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ATMOSPHERIC TRANSPORTATION OF MARIHUANA POLLEN FROM NORTH AFRICA TO THE SOUTHWEST OF EUROPE

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Abstract—As a result of aerobiological samples taken on the Costa del Sol (S. Spain), *Cannabis sativa* L. (marihuana) pollen was detected from May to September 1991–1996, always sporadically and usually during the afternoons. Sampling was by two volumetric spore traps set up in Malaga and Estepona, two coastal towns approximately 90 km apart. A study of the days when this pollen was recorded points to the movement of air masses from North Africa to southern Spain. Furthermore, the isentropic air trajectories calculated for these days reinforce the possibility of the pollen originating in marihuana plantations in northern Morocco (Rif). This study demonstrates the application of aerobiology to the control of the source, quantity and phenology of the crop. © 1997 Elsevier Science Ltd

Key word index: Aerobiology, long-distance transport, isentropic air trajectories, phenology, crop.

INTRODUCTION

Cannabis sativa L. is an annual plant, sometimes monoicous, originating in Central Asia, which is cultivated for its fibrous stems to produce hemp and for its seed (hempseed), which is used as a commercial bird food. Some varieties are cultivated to produce drugs (marihuana, hemp) from the resin found in stems, young leaves and flowers. It is also found in cereal crops and fallow lands of the temperate regions of Europe (Moore *et al.*, 1991).

The plant produces abundant pollen, 70,000 grains in one anther (Faegri and Iversen, 1989). Since the stamens are free and the masculine inflorescences are found at the top of the plant, wind pollination is favoured and pollen has been identified in airborne pollen samples in a wide variety of places as South Africa (Cadman and Dames, 1993), India (Malik *et al.*, 1991; Gupta and Chanda, 1991), Florida (Jelks, 1991) and North Africa (Reille, 1992; Calleja *et al.*, 1993). In Europe it has only been cited in Madrid (Central Spain) (Sáenz and Gutiérrez, 1983), and in the coastal areas of South Spain (Recio *et al.*, 1995), where it was registered in two volumetric traps in two separate parts of this coast during May–September 1991–1996. In order to ascertain the origin of this pollen the meteorological characteristics of the days when it was recorded were examined and the isentropic trajectories were calculated. The importance of identifying the origin lies not only in attempts to control the illegal movement of drugs but also in the possibility of the pollen producing allergenic reactions in some sensitive individuals, as has happened in the north-central regions of North America where *Cannabis* was widely grown (Maloney and Brodkey, 1940; MacQuiddy, 1955). Many papers on medium or long-range transport of other pollen grains have been published (Tampieri, 1977; Mandrioli *et al.*, 1980, 1982, 1984; Johansen and Hafsten, 1988; Peeters and Zoller, 1988; Hjelmroos, 1991; Franzen *et al.*, 1994; Rantio-Lehtimäki, 1994), but this is the first on marihuana pollen.

ANALYSIS OF THE ATMOSPHERIC POLLEN CONTENT

Methods

By using a spore trap sited 15–20 m above ground level in an open area with no nearby buildings to interrupt the free movement of air, it is possible to get a good idea of the atmospheric pollen content of an area of approximately 50 km radius (Faegri and

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Iversen, 1989). We used two Hirst-type volumetric traps (1952), one manufactured by Burkard® situated in Malaga (36°47′N, 4°19′W) and the other manufactured by Lanzoni® and set up in Estepona (36°25′N, 4°9′W). The former trap began operating in 1991 and the latter in 1995.

To count the different pollen types, four longitudinal scans per slide were made using a lens ×40 (0.45 mm microscopic field) according to the method proposed by the Spanish Aerobiological Network, REA (Domínguez *et al.*, 1991). The pollen concentrations are expressed as number of pollen grains per m^3 of air and day.

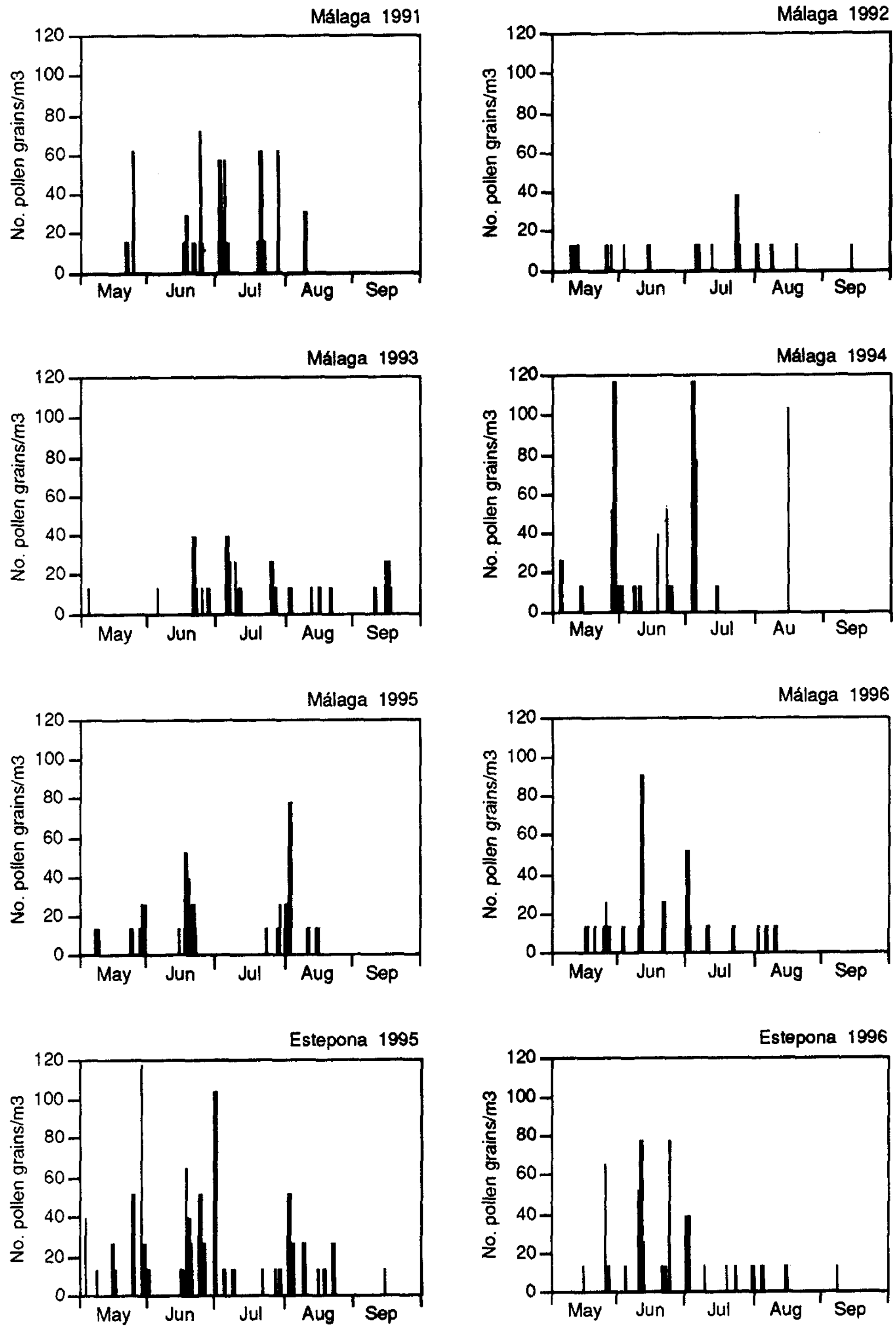

Fig. 1. *Cannabis* pollen counts in Malaga and Estepona (total daily values expressed as number of pollen grains m^{-3} of air).

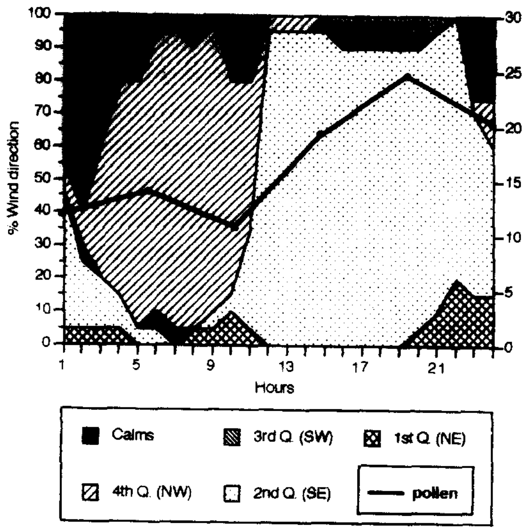

Fig. 2. Intradiurnal distribution of *Cannabis* pollen and wind direction in Malaga during 1991–1996, expressed as percentage and taking the days when more than 30 pollen grains m^{-3} of air were registered. The hourly data of wind direction correspond to Malaga Airport, 5 km south of the sampling site. Each of the wind quadrants has the compass point indicated in parentheses as its centre. Spanish time (+2 UT).

Results and discussion

During the six years of sampling (1991–1996) *Cannabis* pollen was registered between May and September (Fig. 1), always sporadically and in quantities not exceeding 117 pollen grains m^{-3} of air daily. In Malaga the annual number of days when this pollen was registered varied from 15 to 22 and in Estepona it was recorded on 29 days during 1995. The mean annual total of *Cannabis* pollen grains was 452 grains m^{-3} in Malaga, while Estepona showed almost the double in 1995 (894 grains m^{-3}). The lengthy pollination period recorded points to a wide phenology, suggesting that the species is cultivated at different altitudes in mountainous regions. The quantity of pollen grains collected indicates the greater or lesser production.

One of the advantages of the Burkard and Lanzoni samplers is that they enable the intradiurnal variation of the pollen content to be known. They showed, for example, that *Cannabis* pollen occurs basically during the afternoon (Fig. 2), which coincides with the greatest frequency of winds from the second quadrant (south easterly) which blow off the sea.

METEOROLOGICAL SITUATION

To study the meteorological situation topographic maps of 500, 850 and 1000 hPa were used.

The atmospheric characteristics of the days when pollen of this species was recorded are:

- jet stream on high latitude;
- light westerly winds on high level over the Iberian Peninsula;
- light winds on level of the Alboran Sea, predominantly westerly, and with breeze on the coast;
- slight visibility and fog patches in the Alboran Sea;
- thermal inversion on levels near to the surface;
- anticyclonic circulation over the Gulf of Cadiz;
- weak pressure gradient along the Alboran;
- thermic low in the Iberian Peninsula, displaced to the east.

One of these days, for example, was 18 June 1995, when on high level (Fig. 3a) light westerly winds blew over the Iberian Peninsula and a jet stream crossed the British Isles. On the surface (Fig. 3b) there was a strong anticyclone to the west of Portugal extending to the Gulf of Cadiz. In the Peninsula itself there was a certain cyclonic circulation due to daytime heating. To the west of the Iberian Peninsula the wind blew from the north and a weak westerly wind blew in the Straits of Gibraltar due to the pressure gradient. This air, which blows towards the Alboran Sea, is relatively cold and comes from the discharge of cold fronts circulating at higher latitudes below a subsidence temperature inversion, which, in the latitudes of the study area, descends to very low levels. This layer of air is very thin and is transformed over the Peninsula and North Africa by the sun's heat, maintaining its identity only over the sea. The 850 hPa isotherms, which in Fig. 3b are superimposed on the 1000 hPa geopotential contour lines, stretch from North Africa to form a relative maximum over the Iberian Peninsula (prolongation of the thermic low from Africa to the Peninsula) and give rise to southerly thermic winds which, due to weakness of surface winds, favours the appearance of southerly winds of little turbulence just above the Alboran surface, especially in the afternoon, when the thermic low is reinforced.

ORIGIN AND TRANSPORTATION OF THE MARIHUANA POLLEN

We observed that during the days when marihuana pollen was recorded in southern Spain, there is a meteorological situation that reinforces the possibility of these pollen originating in plantations of northern Morocco. The convection in North Africa raises the pollen grains above the inversion of the maritime layer of air, which prevents the pollen from being pulled down towards the sea surface by convection. The southerly wind carries the pollen towards the Spanish coast, where the vertical circulation of the breeze (predominant during summer, on days of weak pressure gradient) leads to a higher presence of pollen

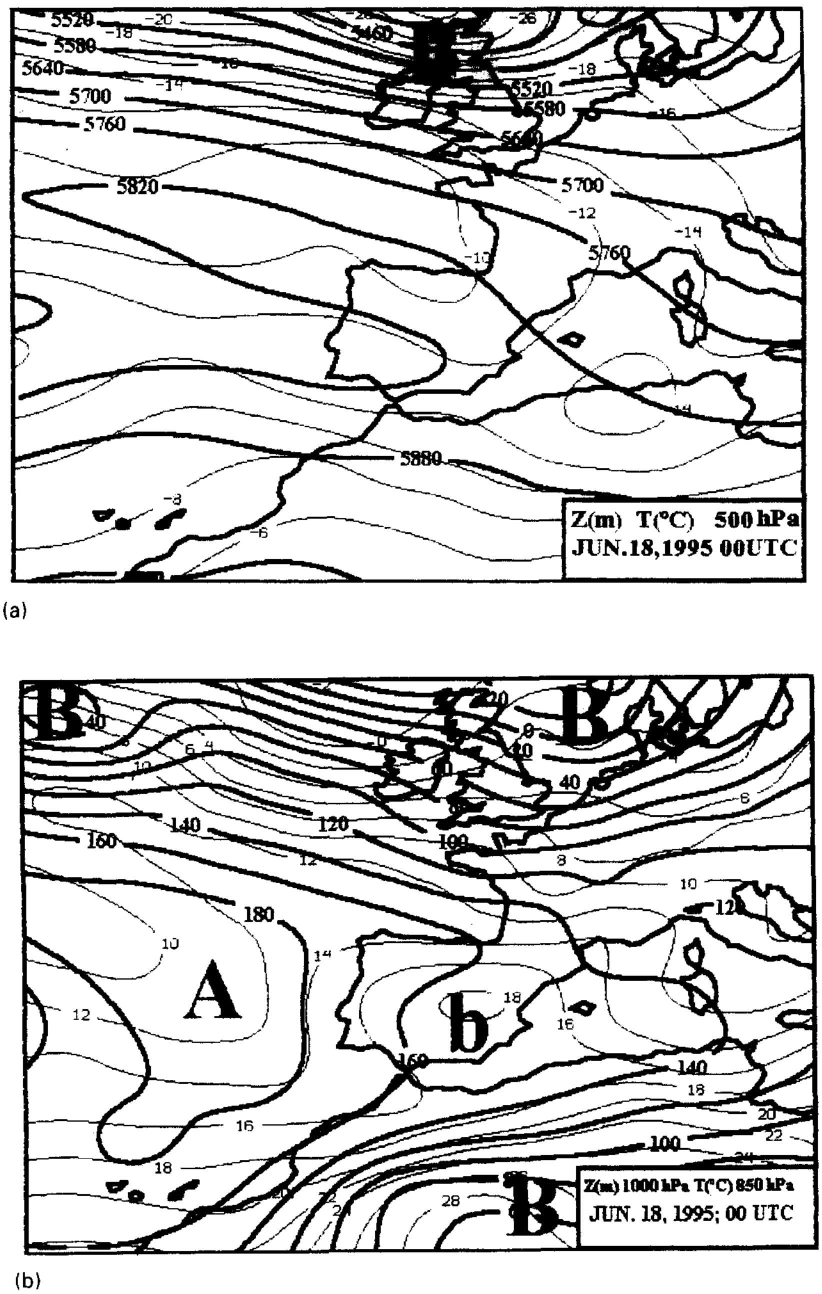

Fig. 3. Synoptic maps of 18th June 1995 at 00.00 h UT in the Iberian Peninsula and North Africa. (a) High-level topography. Thick lines: geopotential at 500 hPa; thin lines: isotherms. (b) Low-level topography (close to the surface). Thick lines: geopotential at 1000 hPa; thin lines: isotherms at 850 hPa.

grains on the surface. To confirm this, the air trajectories of these days were examined.

Air trajectories analysis

The trajectories were calculated from an analysis of the limited area model of the National Institute of Meteorology (LAM-INM), by kinematics procedure. This method is an improvement, carried out by INM in SAIDAS (Martínez *et al.*, 1988), of the original code of Mcldas trajectories (Suomi *et al.*, 1983), into which the possibility of using known intermediate states, the calculation of retrogressive trajectories and the acceleration have been introduced. Interpolations were made every 30 min.

These air trajectories were calculated for the days when marihuana pollen was recorded in the southern part of Spain. As an example, Fig. 4 shows isentropic air trajectories calculated from 16th to 18th of June

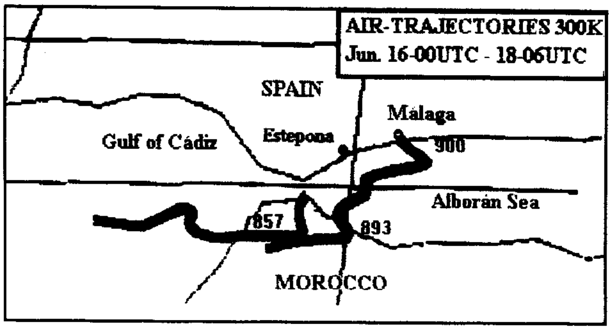

Fig. 4. Three-dimensional isentropic air trajectories for 16–18 June 1995 over Iberian Peninsula and North Africa. (○) Malaga; (●) Estepona. The number over the lines are pressure in hPa.

1995. From them, the origin of the marihuana pollen recorded in Malaga and Estepona on the 18th becomes clear: northern Morocco. Similar trajectories were calculated for the other days when marihuana pollen was recorded.

CONCLUSIONS

It seems probable that the *Cannabis* pollen which reaches southern Spain has its origin in plantations in northern Morocco.

Based on the quantities of pollen detected, the annual *Cannabis sativa* harvest can be estimated and increased trafficking foreseen between the producing region (Morocco) and the consumer countries (Europe).

Independent of the quantity, recent years have seen an increase in the length of the period during which marihuana pollen is recorded (number of days between the first and the last grain registered), which seems to suggest an extension in altitude of its cultivation because the north of Morocco is very mountainous. This would harm the native *Cedrus* woods, and there is also the possibility of producing allergenic reactions in some sensitive individuals.

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