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Forecasting airborne *Platanus* pollen in the Madrid region

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Abstract

This study analyses the atmospheric concentration of *Platanus* pollen in four stations in the Madrid region over a period of 10 years (1994–2003). Various statistical analyses (regression analysis and decision tree) were used to prepare a forecasting model for possible application as a preventive measure in pollinosis. The data comes from the PALINOCAM network and the samplers used were Hirst type (Burkard pollen trap). *Platanus* pollen is present in the atmosphere during a short period of time in spring, and the maximum concentrations are detected during the last two weeks of March and the first week of April. Regression analysis shows that the pollen concentration of the two previous days is the best predictive variable. The models obtained for the four stations analysed account for between 37 and 61% of the variation in pollen levels in the air. The decision trees show how the introduction of meteorological variables improves prediction for this pollen type.

Keywords: Aerobiology, airborne pollen, *Platanus*, meteorological parameters, pollen forecast, Madrid

The sycamore or plane tree (*Platanus orientalis* L. var. *acerifolia* Aiton, *Platanus hispanica* Mill. ex Münchh., *Platanus hybrida* Brot., *Platanus acerifolia* (Aiton) Willd.) is an ornamental shade tree which is very common in numerous cities throughout Spain, and can frequently be found in avenues, boulevards, parks and gardens. It flowers in the spring, in the period between March and May, depending on the climatology of each particular year. It is a deciduous tree up to 35 meters high with anemophilous pollination and a high pollen production estimated at 13×10^6 pollen grains per inflorescence (Tormo et al., 1996).

Platanus is the pollen type which is most frequently found in the majority of the volumetric samplings throughout the region as a whole (Gutiérrez et al., 2001). According to national and regional aerobiological data, Madrid and Barcelona have the highest concentration of *Platanus* pollen (Díaz de la Guardia et al., 2000; Gabarra et al., 2002).

Many authors consider that *Platanus* pollen has allergenicity low (Bousquet et al., 1984; D'Amato & Spieksma, 1990; Negrini, 1992). In Spain, clinical data on allergenic sensitisation to this pollen are very different. In Barcelona, it represents 3.6% of pollen allergies (Valero et al., 1999), whereas in Toledo this figure rises to 52% (Moral et al., 1998), and 62% in Cordoba (Alcázar et al., 2004). In Madrid, according to data presented by Subiza (2001), 28% of patients affected by pollen allergies show symptoms which are clearly related to exposure to this pollen. Cross-reactivity has been described between *Platanus* pollen and grass pollen (Varela et al., 1997), and this may be responsible for the fact that the prevalence of sensitisation to *Platanus* pollen in some areas of Spain, such as Barcelona, is lower than in Madrid, as the concentrations of grasses in Barcelona are very low. A certain amount of cross-reactivity has also been described for *Parietaria*, *Olea* and *Artemisia* pollen (Bartolomé et al., 1996). We believe that the role of these trees in the environment

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Table I. Main geographical and climatic characteristics and general abundance of *Platanus* trees in each aerobiological sampling station.

Station	Geographical characteristics				Climatic characteristics		General abundance of <i>Platanus</i> trees
	Altitude (m)	Geographical coordinates	Population	Distance and direction to Madrid (km)	Mean annual temperature (°C)	Annual rainfall (mm)	
<i>Alcalá de Henares</i>	588	40° 28' N; 03° 22' W	200 000	30 E	13.8	418	Very abundant (no date specimen)
<i>Aranjuez</i>	503	40° 02' N; 03° 45' W	47 000	47 S	14.7	349	Very abundant (3242 specimens)
<i>Getafe</i>	531	40° 18' N; 03° 44' W	150 000	14 S	16.7	378	Abundant, young specimens
<i>Madrid (University campus)</i>	637	40° 05' N; 03° 07' W	3 500 000		15.6	462	Very abundant (no date specimen)

and landscape is extremely important, owing to the limited period of exposure for people sensitised to this pollen type.

There are few works dealing with the prediction of mean daily levels of *Platanus* pollen (Gabarra & Belmonte, 2002; Mendez et al., 2002), although there are many which analyse the influence of meteorological parameters on the start of the *Platanus* pollen season (Norris-Hill, 1998; Alba & Díaz de la Guardia, 1998; Gonzalez Minero et al., 1999) or the relationships between the atmospheric concentration of *Platanus* and the weather factors during the main pollen season (González Minero & Candau, 1997; Jato et al., 2001).

Material and methods

The study was carried out in four sites in the Madrid region, located in the centre of the Iberian Peninsula, over a period of 10 years (1994–2003). Table I shows the aerobiological sampling stations and their main geographical and climatic characteristics. The data comes from the PALINOCAM network, which has been operating since March, 1993; the samplers used were Hirst type (Burkard pollen trap) and the research methodology followed the recommendations of the REA (Spanish Aerobiology Network) and the IAA (International Association for Aerobiology) (Domínguez et al., 1991; Jäger, 1995). The sampling stations selected for this research are located in Alcalá de Henares, Aranjuez, Getafe and Madrid (University campus).

In our analysis we used the whole of the pollen season from the day on which the first *Platanus* pollen grain appears in the atmosphere until the last day it is present. We did not apply any of the usual formulae for the calculation of the main (MPS) pollen season (Jato et al., 2006) because the statistical results obtained were better in the first case.

Two statistical analyses were done in order to obtain prediction models for this pollen type: regression analysis and decision trees. The first determines the relationships between the daily pollen data compared to meteorological parameters and previous pollen series values by means of a linear equation, and the second is expressed by means of a decision tree, which produces successive segmentations of the data set analysed. Decision trees are constructed top-down, beginning at the root node and successfully partitioning the data set. The construction involves two main steps:

1. Selecting a splitting rule for each internal node. In a node with more than 50 cases, the most significant variable is selected. The optimum partition generated by this variable should generate classes with more than 20 cases.
2. Determining which nodes are terminal nodes. The process is stopped when the node has more than 50 cases, or when there is no significant variable.

The independent variables considered are:

Plat_2 (pollen concentration of 2 previous days), Plat_3 (pollen concentration of 3 previous days), Plat_4 (pollen concentration of 4 previous days), Tmax (maximum temperature), Tmed (mean temperature), Tmin (minimum temperature), Hsol (hours of sunlight), P (rainfall), H (relative humidity), Vel (wind speed), Calms (frequency percentage of the wind calms), C1 (frequency percentage of wind in the first quadrant), C2 (frequency percentage of wind in the second quadrant), C3 (frequency percentage of wind in the third quadrant), C4 (frequency percentage of wind in the fourth quadrant), and Tmax_r, Tmin_r, Tmed_r, Hsol_r, P_r, H_r, Vel_r, Calms_r, C1_r, C2_r, C3_r, C4_r, where the values correspond to the average value of that day and the two previous days.

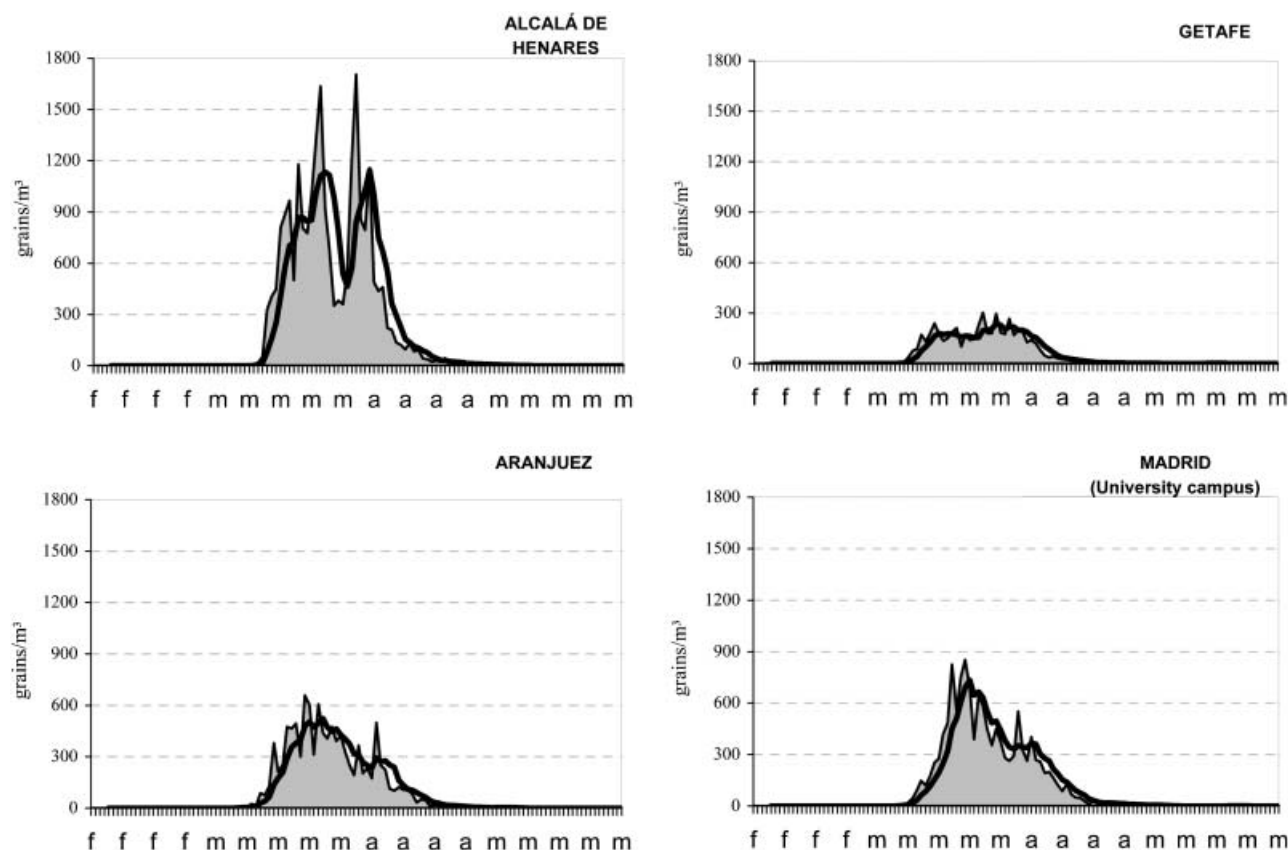


Figure 1. Seasonal variations of mean daily pollen of *Platanus* (1994–2003).

The meteorological data were provided by the Meteorological Centre for the territory of Madrid and the Castile–La Mancha region.

Results

Platanus pollen is present in very significant quantities in the atmosphere in the Madrid region, averaging 33.7% (Alcalá de Henares), 30.2% (Aranjuez), 22.1% (University campus) and 15.4% (Getafe) of the total pollen counts.

The *Platanus* pollen season occurs within a very short and specific time frame, which in all the four stations selected in the Palinocam network falls in March, April and May (Figure 1, Table II). Due to the short flowering period of the *Platanus*, the pollen season generally lasts only a few weeks; in our study it varies between 114 days in Madrid (in 2000) and 39 days in Getafe (in 1994), and has an average duration of 67 days. The days of maximum concentrations (peak days) occur in the last two weeks of March or the first two weeks of April. The maximum daily levels reached very high values mainly in the stations of Alcalá de Henares (12 917 grains/m³ in 2001), Aranjuez (3 276 grains/m³ in 1994) and Madrid (University campus), with 4 936 grains/m³ in 1998 (Table II). In Getafe the maximum daily value was lower at 2 043 grains/m³, recorded in 2002.

In Alcalá de Henares, the equation for both the multiple step regression model and the univariate model only includes the variable Plat_2 as a predictor, obtaining $R^2=0.37$ (Table III). In Aranjuez the univariate regression model explains 43% of the variation in *Platanus* pollen levels when only the concentration of the two previous days is introduced; when 2 more variables (Pla_3 and Vel_r) are added, the R^2 only increases by 0.02. In Madrid, we obtain $R^2=0.55$ with the pollen concentration of the two previous days, and if we include the Plat_3 and Tmin_r variables, $R^2=0.58$. Finally, in Getafe the univariate regression analysis selects the Plat_2 variable as the predictor, obtaining $R^2=0.52$. The multiple step regression model introduces two variables, Calms_r and Plat_3, and the regression coefficient (R^2) increases by only 0.02 (Table III), as occurs in Aranjuez and Madrid.

In decision trees, as in the regression model, the Plat_2 variable is always selected first, (Table IV), and it can be seen that in all the stations, as the Plat_2 variable increases the estimated concentration of *Platanus* pollen also increases progressively.

No new segmentation with any significance was obtained in Alcalá de Henares.

In Aranjuez, we obtained four segmentations based on the different intervals of the highest

Table II. Characteristics of the pollen season (PS) in each of the sampling stations, per year.

Stations/ Year	S _{PS}	E _{PS}	L _{PS}	PD _{PS}	Grains/m ³
Alcalá					
1994	14 Mar.	02 May	49	22 Mar.	320
1995	12 Mar.	03 May	52	25 Mar.	1124
1996	23 Mar.	02 May	40	08 Apr.	660
1997	07 Mar.	21 Apr.	45	19 Mar.	2125
1998	08 Mar.	05 May	58	21 Mar.	2356
1999	21 Mar.	20 May	60	04 Apr.	9886
2000	07 Mar.	27 May	81	15 Mar.	7536
2001	05 Mar.	11 May	67	24 Mar.	12917
2002	15 Mar.	12 May	58	01 Apr.	7929
2003	10 Mar.	08 May	59	01 Apr.	741
Aranjuez					
1994	18 Mar.	07 May	50	22 Mar.	3276
1995	13 Mar.	05 May	53	27 Mar.	3151
1996	17 Feb.	15 May	88	02 Apr.	2048
1997	03 Mar.	30 Apr.	58	17 Mar.	2962
1998	07 Mar.	13 May	67	21 Mar.	2061
1999	20 Mar.	13 May	54	06 Apr.	3201
2000	08 Mar.	10 May	63	14 Mar.	780
2001	08 Mar.	10 May	63	23 Mar.	728
2002	18 Mar.	26 May	69	31 Mar.	363
2003	19 Mar.	31 May	73	02 Apr.	279
Getafe					
1994	16 Mar.	24 Apr.	39	18 Mar.	281
1995	10 Mar.	14 May	65	25 Mar.	786
1996	26 Mar.	20 May	55	06 Apr.	552
1997	07 Mar.	26 Apr.	50	14 Mar.	1185
1998	08 Mar.	16 May	69	19 Mar.	1048
1999	04 Feb.	03 May	88	03 Apr.	1453
2000	29 Feb.	22 May	83	11 Mar.	1426
2001	06 Mar.	19 May	74	24 Mar.	944
2002	11 Feb.	20 May	98	28 Mar.	2043
2003	16 Mar.	28 May	73	25 Mar.	103
Madrid (University campus)					
1994	05 Mar.	28 May	84	25 Mar.	2013
1995	16 Mar.	31 May	76	26 Mar.	1952
1996	25 Mar.	30 May	66	02 Apr.	1553
1997	05 Mar.	04 May	60	18 Mar.	2920
1998	10 Mar.	31 May	82	21 Mar.	4936
1999	16 Mar.	16 May	61	05 Apr.	1487
2000	01 Feb.	25 May	114	16 Mar.	1312
2001	26 Feb.	31 May	94	02 Apr.	1158
2002	23 Mar.	27 May	65	02 Apr.	343
2003	09 Mar.	12 May	64	02 Apr.	1126

PS – pollen season; S_{PS} – start date of pollen season; E_{PS} – last date of pollen season; L_{PS} – pollen season duration (in days); PD_{PS} – peak day of pollen season;

concentrations of the Plat₂ variable. Thus for the concentration interval of 23–56 grains/m³, the delayed calms variable was selected; for the 56–143 grains/m³ interval the delayed maximum temperature variable; for the 143–481 grains/m³ interval the calms variable and for a *Platanus* concentration of over 481 grains/m³, the delayed wind speed variable (Table IV). Thus using Plat₂ and several meteorological variables we obtained a classification of 12 classes or types of days, with widely varying concentration averages. For example,

the 31 days where Plat₂ >481 and Vel_r <5.5 show the highest levels of *Platanus* pollen concentration, with an average value of 1278.9 grains/m³.

The decision tree obtained for Getafe (Table IV) shows that when the concentration of *Platanus* pollen in the previous two days is over 200 grains/m³, the predictive variable selected is the relative air humidity. If this is less than 55.2%, the estimated concentration is 582 grains/m³, and if it is greater, the estimated concentration is lower (278 grains/m³). In Madrid (University campus) for a value of Plat₂ of between 140–495 grains/m³ we obtained a subdivision based on the frequency of calms in the third quadrant (if this is less than 34% the estimated concentration is 514 grains/m³, and if it is greater, the estimated concentration is 217 grains/m³) and another based on the delayed hours of sunlight (if this figure is less than 11.2 hours, the estimated concentration is 797 grains/m³ and if it is greater, the estimated concentration is 1 669 grains/m³). The variables selected using the tree divide the days into 9 classes, with averages ranging between 4.1 grains/m³ and 1668.9 grains/m³.

The R² coefficient obtained with the decision trees was 0.36 for Alcalá de Henares, 0.60 for Aranjuez, 0.49 for Getafe and 0.55 for Madrid (Table IV).

Discussion

The total annual concentrations of *Platanus* pollen in the different stations analysed in the Madrid region were higher than those obtained in several cities throughout the Iberian Peninsula such as Ourense, Tarragona, Malaga or León among others, and were similar to those recorded for Barcelona (Díaz de la Guardia et al., 2000).

Platanus pollen is present in the atmosphere for a short period of time (average 67 days) which means that there are numerous days with very high concentrations of this pollen. The pollen season generally occurs between the second half of March and the first half of April; a similar period is also described for other Spanish cities (Díaz de la Guardia et al., 2000; Gabarra et al., 2002).

The prediction models obtained for *Platanus* were made for the 10 years in the sample as a whole (1994–2003) in order to obtain a predictive model which reflects the average behaviour rather than individual years. We consider that the data series that we have available is sufficient to cancel out any deviations produced by atypical years which may differ widely from the average. The regression models obtained for the four stations show how the concentration of *Platanus* for the two previous days (Plat₂) is the variable which explains the greatest percentage of the variation of this taxon in the air.

Table III. Results of multiple regression analysis for the *Platanus* pollen season (1994–2003). R^2 – Spearman correlation coefficient; Plat_2 – pollen concentration of 2 previous days; Plat_3 – pollen concentration of 3 previous days, {Tmin_r – minimum temperature, Vel_r – wind speed, Calms_r – frequency percentage of the wind calms}, these three last data correspond to the average value of that day and the two previous days.

Station	Multiple Step Regression Model	R^2	Univariate Model	R^2
Alcalá de Henares	$Y=0.609 \text{ Plat}_2+158.153$	0.370	$y=0.609 \text{ Plat}_2+158.153$	0.370
Aranjuez	$y=0.523 \text{ Plat}_2-20.032 \text{ Vel}_r+$ $0.160 \text{ Plat}_3+183.232$	0.456	$y=0.658 \text{ Plat}_2+55.118$	0.434
Getafe	$y=0.544 \text{ Plat}_2+3.348 \text{ Calms}_r+$ $0.206 \text{ Plat}_3-24.160$	0.546	$y=0.711 \text{ Plat}_2+19.507$	0.522
Madrid (U.C.)	$y=0.537 \text{ Plat}_2+0.249 \text{ Plat}_3-$ $13.514 \text{ Tmin}_r+149.917$	0.581	$y=0.770 \text{ Plat}_2+52.012$	0.555

We can see that when introducing more than one variable (either delayed values of the pollen series or meteorological parameters) in the multiple step

regression model, the R^2 value increases only slightly (0.02), and this increase is not great enough to consider the information provided by the new

Table IV. Decision tree for the *Platanus* pollen season (1994–2003). EC – estimated concentration; n – number of cases; R^2 – Spearman correlation coefficient; Plat_2 – pollen concentration of 2 previous days; H – relative humidity; Calms – frequency percentage of the wind calms; C3 – frequency percentage of wind in the third quadrant; {Tmax_r – maximum temperature, Hsol_r – hours of sunlight; Vel_r – wind speed; Calms_r – frequency percentage of the wind calms}, these four last data correspond to the average value of that day and the two previous days.

Station	Plat_2	EC	Variables	EC	n
Alcalá de Henares $R^2=0.362$	0–1	2.7			49
	1–3	7.2			36
	3–10	11.7			59
	10–23	53.8			59
	23–60	95.8			56
	60–109	173.7			56
	109–312	310.4			56
	312–728	661.6			56
	>728	2674.8			55
Aranjuez $R^2=0.607$	0–1	8.4			81
	1–3	8.3			39
	3–9	9.8			66
	9–23	24.6			61
	23–56	52.8			36
			Calms_r ≤ 17	34.6	26
			Calms_r > 17	79.3	23
	56–143	148.1	Tmax_r ≤ 19.8	81.1	35
			Tmax_r > 19.8	207.7	25
	143–481	348.6	Calms ≤ 8	222.9	31
			Calms > 8	494.9	23
	>481	1053.6	Vel_r > 5.5	502.2	31
			Vel_r ≤ 5.5	1278.9	70
Getafe $R^2=0.491$	0–1	3.2			58
	1–3	3.2			68
	3–8	7.6			71
	8–23	40.3			69
	23–57	57.4			70
	57–200	150.4			20
	>200	494.1	H > 55.2	278.9	49
			H ≤ 55.2	581.9	55
	0–1	4.1			82
	1–5	6.3			77
Madrid (University campus) $R^2=0.558$	5–17	33.5			72
	17–49	43.6			76
	49–140	174.7			41
	140–495	351.9	C3 > 34	217.2	34
			C3 ≤ 34	514.2	52
	>495	1056.1	Hsol_r ≤ 11.2	796.7	22
			Hsol_r > 11.2	1668.9	

variables as optimal. We consider that it is advisable to use the simplest or most cautious method, that is, the one which includes a lower number of predictive variables (Abraira & Pérez de Vargas, 1996; Camacho, 1998). The regression equations obtained with the univariate model allow us to make reliable forecasts without the need for meteorological parameters; however these have the disadvantage of providing only short-range predictions. Other works have used previous-day pollen concentrations as an independent variable for forecasting daily pollen counts (Galán et al., 2000; Méndez et al., 2002).

The decision tree model shows how the introduction of certain meteorological parameters (calms_r, tmax_r, calms, vel_r, C3, Hsol_r and H) improves the prediction of *Platanus* pollen in the air. In University campus we observe that when Plat_2 > 495, the levels of this pollen rise as the delayed hours of sunlight increase. The positive correlation between pollen levels-hours of sunlight has been highlighted in previous works (Galán et al., 1995; Moreno Grau et al., 2000) as sunlight provokes the dehiscence of the anthers and the resulting release of pollen into the atmosphere. In this station we also see that when Plat_2 (140–495 grains/m³) the levels of this pollen also rise if the wind frequency in the third quadrant decreases. In Aranjuez, the wind also has a very significant influence on the atmospheric concentrations of *Platanus* pollen; these increase on days when the frequency of wind calms is high and wind speed is low. If the maximum delayed temperature (Tmax_r) is greater than 19.8°C, more pollen will be detected in the aerobiological samples. Many authors establish a positive relationship between pollen concentrations and temperature (Green et al., 2004; Dvorin et al., 2001), while others estimate that a temperature of between 20 – 25°C is ideal for the detection of the greatest pollen concentrations (Andersen, 1991; Emberlin, 1994).

In Getafe we can observe that a high relative humidity (>55.2%) causes a decrease in pollen levels for a value of Plat_2 > 200; the negative effect of humidity on pollen levels has been reported by Jato et al. (2000) and Aira et al. (2001), among others, as the grains of pollen absorb this humidity, become heavier and thus sediment. Finally, in Alcalá de Henares the meteorological variables did not have any significant influence on the concentrations of this pollen type in the atmosphere.

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