PLANT BIOSYSTEMS, **134** (2) 199-204, 2000

Aeropalynological and phenological study in two different Mediterranean olive areas: Cordoba (Spain) and Perugia (Italy)

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received 25 February 1999; revised version accepted 3 November 1999

ABSTRACT - An aerobiological and phenological investigation on the olive tree was carried out during three years in two areas: Cordoba (Spain) and Perugia (Italy). In these countries, this species is economically important and those areas were chosen because of the long series of aeropalynological data (1982-1998) available, obtained by means of identical volumetric pollen traps. The aim of this study was to use phenological observations to prove the real contribution to the pollen curves in different cultivated areas. Results show that in Cordoba province (302.152 ha) the pollen curve is characterised by different peaks because of the pollination of different cultivated crops. In some cases, these crops are located far from the pollen trap (50 km) but pollen is transported thanks to favourable winds during the flowering period. In Perugia (750 ha) the pollen curve is characterised by only one peak; it is very concentrated because of the proximity of the investigated crops. The objective of this research was to obtain information on this species in order to elaborate statistical models aimed at forecasting the potential fruit production based on the amount of pollen released into the atmosphere.

KEY WORDS - aerobiology, aeropalynology, agronomy, Mediterranean areas, *Olea*, phenology, pollination

The great increase in olive oil consumption worldwide (COI, 1996) has spurned economic interest and scientific investigations on this species (ROCCHI, 1993; PARRAS ROSA, 1996; TOMBESI *et al.*, 1996). Recent economic measures adopted in Europe have created conflict between the two major producers (Spain and Italy) leading to protests against the European Union.

The EU has financed projects aimed at building statistical models to forecast future yields (DALLEMAND & VOSSEN, 1995). In one of these projects, called MARS Pilot Project, one of the variables was the amount of pollen grains released into the atmosphere during the flowering period, and its correlation with annual fruit production. In this study, phenological observations were carried out to observe the different behaviour of the cultivars of this crop which are normally planted.

Two large cultivated areas (Figure 1) were chosen because of their importance in olive oil production. In both the areas, a large data bank for pollen monitoring has been created.

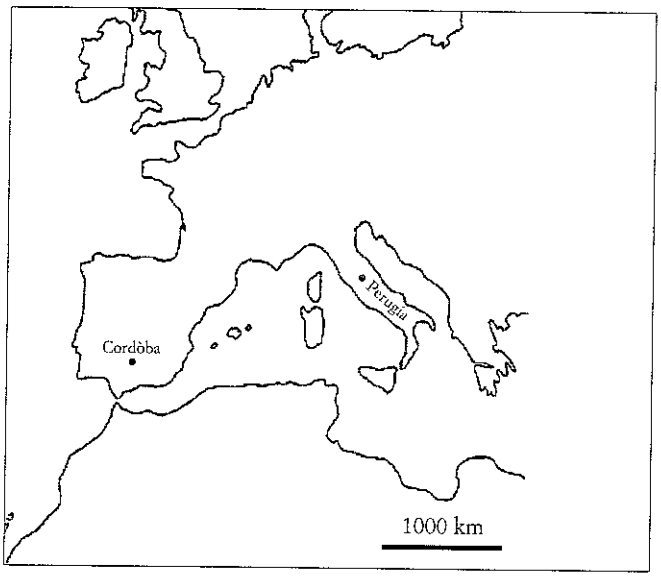

FIGURE 1 - Map of the Cordoba and Perugia investigated areas.

In the aerobiological studies carried out previously (DOMINGUEZ *et al.*, 1993; ROMANO *et al.*, 1988, 1991), the pollen curve representation was composed of pollen grains released by different cultivars and, in some cases, the different flowering contributions of the crops. For that reason, phenological investigations were carried out over three years in those areas to verify the behaviour of the different cultivated zones, and the similarity or diversity of pattern within this species.
All of this information will help us to improve statistical models which also take into account biological information in order to forecast potential olive fruit production.

MATERIALS AND METHODS

Olea europaea L. is one of the most important crops in Andalucia (Spain), especially in the Cordoba province where above 302.152 ha are dedicated to olive groves (22% of the total surface). The city is 120 m above sea level, in the valley of the Guadalquivir River.
The climate of Cordoba is Mediterranean with a touch of continentality; average annual rainfall is 600 mm and annual average temperature is 18°C (mean of last 40 years from Estacion Meteorologica de Cordoba, Instituto Nacional de Meteorología).
From the city of Cordoba, the area dedicated to olive production increases gradually toward the south of the province. For this reason, three phenological sampling points located between the capital and the Sierra Subbetica, the most intensive cultivated area, were chosen for our study. One of them is located in the so-called "Campina baja" (low plain): Santa Cruz, with an altitude of 200 m above sea level. Another is located in the "Campina alta" (high plain): Castro del Rio, at 15 km from the first and 300 m above sea level. The third is located in Baena, a village on the mountain slopes of Sierras Subbeticas, at an altitude of 450 m above sea level and 17 km away from the second location. During 1998, the phenological investigations were carried out only in Santa Cruz and Castro del Rio, because of a disease that affected growth in Baena.
Olea europaea L. is also an important crop in Umbria (Italy) and particularly in the province of Perugia. The trap was placed at the centre of the cultivated area which is 750 ha wide. The town of Perugia is located 493 m above sea level.
The climate is sub-continental, average annual rainfall is 900 mm and average annual temperature is 13°C (mean of the last 100 years, courtesy of Istituto di Ecologia Agraria, University of Perugia). Due to the orography of the province, the climatic conditions were similar in all the investigated zones. The phenological observations were made in two zones: one situated in the city of Perugia, with the olives groves growing on the hillsides, and the other one in Torgiano village, located on another hill 6 km away from the city.
The study was carried out in the years 1996, 1997 and 1998. The phenological data were collected directly from the crops once a week, using the method described by L'OLIVIER (1978). The phenological observations were made on 30 trees in each country. The different phenological phases (bud dormancy and sprouting, raceme, initial, full and final stages of flowering, seed-set and fruit formation) were transformed into numerical points (Table 1).
Pollen monitoring was carried out with the aid of two volumetric Hirst type samplers. Daily pollen concentration in the atmosphere was measured as the number of pollen grains per cubic meter (p/m^3). The pollen trap in Cordoba was placed on the roof of the Science Faculty; in Perugia the trap was located on the roof of the Faculty of Agriculture. Both pollen samplers were installed 15 m above ground level, and have been running continuously from 1982.

TABLE 1
Phenological phases

1 = Bud dormancy	2 = Sprouting
3 = Raceme	4 = Start of flowering
5 = Full flowering	6 = End of flowering
7 = Seed-set	8 = Fruit ripening

RESULTS

In Figure 2 the aerobiological results in the two monitoring stations are represented as pollination curves based on daily pollen concentrations during the three years of the study.

In Cordoba, the three years exhibit different patterns from an aerobiological point of view. In general, the curve representing pollen grains of the olive tree present in the air of the city is very irregular. In 1996, there was a long period of pollen presence in the air, although the total amount of pollen was low. On the contrary, during 1997 and 1998 the pollen curves were shorter and the quantity of pollen higher. At the same time, in 1997 there was an advancement compared with the normal pollen curve of the last 10 years (DOMINGUEZ *et al.*, 1993).

In Perugia, pollen is present in the atmosphere usually from the beginning of June to the end of July (ROMANO & FORNACIARI, 1994; FORNACIARI *et al.*, 1995) and exhibits only one peak. In the three years of this investigation the olive pollen grains showed some differences both in the total quantity and the occurrence of peaks. During 1996, total amount was very high and showed the highest peak. During 1998 there was a relatively early pollination period and a low total amount (Figure 2).

Figure 3 shows the phenological results relative to the three years in the Cordoba areas. In all years full pollination was different in the three different zones. Differences also occurred from a phenological point of view: olive trees cultivated in Santa Cruz flowered earlier than those in Castro del Rio, and these earlier than those in Baena. During 1997 and 1998 the differences between the areas were weekly while in 1996 they were of two weeks. As indicated by the aerobiological results, flowering occurred earlier in 1997 compared with the other two years.

In Figure 4 the phenological observations made in the Perugia province are represented. These show that pollination occurs in the same period at both stations in all years. Moreover, aerobiological results indicate that, in 1997 and 1998, full pollination occurred in the same week, while in 1996 there was a delay of one week.

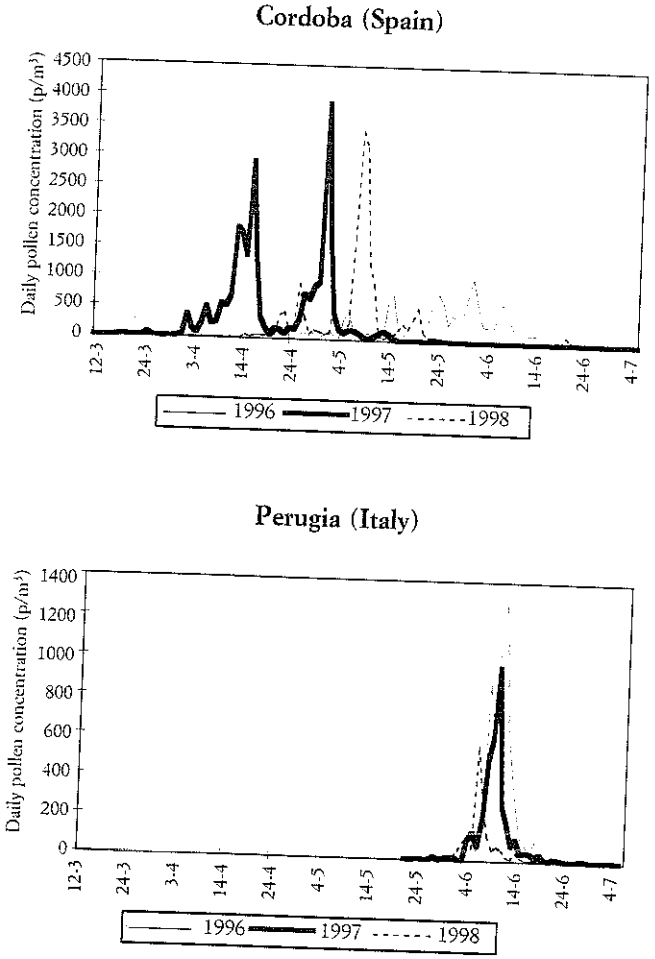

FIGURE 2 - Daily pollen concentrations monitored in Cordoba (Spain) and Perugia (Italy) during the three investigated years.

DISCUSSION

To explain the behaviour of pollen present in the atmosphere it is very important to take into consideration the meteorological conditions not only during the pollen season but also in the period prior to pollination. For this reason, previous investigations in the two studied areas were carried out using aerobiological data (DOMINGUEZ *et al.*, 1998; FORNACIARI *et al.*, 1997, 1998), and phenological data (RALLO & MARTIN, 1991; ALCALA & BARRANCO, 1992; PROIETTI, 1990; BIGNAMI *et al.*, 1994; ANTOGNOZZI *et al.*, 1994) in order to correlate the pollen season with some climatic parameters.

It has been generally observed that rainfall and temperature can influence the start and duration of pollination (ALCALA & BARRANCO, 1992; FORNACIARI *et al.*, 1998), as observed in Cordoba in 1997. In fact, in March and April the mean temperature was higher (by 2.8 and 3.4°C, respectively) than the average of the last 15 years, and no rain fell during winter and early spring (Table 2).

In Perugia, the delay of pollination in 1998 was probably due to the abundant rainfall: 94.2 and 94.6 mm during May and June, respectively.

Moreover, when comparing the aerobiological results in the two monitoring stations (Figure 2), it is clear how a displacement occurs in the curves which represent the pollen counts in Perugia compared with those of Cordoba. This is due to the climatic conditions (average temperature near 18°C) that occurred earlier in Cordoba

CORDOBA

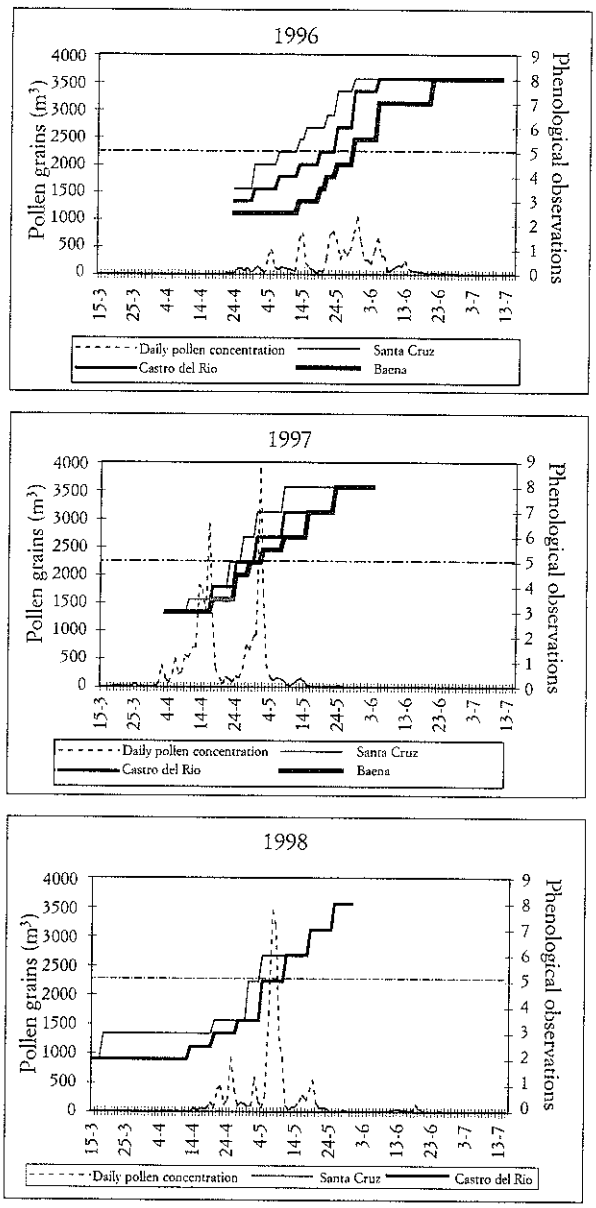

FIGURE 3 - Comparison between the pollen curve (—) and phenological data from the three sampling points of the Cordoba area during the investigated period.

PERUGIA

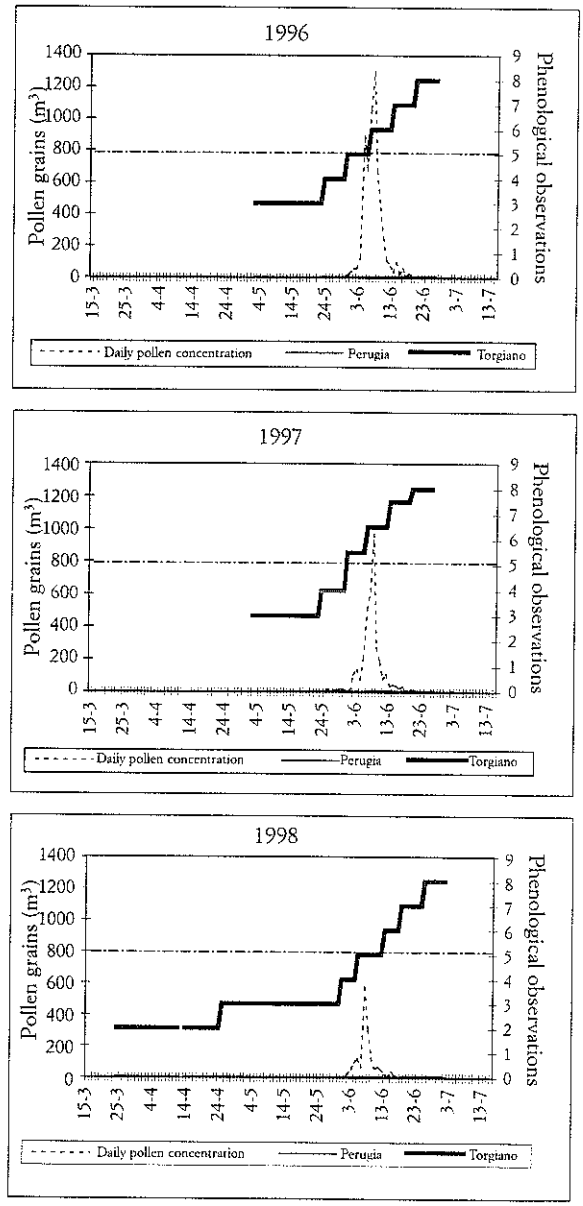

FIGURE 4 - Comparison between the pollen curve (—) and phenological data from the two sampling points of the Perugia area during the investigated period.

than in Perugia, because of the Mediterranean climate of the former (FORNACIARI *et al.*, 1995).

Figure 3 compares the annual aerobiological and phenological data from Cordoba. The peaks represent different crops. The first one, already investigated by BARRANCO *et al.* (1994), is located in Cordoba, the second is in Santa Cruz, the third in Castro del Rio and the fourth in Baena. This was more evident in 1996, with a longer pollen curve and larger phenological differences between crops. During 1997, a long rainy period (Table 2) occurred in Santa Cruz and Castro del Rio when the crops were flowering. During 1998, disease and rainfall affected the Baena data.

The aerobiological and phenological data from Perugia (Figure 4) indicate that the trap detects pollen released into the atmosphere almost immediately. The cultivated areas in which phenological investigations were carried out, are located near the city, and the climatic conditions were similar in all the areas. In 1998, these data coincide perfectly, while during 1996 and 1997 a short delay was

TABLE 2
Monthly meteorological data during winter and spring in Córdoba

	Mean of the last 15 years		1997	
Month	Average temp.°C	Rainfall (mm)	Average temp.°C	Rainfall (mm)
January	9.3	77	10.8	231
February	10.9	51	13.4	0
March	13.9	48	16.7	0
April	15.7	56	19.1	18
May	19.3	36	20	72

observed. This fact is probably due to the great ease with which this pollen is transported so that the pollen detected could come from sources which were not phenologically investigated.

CONCLUSIONS

Samplers located in city areas detect pollen from different cultivated areas, some of which may be far from the pollen trap. The pollen season appears to be longer in Cordoba, due to the pollen grains produced by the broad spectrum of cultivation areas in that province. This study also shows that olive pollen grains can be easily transported in the atmosphere. In Cordoba, the highest peak occurs when the crops located in Baena, the most important olive-growing area 50 km from the trap, was in full flowering.
In Perugia, on the contrary, the investigated olive zones all flower at the same time. It is, however, possible that due to the great capacity of this pollen to be transported in the atmosphere, when pollen detection by the trap is delayed, pollen grains also come from crops which are not located near the trap.

ACKNOWLEDGEMENTS

The pollen data of Perugia were kindly provided by the PG1 station of the Italian Association of Aerobiology. The Italian research was supported by the Strategic project of CNR. "Biodiversity' and MURST (60%) grants.
The Spanish research was carried out in framework of Project PB96-0513, financed by Programa Sectorial de Promocion del Conocimento.

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