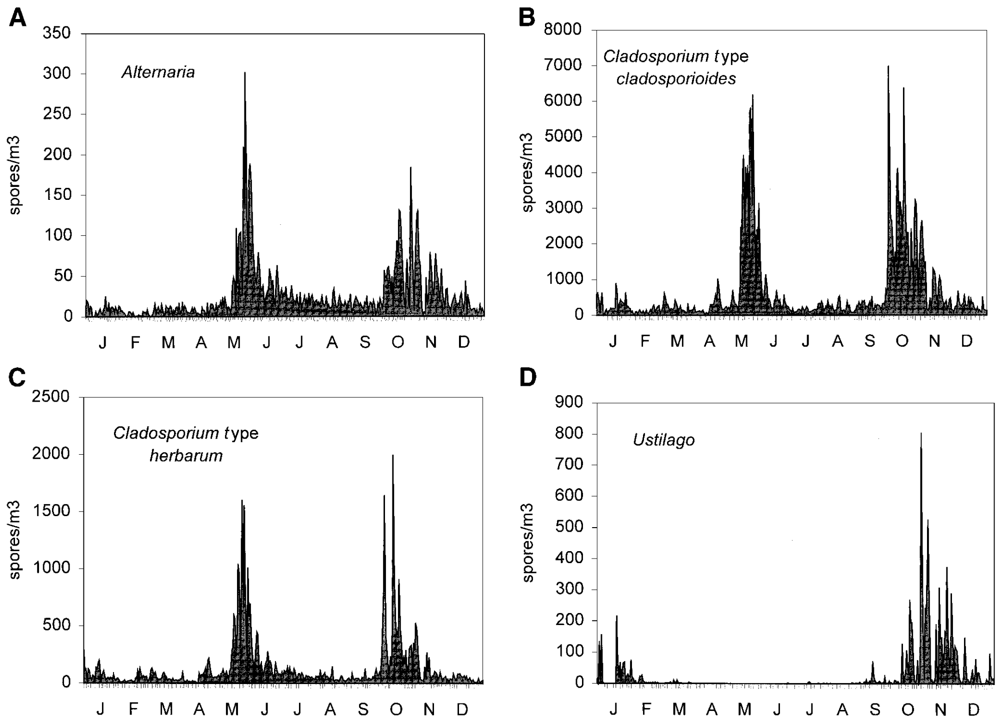

Fig. 1 Seasonal variations of mean daily spore levels in 1994

Table 1 Absolute and relative values for airborne spores analysed in Granada

Spore type	Annual total	
	(m^3)	(%)
Alternaria	9474	3.12
Cladosporium type *cladosporioides*	235383	77.52
Cladosporium type *herbarum*	49515	16.30
Ustilago	9236	3.04
Total	303608	100

The equations that provide the best fit for our data correspond to polynomial curves with a single meteorological variable for each genus.

The meteorological data were provided by Agro-Meteorological Station No. 5 of the Agricultural Research and Development Centre (CIFA) of the Department of Agriculture and Fisheries of the Andalusian Regional Government. This station is located 4 km from the University of Granada Monitoring Unit.

Area of study

The city of Granada is located at 37° 11’ N, 3° 35’ E in the south-southeast of the Iberian Peninsula. It lies in what is known as the intra-Betic gap at the eastern end of the vega (plain) of Granada. This depression is surrounded by the mountains of the Betic Cordillera ranges, a major geological unit in the southern and south-eastern Iberian Peninsula. The area of influence was considered to be within a 50-km radius of the point of reference (the Aerobiological Control Station), with the mountain ranges acting as natural barriers.

According to Elias Castillo and Ruiz Beltrán (1977) the study area has a continental Mediterranean climate with major seasonal variations in temperature and rainfall. The mean annual temperature is 15.3°C, with January the coldest month (mean minimum temperature: –1.7°C) and July the hottest month (mean maximum temperature: 36.4°C). The mean annual relative humidity is 60%, with the maximum values being obtained in winter. The mean annual rainfall is 402.2 mm, thus determining a dry ombroclimate in which rainfall mainly occurs in the autumn, winter and early spring.

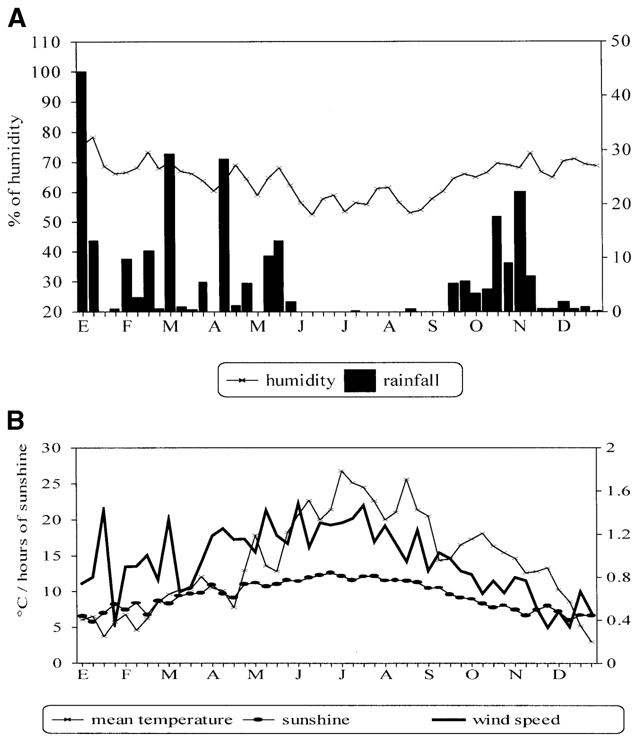

Fig. 2 Weekly means of meteorological data for temperature, hours of sunshine, relative humidity and wind velocity. Accumulated weekly precipitation

Table 2 Spearman's correlation coefficients (r_s) between meteorological parameters and spores analysed

Parameter	r_s			
	Alternaria	*Cladosporium* type *cladosporioides*	*Cladosporium* type *herbarum*	*Ustilago*
Sunshine	0.4680**	0.2065**	0.3806**	–0.3597**
Maximum temperature	0.5995**	0.1592**	0.3279**	–0.2682**
Mean temperature	0.6312**	0.2324**	0.4056**	–0.2901**
Minimum temperature	0.5809**	0.2802**	0.4530**	–0.2868**
Humidity	–0.3540**	0.0691	–0.0547	0.3412**
Rainfall	–0.1905**	0.0690	0.0023	0.0869
Velocity	0.0901	–0.1024	0.0743	–0.5770**

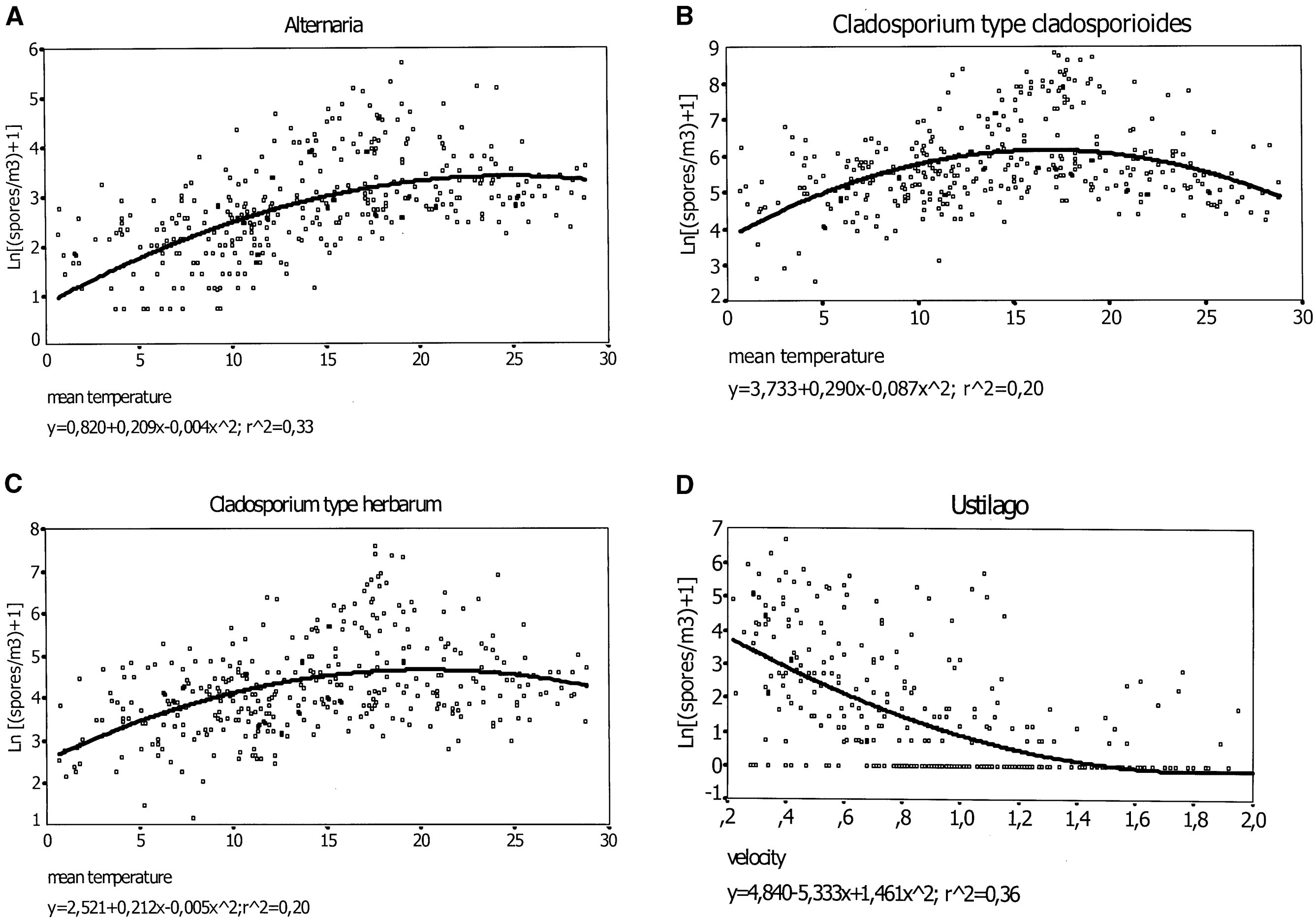

Fig. 3 Theoretical model for adjusting daily spore data to a predictive curve and equation (y = spore data; x = meteorological parameter; r^2 = squared correlation coefficient)

Results

Although the concentrations of airborne fungal spores recorded in Granada are high throughout the year, the highest levels are detected in spring and autumn, with an easily discernible peak in each of these two seasons. The minimum concentrations occur in summer and winter, with quite similar values being recorded in the two seasons. The seasonal variations of daily spore levels (Fig. 1) indicate that the aerobiological behaviour of the genera *Alternaria* and *Cladosporium* is very similar, with each presenting two periods of maximum concentration, the first mostly in May and the second in October. However, the spores of *Ustilago* only reach high levels in the autumn and part of the winter, the highest values being recorded in October and November. In 1994 the total spore density for these three taxa was 303 608 spores/m^3 (Table 1). *Cladosporium* spores of the type *cladosporioides* were the most abundant (235 383 spores/m^3), constituting 77.52% of the total. *Alternaria* and *Ustilago* accounted for only 3.12% and 3.04% respectively.

The weekly and seasonal variations in the meteorological data for the year of study are shown in Fig. 2. The results show that the genera *Alternaria* and *Clado-*

sporium are positively correlated (P≤0.01) with the three temperature types and sunlight (Table 2); however, the relative air humidity and rainfall provide significantly negative correlation coefficients with airborne *Alternaria* spore levels; the negative effect of these variables was not observed with the other genera.

Ustilago, unlike *Alternaria* and *Cladosporium*, responds to the meteorological parameters with a different pattern of behaviour, since it appears in the atmosphere in different seasons, presenting negative correlation coefficients with maximum, mean and minimum temperature, sunlight and wind speed, and positive coefficients with relative air humidity (Table 2). The spores of this taxon are mostly detected in the autumn and winter when temperatures fall, the wind speed is low and the relative air humidity is high (Fig. 2).

Figure 3 shows the curves that best fit our results, together with the prediction equation, using the mean temperature as an independent variable for *Alternaria* and *Cladosporium* and wind speed for *Ustilago*.

Discussion

The sporulation and dispersion of the spores of the taxa studied are closely related to the variations in the atmospheric conditions. The content of *Alternaria* spores in the atmosphere increases when maximum, mean and minimum temperatures rise and there are more hours of sunshine; these results are very similar to those obtained by other authors in other locations (Infante et al. 1987; González Minero et al. 1994; Munuera Giner and Carrión García 1995; Ricci et al. 1995; Méndez et al. 1997), who considered that these factors (together with relative humidity) played a major role in the dispersion of *Alternaria*. A negative correlation is observed with rainfall and humidity, although Herrero et al. (1996) reported a positive correlation with rainfall. The spores of *Cladosporium* correlated positively with the three temperature parameters and hours of sunshine; this link with temperature has been reported by other authors, who observed that maximum *Cladosporium* levels coincided with high temperatures; in locations in the northern Iberian Peninsula the highest concentrations were thus recorded in summer (Herrero et al. 1996; Méndez et al. 1997) whereas farther south (Infante et al. 1998) the peaks occurred in the spring and autumn, as was found in the present study. These differences are due to the fact that the most favourable temperature for the release of these spores is reached in different months in the different study sites. Although some authors (Rubulis 1983; Ebner and Haslwandter 1989; Hawke and Meadows 1989) have stated that the significance of the correlation with humidity depends on the type of spores, in the present study only the spores of *Ustilago* presented significant positive indices for this parameter.

Although data from a single year are not sufficient for predictive modelling of relationships between spore contents and meteorological variables, the theoretical patterns shown in Fig. 3 indicate that for *Alternaria* there is an optimum for spore release, with values of over 20 spores/m^3 when the mean temperature is 22–29°C. The highest *Cladosporium* type *cladosporioides* levels occur within the mean-temperature range of 13–21°C, whereas *Cladosporium* type *herbarum* is optimum when the mean temperature is 15–25°C, with counts of over 200 spores/m^3 and 60 spores/m^3 respectively. *Ustilago* spore levels are directly related to the wind speed, with levels of over 5 spores/m^3 when the wind speed is under 0.8 m/s.

The predictive equation (Fig. 3) shows the airborne spore levels for each genus on any day; however, the r^2 coefficient indicates that mean temperature explains only 33% of the variation in *Alternaria* spores, and 20% for the *Cladosporium* spore types, whereas for *Ustilago* the wind speed accounts for 36% of the spore dynamics.

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