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Maria del Mar Trigo^a, Marta Recio^a, Francisco Javier Toro^a & Baltasar Cabezudo^a

^a Departamento de Biología Vegetal, Universidad de Málaga, Apdo. 59., Málaga, E-29080, Spain

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Intradiurnal fluctuations in airborne pollen in Málaga (S. Spain): A quantitative method

M. MAR TRIGO, MARTA RECIO, F. JAVIER TORO and BALTASAR CABEZUDO

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Intradiurnal fluctuations in the airborne pollen count of nine of the taxa which are most important in the atmosphere of Málaga (SE Spain) were studied. A mathematical formula, the “intradiurnal distribution index” (IDI), permitted an accurate numerical comparison of the different years and taxa studied. Sampling was carried out during the period 1992–1995 with the aid of a Burkard volumetric spore trap. Although on the basis of the IDI values obtained, three types of behaviour were distinguished, most taxa showed maximum concentration peaks around midday.

Maria del Mar Trigo, Marta Recio, Francisco Javier Toro and Baltasar Cabezudo, Departamento de Biología Vegetal, Universidad de Málaga, Apdo. 59. E-29080 Málaga, Spain.

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Most aerobiological studies have concentrated on seasonal pollen variations in a particular area, but studies of intradiurnal variations are becoming more frequent because pollen concentrations in the air vary considerably over a 24 hour period. In attempts to obtain predictive models, some authors have related intradiurnal variations to meteorological parameters such as temperature, relative humidity, rainfall and windspeed (Hirst 1953, K  pyl   1984, Spieskma & den Tonkelaar 1986, Emberlin & Norris-Hill 1991, Berggren et al. 1995).

Most authors choose to illustrate their results graphically, transforming the pollen concentrations observed into percentages of the total daily count, so that differences between different years and localities can be compared (K  pyl   1981, 1984). Other authors, such as Lacey & McCartney (1994), express the results in relation to the daily mean concentration, with the aim of giving all the days equal weight. However, no method has been used to establish the differences observed more accurately, although Gal  n et al. (1991) used a Centred-data analysis (CDA) to distinguish different behaviour types from the curves. One of the problems of depicting data graphically is the scale used by the different authors and the degree of stretching. This can give rise to misinterpretations.

The above considerations led us to look for an index which would make it possible to present any differences in a numerical form using simple data. The index proposed, the “intradiurnal distribution index” or IDI, has been applied to the nine most common airborne pollen taxa in the atmosphere of M  laga (Cabezudo et al. 1994, Recio et al. 1995) and the results compared with graphical models.

MATERIAL AND METHODS

Atmospheric pollen was sampled over four consecutive years (1992–1995) using a Burkard volumetric trap (Hirst 1952) located 15 m above ground level on the flat roof of the Medical Faculty of the University of M  laga, with no nearby buildings to interrupt air movement. The Medical Faculty is one kilometre west of the city

centre. Pollen counts were obtained by counting, hourly, four horizontal sweeps per preparation and using a $\times 40$ objective, following the method adopted by The Spanish Aerobiology Network, the R.E.A. (D  minguez et al. 1991). White petrolatum was used as an adhesive substance and glycerine jelly stained with basic fuchsin as the mounting medium. The taxa studied were Cupressaceae, *Casuarina*, Chenopodiaceae-Amarathaceae, *Platanus*, *Plantago*, Gramineae, Urticaceae, *Quercus* and *Olea europaea*.

Only rainfree days when the mean daily pollen concentration equalled or exceeded the mean for the principal pollination period were used to establish the intradiurnal variations of these taxa. The principal pollination period was defined as the period which included 95% of the seasonal total, from the time when the accumulated concentrations exceeded 2.5% of the total (Trigo et al. 1996). The graphic representations show percentage values for every two hours, with the time corresponding to official Spanish time (UT + 1 hour during autumn and winter and UT + 2 hours during spring and summer).

The IDI was calculated by taking the maximum and minimum values of the total hourly count of the days considered and applying the formula:

$$IDI = \frac{M - m}{T}$$

where M is the maximum value obtained in a certain time interval, m the minimum value and T is the total value (Table I).

The value of this index ranges between 0 and 1, depending on the distribution of pollen concentration throughout the day. The two extremes of this index are:

1. All the pollen collected fall within one time interval, so that M is the same as T, and the value of m is zero. This would give an IDI of 1.
2. The pollen is perfectly evenly distributed throughout the day, so that M and m are the same. In this case, the IDI value is zero.

In this way, the higher the value of the index, the more pronounced the maximum distribution peak will be.

RESULTS

Most of the taxa studied showed maximum intradiurnal concentrations between 12 and 14:00 h (Figs. 1–3), when

Table I. Disposition of the data matrices for calculating *M*, *m* and *T* values.

Hours	Days							$\sum x_i$
	1	2	3	4	5	6	7	
2	x_i							Maximum (M)
4								
6								
8								
10								
12								
14								
16								
18								
20								
22								Minimum (m)
24								
								Total (T)

temperatures are high and relative humidities low (Käpylä 1984). However the peaks for *Platanus* (Fig. 2) were displaced slightly towards early afternoon, while *Olea europaea* and *Quercus* (Fig. 3) showed no stable tendency.

Cupressaceae, *Casuarina* and Chenopodiaceae-Amaranthaceae are the taxa which have the highest peaks and the most stable variation patterns. Cupressaceae is chiefly represented by several species of the genera *Juniperus* and *Cupressus*, the latter, particularly *Cupressus sempervirens*, being very commonly cultivated as an ornamental plant. The intradiurnal pollen variation curves of this taxon behaved in a curious way (Fig. 1), with peaks which gradually decreased from one year to the next and an IDI of between 0.59 and 0.22. It was also the taxon with largest coefficient of variation (Table II).

Casuarina, by contrast, is only represented by one species, *C. cunninghamiana*, which is used as an ornamental plant in parks and along roadsides. As Figure 1 shows, almost 75% of the total daily pollen of this species occurred between 10 and 16:00 hours, with few variations between the years and an IDI of between 0.34 and 0.43.

Chenopodiaceae-Amaranthaceae is chiefly represented by species of the genera *Chenopodium* and *Amaranthus*, but also by *Beta vulgaris*, which is very common near the sampling site and was also responsible for the seasonal concentration peak detected during April (Cabezudo et al. 1995). During the four years studied, this taxon showed a maximum peak at about 14:00 h (Fig. 3), with the IDI varying between 0.21 and 0.34 (Table II).

Platanus, *Plantago* and Gramineae pollen (Fig. 2) showed intradiurnal variation patterns with small peaks and an IDI of between 0.10 and 0.20. *Platanus*, represented by only one species (*Platanus × hispanica*) which is cultivated as an ornament, showed maximum concentrations between 14 and 20:00 h, varying from one year to another. *Plantago* is chiefly represented by *P. lagopus*, which is very common in all abandoned spaces of the city. The maximum daily concentrations of this taxon occurred around 12:00 h., except during 1995 when it was displaced slightly to 14.00 h. Gramineae, on the other hand, is a multispecific taxon with 195 cited species in the province of Málaga (Cabezudo et al. 1990).

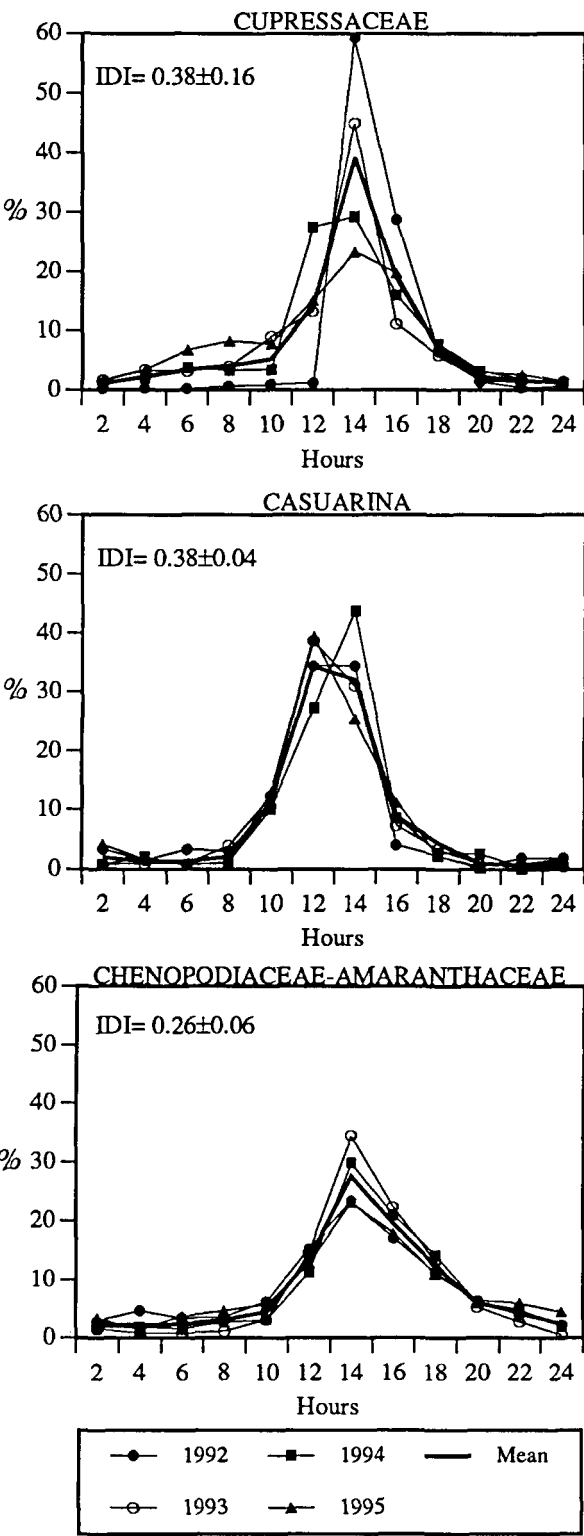


Fig. 1. Diurnal variation patterns of Cupressaceae, *Casuarina* and Chenopodiaceae-Amaranthaceae during the period 1992-95. Mean IDI values $\pm$ standard deviation.

This taxon showed a similar behaviour pattern to the above taxon except that in 1995 the peak was displaced to 6:00 h.

The graphic models for Urticaceae, *Quercus* and *Olea*

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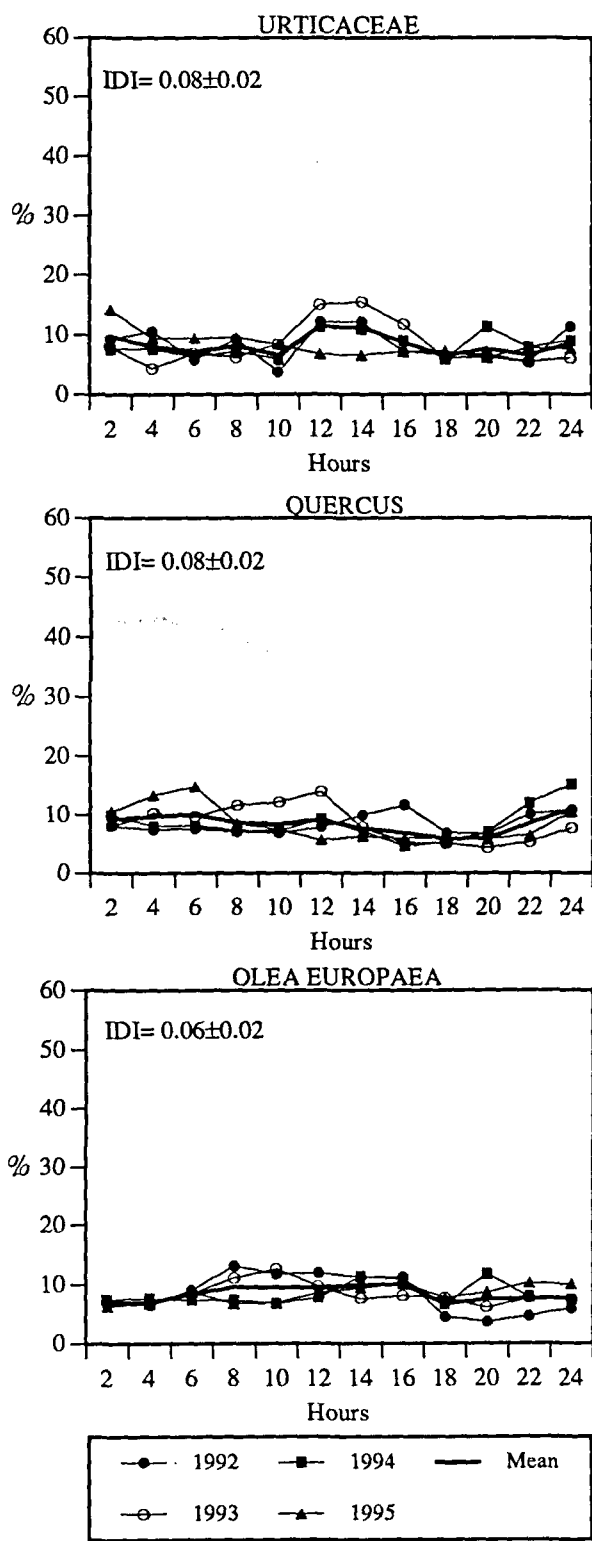
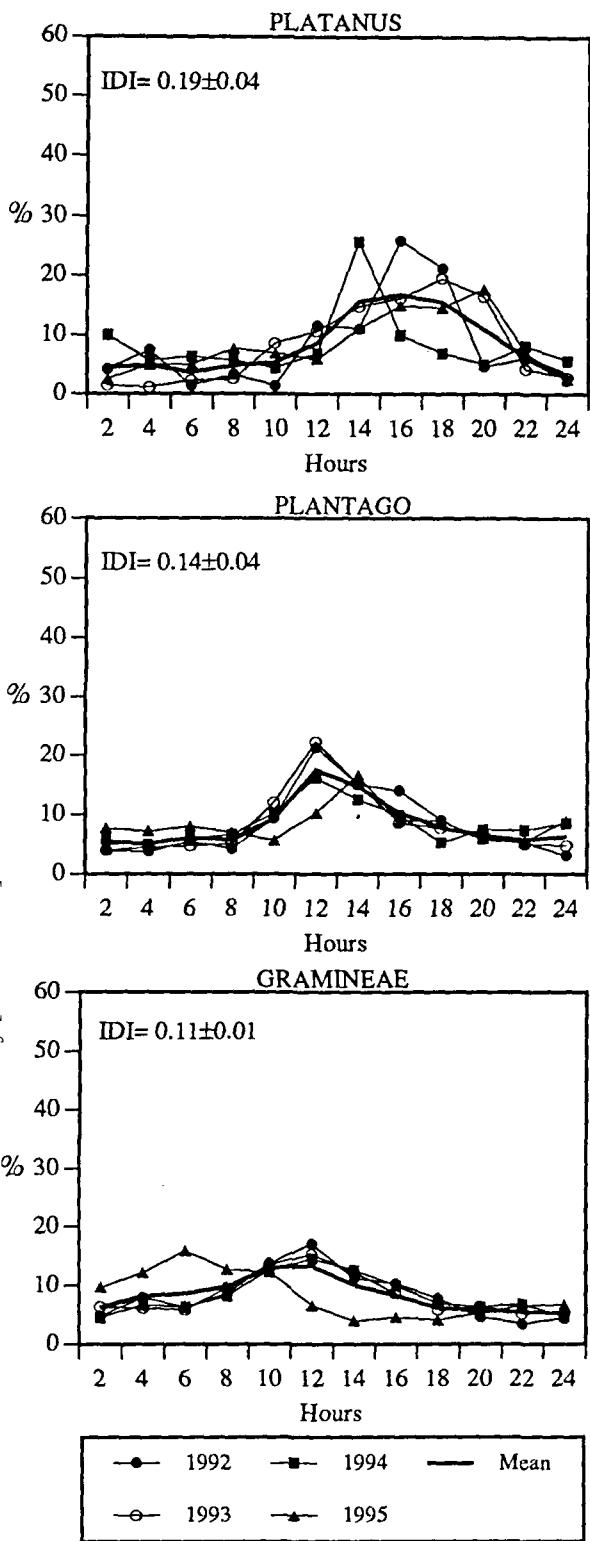


Fig. 2. Diurnal variation patterns of *Platanus*, *Plantago* and *Gramineae* during the period 1992-95. Mean IDI values $\pm$ standard deviation.

Fig. 3. Diurnal variation patterns of *Quercus*, *Urticaceae* and *Olea europaea* during the period 1992-95. Mean IDI values $\pm$ standard deviation.

europaea showed that their pollen was more evenly distributed throughout the day (Fig. 3). The value of the intradiurnal distribution indices remains below 0.10, *Olea europaea*

being the taxon with the smallest IDI value. *Urticaceae* is represented by species of *Parietaria* (*P. judaica* and *P. mauritanica*) and *Urtica* (*U. membranacea* and *U. urens* L.)

Table II. Intradiurnal distribution index (IDI) obtained for the taxa studied during the period 1992–95.

Taxon	IDI				Mean	SD	CV
	1992	1993	1994	1995			
Cupressaceae	0.59	0.43	0.28	0.22	0.38	0.16	42.1
<i>Casuarina</i>	0.34	0.38	0.43	0.39	0.38	0.04	10.5
Chenop.-Amaranthaceae	0.21	0.34	0.28	0.22	0.26	0.06	23.1
<i>Platanus</i>	0.24	0.18	0.21	0.15	0.19	0.04	21
<i>Plantago</i>	0.18	0.18	0.11	0.11	0.14	0.04	28.5
Gramineae	0.12	0.10	0.10	0.12	0.11	0.01	9.1
Urticaceae	0.08	0.11	0.05	0.08	0.08	0.02	25
<i>Quercus</i>	0.05	0.10	0.10	0.09	0.08	0.02	25
<i>Olea europaea</i>	0.09	0.06	0.05	0.03	0.06	0.02	33

which are frequent on walls and moist nitrogen-rich soils, respectively, while the most abundant species of *Quercus* are *Q. ilex*, *Q. suber* and *Q. coccifera* which comprise the typical Mediterranean woods and shrubs. *O. europaea* is widely cultivated throughout the province and is, together with Gramineae and Urticaceae, one of the principal causes of pollinosis in Andalusia (SEAIC & Abelló 1995).

DISCUSSION

Among those taxa studied, three types of intradiurnal concentration curves can be distinguished. Cupressaceae, *Casuarina* and Chenopodiaceae-Amaranthaceae (Fig. 1) showed a very stable behavioural patterns with one clear peak occurring around midday (12–14:00 h), with an IDI of above 0.20, reaching, in the case of Cupressaceae, nearly 0.60. *Platanus*, *Plantago* and Gramineae (Fig. 2) showed more irregular behaviour with little differences between the timing of the maximum and minimum concentrations, resulting in mean IDI values of between 0.10 and 0.20. Urticaceae, *Quercus* and *Olea europaea* (Fig. 3) generally showed small IDI values of less than 0.10, with very small peaks and very little differences in the hourly concentrations recorded, the pollen being evenly spread throughout the 24 hour period.

Cupressaceae was the taxon that showed the largest coefficient of variation in its IDI (42.1%), the value decreasing gradually over the four years studied from 0.59 in 1992 to 0.22 in 1995 because in the last two years of the study maximum concentrations were more evenly spread between 12 and 16:00 h., while in the two previous years concentrations peaked at about 14:00 h. The other taxa, especially *Casuarina* and Gramineae, had a more stable IDI with smaller coefficients of variation.

The exact moment at which the peaks appear depends directly on the times of anther dehiscence and of liberation of pollen into the atmosphere, which in turn depend on the prevailing meteorological conditions near the source of production, particularly temperature and relative humidity (Käpylä 1984, Rantio-Lehtimäki et al. 1991, Berggren et al. 1995). However, the pattern of the intradiurnal variation curve must also depend on the distance between the source and the sampler (Käpylä 1981, Spieksma & den Tonkelaar 1986) and on the number of species comprising the taxon studied, although no differences have been observed between trees and grasses. Thus, taxa comprising only one species,

such as *Casuarina*, show relatively stable intradiurnal patterns of behaviour with pronounced peaks around midday and with an IDI sometimes exceeding 0.40, while other taxa, such as *Olea europaea*, show more homogeneous concentrations with low IDI values (0.03–0.09). However some multispecific taxa, such as Cupressaceae gave large index values and others, such as Urticaceae and *Quercus*, gave small indices.

These behaviour patterns can perhaps be explained, at least in part, by the distance between the source of production and the sampling site, the taxa which are closest to the sampler behaving in a more stable fashion with more pronounced peaks than those at a greater distance. This, of course, means that patterns obtained for a specific taxon in one locality can differ from that obtained elsewhere. Some of the patterns obtained in Málaga differ from those obtained in nearby Cordoba (Galán et al. 1991). For example, the patterns obtained for Cupressaceae, *Casuarina*, Chenopodiaceae-Amaranthaceae, Urticaceae and *Plantago* in Málaga are similar to those obtained by the above authors in Córdoba, while those obtained for *Quercus* and olive differ. This is because the first group of taxa comprise the same species that are common in the proximities of both sampling sites, while the second group comprises trees whose pollen must travel long distances from the abundant population in the interior of the province to the Northeast of the sampling site. Winds, from this direction blow more frequently during the night and early morning.

The curves for *Platanus* in Málaga are slightly displaced towards the afternoon compared with those at Córdoba, perhaps because large populations of these trees are sited Southeast of the city and their pollen is transported by light winds blowing off the sea, which are more frequent after midday.

The largest differences in the intradiurnal behaviour of the taxa studied occurred in 1995. In this year, the maximum concentrations of *Platanus*, *Plantago*, Gramineae and Urticaceae were displaced from the general pattern found in the previous years (Figs. 2–3), while Cupressaceae, *Platanus* and *Olea europaea* showed smaller IDI values to those of the previous three years (Table II). However, 1994–95 was the driest year for fifty years and this may have changed patterns of behaviour, with the development of some species being favoured in comparison with others. *Casuarina* and Chenopodiaceae-Amaranthaceae were the taxa showing the

smallest differences in their behaviour (Fig. 1) since they comprise very drought resistant species.

With respect to the IDI, there was a good degree of correlation between the IDI values obtained and the graphic representations, higher values matching more pronounced peaks and lower values reflecting flatter distribution curves. The index can be applied to data referring to a single day, several days or even a whole season, as in our study. Similarly, the time intervals can refer to one, two or more hours.

CONCLUSIONS

On the basis of the mean IDI values obtained, three types of intradiurnal behaviour can be distinguished: those taxa with IDI values of above 0.20 and a very pronounced maximum peak (Cupressaceae, *Casuarina* and Chenopodiaceae-Amaranthaceae); those taxa with an IDI of 0.10–0.20 with a not very pronounced maximum peak (*Platanus*, *Plantago* and Gramineae); and lastly, a group of taxa with flattish curves and a mean IDI below 0.10 (Urticaceae, *Quercus* and *Olea europaea*).

In general, the greatest concentrations tend to occur around midday, although the distance between source and sampling site plays an important role in the behaviour of intradiurnal variation curves, those taxa occurring near the sampling site showing more pronounced peaks than those growing further away. A low IDI may indicate a pollen type which has been transported over long distances.

The last year of the study (1995) produced some behaviour patterns which did not conform to those observed during the previous four years, probably as the result of a prolonged drought and the driest year recorded in 50 years.

The intradiurnal distribution index makes it easy to define numerically the behaviour of pollen from different taxa throughout the day and to compare these patterns for different years or different sampling sites. It is independent of any graphic scale and there is a good relation between the values obtained and the graphical models of the pollen of the different taxa studied.

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