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Winter blooming of *Artemisia*. A 2-year survey in Murcia (Spain)

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Abstract

This paper presents a 2-year survey of *Artemisia* airborne pollen concentrations in Murcia. An important *Artemisia* blooming taking place in winter is confirmed in Murcia (SE Spain). This phenomenon could explain the incidence of winter pollinosis in Murcia. On the other hand, for the first time, three consecutive pollen seasons of *Artemisia*, corresponding to three different species (*A. campestris*, *A. herba-alba* and *A. barrelieri*) have been noted. Mathematical analyses show the relations between pollen concentrations of *Artemisia* in summer and autumn, and precipitation occurring 6–8 weeks before. Blooming outsets seem to be related to cumulative percentage of insolation from 1 March. Meteorological factors do not seem to influence pollen concentration in any significant way once pollination has begun. © 1998 Elsevier Science Ireland Ltd. All rights reserved.

Keywords: *Artemisia*; Meteorological relationships; Murcia; Spain; Winter blooming

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1. Introduction

Murcia is a province located in SE Spain (Fig. 1). The main town is Murcia (155969 inhabitants) and about 50 towns and villages, belonging to seven municipalities, with a total population close to 400000 people, are found within a radius of 15 km around the sampling site. Because of its particular climate there are many plants flowering most of the year and an important *Artemisia* blooming taking place in winter and not mentioned hitherto in Europe was noticed during the first survey carried out in this city in 1993–94 (Munuera et al., 1995). *Artemisia* is an important allergenic genus in SE Spain, with a prevalence of 23.5% and representing approximately 90% of the total count of atmospheric Asteraceae in Murcia (García Sellés and Munuera, 1996).

In order to confirm this winter blooming and study its relationships with meteorological factors, this paper presents a 2-year survey of *Artemisia* airborne pollen concentrations in Murcia area.

2. Materials and methods

Average daily pollen concentrations (grains/m^3) were monitored from 1 March 1993 to 28 February 1995 using a Burkard sampler located on the roof of the Veterinary Faculty (Murcia University, 4 km NW of Murcia city). Meteorological data were obtained from Centro Meteorológico Territorial of the Instituto Nacional de Meteorología, 1 km from the sampling site (Fig. 1). Variables and abbreviations are shown in Table 1.

In order to calculate the length of the main pollen season several methods have been used (Mullenders et al., 1972; Pathirane, 1975; Nilsson and Persson, 1981; Andersen, 1991; Emberlin et al., 1994). Notwithstanding the different approaches, the results are similar. We have preferred the method of Nilsson and Persson (1981): the period from which the sum of daily mean concentrations reaches 5% of the total sum until the time when the sum reaches 95%. For winter blooming we have used the method of Pathirane (1975).

Only seldom does spore production follow a normal distribution (Mäkinen, 1977) and, as expected, *Artemisia* pollen counts are not an exception, even after

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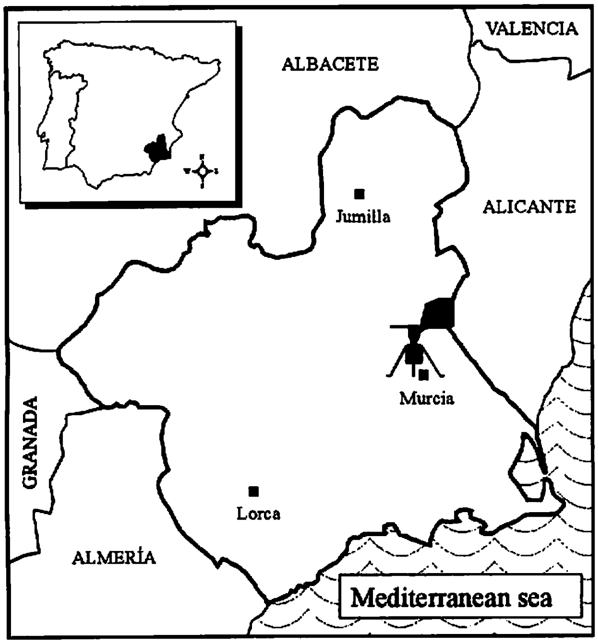

Fig. 1. Sampling site.

logarithmic or square root transformations. The same is true for meteorological data and this is why pollen concentrations and non-parametric tests were used. Mathematical analyses were made using the computer program SPSS 5.0 (SPSS, Chicago). Missing and rainy days (those with rainfall above 0.1 l/m^3) were not considered. In comparative graphical representations daily pollen counts (grains/m^3) were standardised into percentages to take into account the annual variations in pollen abundance, and all days were included.

3. Results

Graphical and mathematical (Mann–Whitney *U*-test) comparisons of the meteorological data showed differences between annual periods, the second period being warmer and drier than the first (Fig. 2), and the first period being windier than the second. However annual tendencies in meteorological factors are both very similar.

3.1. The main pollen season

The starting date and length were very similar in both main pollen seasons: 163 days for the first period (from 31 August 1993 to 9 February 1994) and 172 days for the second (from 24 August 1994 to 11 February 1995). The second flowering period seems to be slightly earlier and the 5-day advancement in the pollen season corresponding to a 1.2°C higher spring temperature is similar to that reported by Fitter et al. (1995) in England. We think this calculation is only a consequence of the annual period considered (1st March to 28th February) and pollen counts from early March '94 (second flowering period) perhaps should be included as the last days of the first annual period.

Large differences were observed between annual (i.e. 1248 and 541 pollen grains/m^3) and between the main pollen seasons (i.e. 1132 and 489 grains/m^3) sums of the average daily airborne pollen concentrations (Fig. 3A). As for meteorological factors, pollen concentrations of *Artemisia* showed no disparity in annual distribution patterns (particularly attending to the running mean of standardised values, Fig. 3B), flowering in late summer (*A. campestris*), briefly about November (*A. herba-alba*) and having a third pollen season starting in late autumn and lasting the most part of the winter (*A. barrelieri*).

The beginning of the main pollen season seems to correlate with the cumulative temperatures from March 1st (Table 2A), particularly with the minimum cumulative temperature measured 15 cm above ground ($T_{\min}$_0.15_cum). Results of additional years are needed to test this hypothesis.

During the main pollen season (whole period), several atmospheric factors show a good correlation with *Artemisia* counts (Table 3). However, extrapolating these results could be risky when bearing in mind the considerable length of the period studied, including three seasons (summer, autumn and winter) and three consecutive and different bloomings. In other words,

Table 1
Meteorological variables and abbreviations used

Evapo	Evaporation	$T_{\max}$	Maximum temperature
Insol	Percentage of insolation	$T_{\max}$_cum	Cumulative $T_{\max}$ from 1 March
Insol_cum	Cumulative Insol from 1 March	$T_{\min}$	Minimum temperature
*P*_cum	Cumulative precipitation from 1 March	$T_{\min}$-*n*	$T_{\min}$ *n* days before
*P*_cum-*n*	*P*_cum *n* days before	$T_{\min}$_0.15	$T_{\min}$ at 15 cm above ground level
RH00	Relative humidity at 00:00 h	$T_{\min}$_0.15_cum	Cumulative $T_{\min}$_0.15 from 1 March
RH07	Relative humidity at 07:00 h	$T_{\min}$_cum	Cumulative $T_{\min}$ from 1 March
RH13	Relative humidity at 13:00 h	WR	Wind run per day
RH18	Relative humidity at 18:00 h	WS	Wind speed

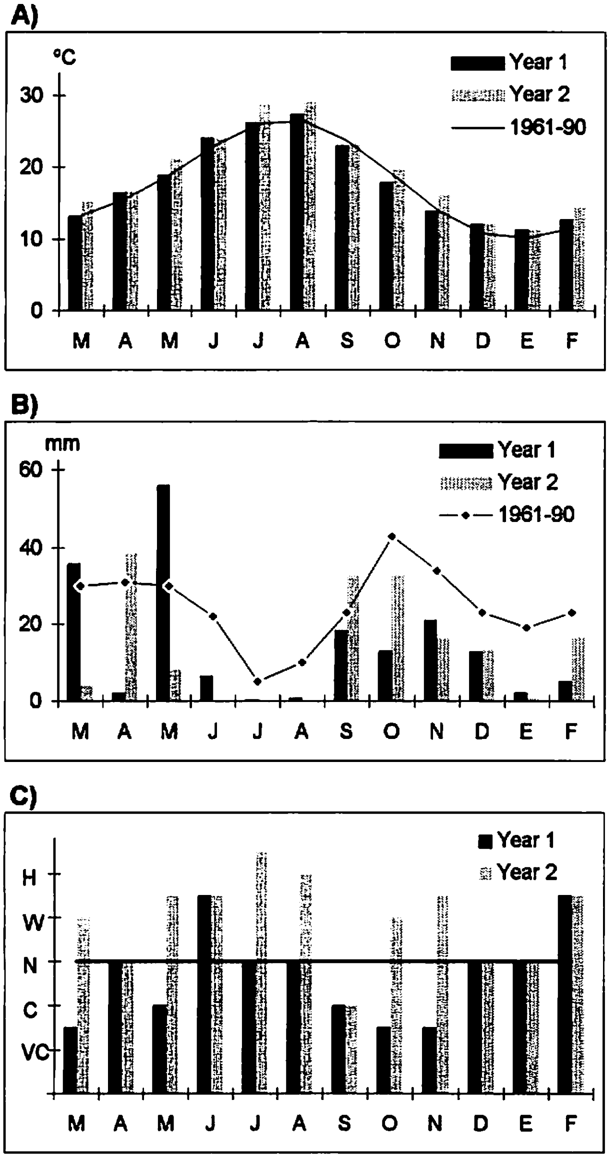

Fig. 2. Rainfall and temperatures in Murcia. A. Monthly mean temperature. B. Monthly total precipitation and average from 1961 to 1990. C. Month type according to temperature: hot (H), warm (W), normal (N), cold (C) and very cold (VC).

the atmospheric pollen content and the meteorological variables for every season might show different relationships. Therefore, it would be more realistic to study these relationships independently for each season.

By following the methods of Nilsson and Persson (1981) and Pathirane (1975), and using some subjective criteria as well, three bloomings can be distinguished for *Artemisia* (Table 4).

Deciding where the winter season limits are is difficult and not free of subjectivity because they are influenced by those previously established for the autumn blooming. Autumn and winter seasons are too close, and this is why the method of Nilsson and Persson (1981) displays two main limitations for the winter season:

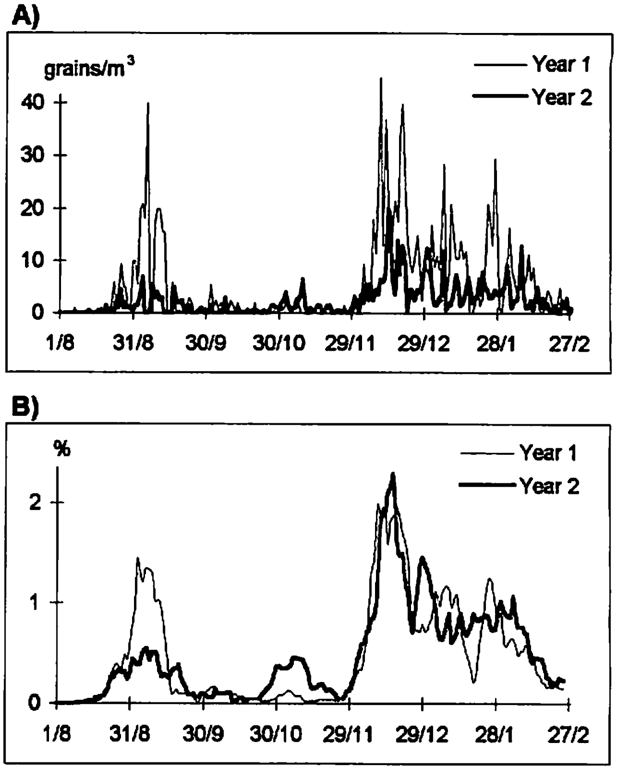

Fig. 3. (A) Daily pollen concentrations; (B) 7-day running mean of standardised values (percentages of annual pollen concentration).

Table 2
Outset of blooming periods and dates when some meteorological factors exceed certain values (cumulatives from 1st March)

(A)	Year 1	Year 2
Outset	31-08-93	24-08-94
T_{max}_cum > 5100°C	01-09-93	23-08-94
T_{min}_cum > 2700°C	03-09-93	23-08-94
T_{min}_0.15_cum > 2300°C	30-08-93	25-08-94
(B)	Summer 1	Summer 2
Outset	24-08-93	24-08-94
Insol_cum > 12 500%	25-08-93	24-08-94
Maximum	06-09-93	04-09-94
Insol_cum > 13 300%	06-09-93	03-09-94
(C)	Winter 1	Winter 2
Outset	03-12-93	02-12-94
Insol_cum > 18 800%	06-12-93	02-12-94
(D)	Autumn 1	Autumn 2
Outset	25-10-93	23-10-94
Insol_cum > 16 600%	24-10-93	24-10-94
Maximum	06-11-93	09-11-94
Insol_cum > 17 200%	08-11-93	06-11-94

Table 3
Correlations between *Artemisia* concentrations and meteorological variables

	Year 1	Year 2	Summer 1		Summer 2		Autumn 1		Autumn 2		Winter 1			Winter 2		
	(Whole period)	(Whole period)	Whole period	Before maximum	Whole period	Before maximum	Whole period	Before maximum	Whole period	Before maximum	Whole period	Before maximum	After maximum	Whole period	Before maximum	After maximum
Evapo	0.0782	0.0499	0.0529	−0.3286	0.4915**	−0.2955	0.0870	0.0242	−0.6447**	−0.6903**	−0.0392	0.0669	−0.1334	0.0539	0.0740	0.0822
Insol	0.2750**	0.1936*	−0.2124	−0.3404	0.2684	0.2072	−0.0434	0.0485	−0.2480	−0.4081	0.1981	0.8158**	0.2126	−0.0362	0.6072*	−0.0924
*P*_cum	0.3795**	0.4852**	0.7801**	0.7408**	−0.5439**	—	0.5563	0.8395**	0.0715	0.7216**	−0.3437**	—	−0.4984**	−0.2855*	—	−0.4105**
RH00	0.1797*	0.2470**	−0.0960	0.0458	−0.4817**	−0.1954	−0.4026	−0.3152	0.5933**	0.5782*	0.1799	0.0596	0.2571*	0.0176	−0.4159	0.0558
RH07	−0.1107	−0.1108	0.0202	0.4638	−0.4135*	0.2058	0.0248	0.1576	0.5233**	0.5116*	0.1703	0.0084	0.2732*	0.0964	0.2137	0.0720
RH13	−0.2659**	0.0614	−0.2461	−0.0510	−0.3485	0.2219	−0.2330	−0.0488	0.5557**	0.5838*	0.0020	−0.4167	0.0846	0.0828	−0.5781*	0.1563
RH18	−0.2250**	−0.0564	0.0669	0.4183	−0.3145	0.2358	−0.1714	−0.0183	0.6054**	0.5802*	0.0610	−0.0667	0.1039	0.1365	0.4327	0.1995
T_{max}	−0.0550	−0.3462**	0.2621	0.3922	0.4351*	−0.1643	0.4642	0.6074	−0.2541	−0.3565	0.3379**	0.6051	0.3541**	0.1102	0.0041	0.1471
T_{min}	−0.2804**	−0.4833**	−0.1560	0.2566	0.3064	0.0251	0.1858	0.5577	0.1232	0.0977	−0.0067	0.0168	−0.0032	−0.0233	−0.7476**	0.0733
T_{min}_0.15	−0.2934**	−0.4910**	−0.1587	0.2531	0.2904	0.2111	−0.0681	0.1455	0.1863	0.2364	0.0656	−0.1333	0.0986	−0.0011	−0.8702**	0.1004
WR	0.0836	0.0160	−0.5912**	−0.5290	0.4640**	0.2022	0.0528	0.0364	−0.5549**	−0.4710	−0.2318	−0.2167	−0.2847*	−0.0458	−0.3503	0.0254
WS	0.0482	−0.0386	−0.1625	−0.3150	0.1452	−0.0679	0.1429	0.0727	−0.5343**	−0.4054	−0.2604*	−0.0667	−0.3264*	−0.0831	−0.4214	−0.0151

2-tailed Spearman correlation coefficients. Significance level: * 0.05 ** 0.01.

Table 4
Outset, maximum concentration and end of the different *Artemisia* blooming seasons

		Summer			Autumn			Winter		
		Outset	Maximum	End	Outset	Maximum	End	Outset	Maximum	End
Year 1	Whole period[a]	01-07-93		24-09-93[b]				16-11-93[d]		28-02-94[e]
	Nilsson	24-08-93	06-09-93	16-09-93	25-10-93[d]	06-11-93	10-11-93[d]	08-12-93	11-12-93	12-02-94
	Pathirane	23-08-93		13-09-93				03-12-93		16-02-94
Year 2	Whole period[a]	01-07-94		06-10-94[b]	13-10-94[c]		21-11-94[d]	22-11-94[d]		28-02-95[e]
	Nilsson	24-08-94	04-09-94	02-10-94	23-10-94	09-11-94	19-11-94	07-12-94	14-12-94	14-02-95
	Pathirane	23-08-94		19-09-94	27-10-94		17-11-94	02-12-94		16-02-95

[a] Corresponding to the deposition year (Mäkinen, 1977).
[b] First day followed by at least 6 days without *Artemisia*.
[c] First day with pollen after previous period.
[d] Subjective according to graphs.
[e] Last day for the annual periods considered.

- the first blooming days (particularly for the second year) could have been considered as the final days of the autumn and, consequently, the beginning of the winter season can be artificially delayed;
- the final date for the whole period of the winter season is not real because we lack data for the whole season (until June) in the second year and, therefore, the calculations have been made taking into consideration the last day registered (28 February) in both years.

Furthermore, if we include up to 30 June 1994 for the first year calculations, the winter blooming termination date is 17 February 1994, which is only one day different from the Pathirane date previously proposed. As a consequence, using Pathirane's limits for the winter season appears to be more appropriate.

3.2. The summer season

The beginning of the late summer blooming coincides for both years, inspite of differences between main pollen season. Dates for the beginning and peak of the blooming seem to be related to the percentage of cumulative insolation from March 1st (Table 2B). However, for the second period the late summer blooming (*A. campestris*) is less than expected when taking into account the first period (Fig. 3). This could be due to the fact that the rainfall recorded up to that time was merely half of the former year (Fig. 2B) which, beyond doubt, would have seriously affected the plant development in the locality. In addition, the summer temperatures were higher during the second year (Fig. 2A,C) which could have favoured the vegetation growing in opposition to the blooming. From a meteorological point of view, first year fit much better into the pathway of the last few decades. It is therefore likely that the features of the first year blooming are more common and must be considered normal.

Relationships between *Artemisia* pollen concentrations and atmospheric variables have been studied for the whole summer period and for the time until the maximum. Although some good correlations have been found (Table 3) it must be noted that they are only significant in both periods for *P*_cum. The negative sign for *P*_cum in the correlation coefficient during the second summer period is a consequence of a casual increasing of *P*_cum at the end. There is no correlation for the period before maximum because of the constant *P*_cum. Of special interest are correlations with the rainfall recorded over the previous few weeks for the first year. It is particularly noticeable for a period of 6–8 weeks (Table 5).

For the second summer especially, quadratic regression shows that values of the nightly relative humidity (RH00 and RH07) greater than 60% could be related to minor *Artemisia* pollen concentrations, but when RH07

Table 5
Correlations between *Artemisia* concentrations and *P*_cum 41–56 days before for summer-1 blooming

	Whole period	Before maximum
*P*_cum-41	0.8001**	0.8082**
*P*_cum-42	0.8253**	0.8667**
*P*_cum-43	0.8063**	0.7921**
*P*_cum-44	0.8265**	0.7591**
*P*_cum-45	0.7845**	0.7484**
*P*_cum-46	0.6921**	0.5850*
*P*_cum-47	0.6927**	0.6264*
*P*_cum-48	0.6106**	0.5590
*P*_cum-49	0.5212*	0.3900
*P*_cum-50	0.5404*	0.3916
*P*_cum-51	0.5557*	0.4111
*P*_cum-52	0.6120**	0.6634*
*P*_cum-53	0.6595**	0.8721**
*P*_cum-54	0.6319**	0.7862**
*P*_cum-55	0.6579**	0.7194**
*P*_cwm-56	0.7472**	0.7553**

2-tailed Spearman correlation coefficients. Significance level: * 0.05; ** 0.01.

Table 6
Correlations between *Artemisia* concentrations before maximum and T_{min} and P_cum several days before autumn blooming

	Autumn 1	Autumn 2		Autumn 1	Autumn 2
T_{min}-26	0.2546	0.1173	P_cum-11	0.8908**	0.7866**
T_{min}-27	0.0364	0.4694	P_cum-12	0.9296**	0.8074**
T_{min}-28	0.1576	0.6769**	P_cum-26	0.9031**	0.6772**
T_{min}-29	0.2303	0.6358**	P_cum-33	0.9031**	0.7129**
T_{min}-30	0.7395*	0.3887	P_cum-40	0.8438**	0.6736**
T_{min}-31	0.2788	0.3406	P_cum-41	0.8778**	0.5390*

2-tailed Spearman correlation coefficients. Significance level: * 0.05; ** 0.01.

surpasses 80%, *Artemisia* increases again. In this context, other factors such as temperature, wind run and evaporation, influencing the relative humidity, are correlated with the atmospheric pollen concentrations of *Artemisia* (Table 3).

3.3. The autumn season

For the second year, late autumn blooming interpretation becomes difficult. The field work suggests that it might be the sum of the *A. herba-alba* expected blooming and a second, unexpected, *A. campestris* blooming as a consequence of a poor pollen dispersal in summer. During the first year, the late autumn blooming is not well defined (Fig. 3) but a slight increase of the *Artemisia* concentrations during early-November is certainly noticed. For the first year, late autumn blooming is probably related only to *A. herba-alba*.

For the autumn blooming, a coincidence can be observed in the dates of the beginning of the station and maximum pollen concentration with the percentage of cumulative insolation from March 1st (Table 2D).

With regard to the second year *Artemisia* pollen concentrations, the existence of a positive correlation with the relative humidity and, as expected, a negative correlation with evaporation, wind speed and wind run is noteworthy (Table 3). The quadratic regression shows that the autumn atmospheric content of *Artemisia* increases when RH13 is higher than 50%, RH18 higher than 65% and, particularly, when nightly relative humidity (RH00 and RH07) is higher than 80%.

It is also worth mentioning that, for both years, there are very significant and positive correlations between *Artemisia* counts (from the beginning until the time when the maximum is reached) and the minimum temperature 28–30 days before, and with cumulative precipitation during the previous few days as well (Table 6). In the second year, correlations with precipitation extend back continuously (all days) until last days of September (41 days before), when rainfall was frequent. In the first year, correlations with precipitation are intermittently significant about 26, 33 and 40 days before. The interpretation of these correlations must be taken cautiously since they could be merely a statistical consequence of the progressive increases of the two variables involved (P_cum and pollen concentration until maximum). In any case, correlation with rainfall accounted 30–40 days before seems to be realistic, because they occur when *A. herba-alba* is starting to develop its stamens in the Murcia area.

During the second year, a more prominent autumn *Artemisia* blooming is observed (Fig. 3). This can be due to: (1) an unexpected late blooming of *A. campestris* and (2) a higher *A. herba-alba* blooming than the former year as a consequence of the slight increase of the minimum temperatures in early October together with the latest September and early October rainfall.

3.4. The winter season

This season coincides with the *A. barrelieri* blooming. The relationship between the beginning date and the percentage of cumulative insolation from March 1st is again outstanding (Table 2C).

Atmospheric variables have been correlated with *Artemisia* pollen concentrations for three periods: the whole winter season and the times before and after the maximum (Table 3). The positive correlation with T_{max} during the first year for the whole season and for the period after the maximum is clearly noticeable. This could be due to the fact that the mean of T_{max} is, in both cases, lower than 19°C (18.65°C and 18.43°C respectively), a value amply exceeded in the second year. For the second year, there is a negative correlation with T_{min} and T_{min}_0.15 since the beginning of blooming until the maximum, perhaps because temperatures are largely above 5.5°C and 3°C respectively, values greater than reached in the first year.

The aforementioned data suggest that *Artemisia* is a heavier pollen producer during the winter blooming

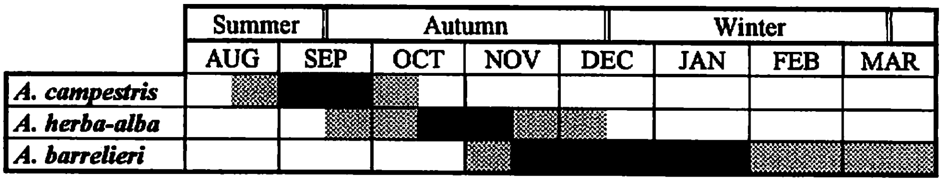

Fig. 4. Blooming calendar of *Artemisia* in the Murcia area. Black zones show the major pollen production, and grey zones minor pollen production.

with an optimum about 19°C T_{max}, 5.5°C T_{min} and 3°C T_{min}_0.15. The results of the quadratic regression for those variables agree with this hypothesis. In any case, more years of pollen counts are needed to positively confirm this.

4. Conclusions

The total pollen sum for the second year was lower because of high temperatures and minor precipitation. In all probability, the arid period suffered in Spain from 1991 had an additive effect. However, there were no significant differences in the pollen distribution patterns throughout the 2 years.

Because of the small differences between starting and end dates of the pollen periods, despite different meteorological conditions, we think it must be an important phenetic factor affecting flowering.

The meteorological features of the weeks before flowering seem to influence the pollen abundance (particularly in summer and autumn blooming) but, once the pollination has begun they do not seem to influence it in any significant way (except, perhaps, relative humidity in summer and autumn and temperature during winter).

Artemisia begins to bloom after summer, when temperatures drop. There are three blooming stages in Murcia (summer, autumn and winter) which appear to correspond with three different species, *A. campestris*, *A. herba-alba* and *A. barrelieri*, respectively (Fig. 4).

There appears to be a relationship between the beginning dates of blooming in summer, autumn and winter pollen seasons, and the percentage of cumulative insolation from March 1st being higher than 12500%, 16600% and 18800% respectively. The same is true for the time when maxima are reached in summer and autumn (13300% and 17200%, respectively).

During different pollen seasons, peaks in the pollen concentration were recorded mainly after 11–13 days from the start.

During the summer blooming, nightly relative humidity (RH00 and RH07) being higher than 60% appears to influence negatively the atmospheric pollen concentrations during the day, but if relative humidity is higher than 80% at 07:00 h, the pollen concentrations increase again. Likewise, the summer pollen production is increased with rain about 6–8 weeks (42–56 days) before blooming and it decreases when temperatures are high during the weeks prior to flowering.

The pollen production during the autumn is strongly dependent on the rainfall recorded weeks before, being particularly important during late September (about 30–40 days before blooming). Increases in the minimum temperatures during October (one month before blooming) could intervene by increasing the *Artemisia* pollen concentrations during autumn. When the nightly relative humidity (RH00 and RH07) is higher than 80% the daily pollen concentrations of *Artemisia* are further increased.

The winter blooming is the most important in Murcia and during this season the greatest pollen concentrations seem to correlate with T_{max} around 19°C, T_{min} around 5.5°C and T_{min}_0.15 around 3°C. The pollen concentrations do not appear to correlate with the meteorological factors considered during both the days and weeks prior to blooming.

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