

Qualitative and quantitative comparison of pollen calendars for plain and mountain areas

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Summary

A comparison of the quantity and the quality of pollen content in the atmosphere of two regions, one of the plains bordering the Mediterranean sea (altitude 40 m), the other of the mountains of the Pyrenees (altitude 1550 m), was made during the climatological year 1974–1975.

The method which was used intercepts the pollen flux of the atmosphere with a vertical filtering unit, which is exposed facing the direction of wind on the filtering door of the weather-vane and collects much larger quantities of pollen than the other techniques of collection.

The atmospheric currents displace from one region to another numerous spores and pollens, the trajectories of which are directly influenced by the general circulation of the atmosphere.

The density of these fluxes can be very large, reaching 2500 grains/m³ of air at M.T.P.R. in the last week of January; the taxons collected are very numerous (more than 700).

The atmospheric transfer of pollen modifies largely the pollen content of the atmosphere of different flowering domains. These interferences manifest themselves in the simplest cases by the presence of two peaks of concentration, the principal corresponding to the local efflorescence, the second to the pollen transferred from other regions. The pollen concentrations in the mountains are one-third of those in the plains.

Pollination in the mountains is several weeks late in comparison to the plain during the first semester, whereas during the second semester, it is the plains that show a certain delay.

These findings show why some allergic patients who go to the mountains during summer are affected twice by pollination.

Introduction

The pollen calendar of a city or region permits allergists to establish a chronological

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relationship between the clinical manifestations which they observe and the responsibility of different varieties of pollen for these manifestations (Davies, 1975; Leuschner, 1974; Charpin *et al.*, 1973). Actually, the atmosphere of a city cannot be considered as an independent entity since it is influenced by the atmosphere of the neighbouring regions to a greater or lesser degree, depending on the weather.

For some time now, we have been able to make quantitative and qualitative measures of spore-pollen atmospheric flow by a new method of data collection with computer analysis of the results. We found that this new method permitted us to compare the pollen calendars of two different sites, both located within the Languedoc-Roussillon, region of France, one being on the Mediterranean shore at an altitude near sea-level (Michel *et al.*, 1975), and the other located on a mountain range of the Eastern Pyrenees.

Materials and methods

Period of observation

The observation period extends from 1 March 1974 to 1 March 1975. March was chosen because it coincides with the beginning of the meteorological spring.

Pollen-sampling locations

The Montpellier station (M.T.P.R.) (situated at an altitude of 40 m, 43° 38' N, 3° 52' E) is installed on the roof of the Aiguelongue Clinic for Respiratory Diseases. The M.T.P.R. region is situated in the centre of the French mediterranean zone. In France, Mediterranean vegetation covers a small, narrow coastal belt of approximately 50 km in depth, except in the Rhone valley where it extends as far north as Montelimar. The area is surrounded by plains, marshes and the sea in the south and by the 'garrigues' and the Cevenne mountains in the north. Its climate is characterized by hot and dry summers and relatively mild and wet winters. The annual rainfall averages 700 mm at M.T.P.R. and occurs essentially in the autumn and spring.

The Font-Romeu station (F.R.) is located at an altitude of 1500 m, 42° 30' N, 2° E and is installed on the terrace of the building which houses the solar reflector of the C.N.R.S. (National Centre of Scientific Research) at Odeillo. F.R. is situated on the upper limit of a mountain range which extends principally toward the north-west along the Têt valley and its tributaries for about 40 km and along the Segre valley toward the south-west for approximately 50 km. The station is dominated on the north, south and west by sub-alpine and alpine ranges that reach altitudes from 2400 to 2900 m. Because of its geographical location, this station is often under the influence of air masses moving in from the Mediterrean region, a distance of only about 50 km to the south and east.

Pollen-sampling techniques

The sampling method employed will not be described here since it has already been reported (Cour, 1974). Only its basic principles will be recalled.

Principles of pollen-sampling techniques. A study of pollen and spore sedimentation on soil surface enabled one of us to perfect a new method for trapping atmospheric pollen (Cour, 1974). Indeed, none of the standard methods permits one to obtain simultaneously both a representative sampling of the atmospheric spore-pollen content and the fraction of pollen and spores which naturally fall on a given surface.

Contrary to the notion of the usual sampling methods based on techniques known as either *gravimetric* (as exemplified by the Durham trap) (Durham, 1944) or as *volu-metric* (as exemplified by the Hirst trap) (Hirst, 1952), we considered it necessary to devise a mixed or 'volugravimetric' technique of pollen sampling, i.e. a method which would permit the simultaneous exploration of atmospheric spore-pollen sedimentation in both the vertical and horizontal components. Only filtering supports are satisfactory for this system of combined trapping. By selecting an active surface measuring 400 cm^2 , which conforms to the surface of pluviometers used in meteorology, we were able to devise a filter which we call an 'autonomous filtering unit'.

The sampling apparatus (Fig. 1). Vertical filtering units (VFU) are made of five

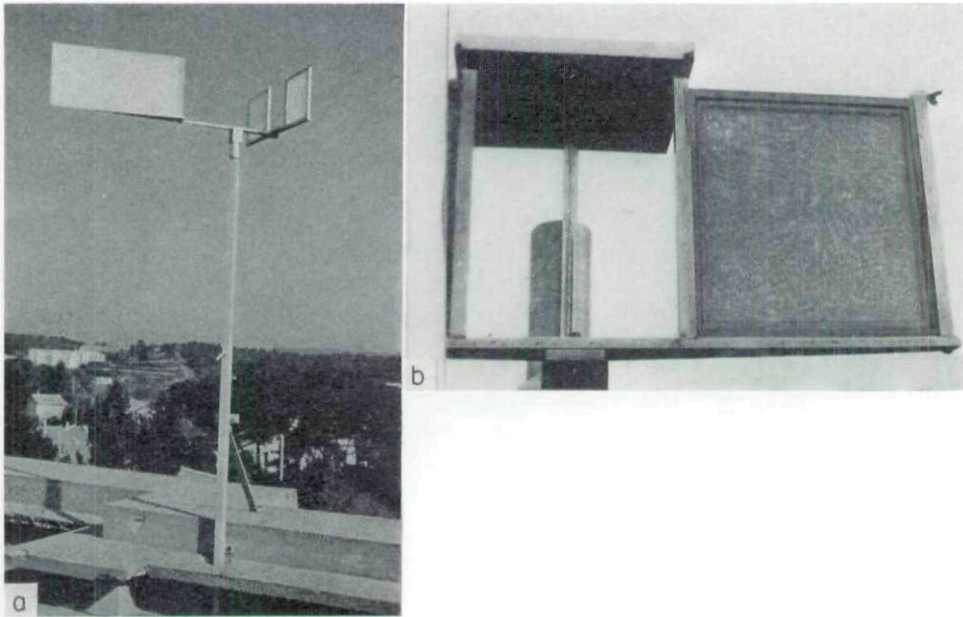


Fig. 1. The sampling apparatus. (a) The VFU-bearing weather-vane; (b) detail of a vertical filtering unit.

hydrophil gauze layers impregnated with a silicone oil. Thus, sampled atmospheric particles stick to the gauze and cannot be washed away by heavy rains. After soaking, the gauze layers are inserted between two frames measuring $20 \times 20\text{ cm}$, i.e. a filtering surface of 400 cm^2 . These filters, being very light, can easily be sent through the mail in an envelope like an ordinary letter.

The filters are mounted on a large-tailed weather-vane that is very sensitive to the instantaneous variations in wind directions. Thus, the filters (VFU) are constantly exposed to the atmospheric flux of spores and pollen.

Quantitative measurements

After exposure, a series of chemical treatments permits the release of all the trapped grains. The filter and most of the organic and mineral particles are destroyed during this process. After treatment, the residue contains nearly exclusively pollen and spores.

It is virtually impossible to observe the total number of spores and pollen present in such residue. An analytical fractional volumetric method enables one to evaluate the average quantities of pollen and spores by microscopic observation of a fraction of the residue.

In addition to the classical calculation of the relative frequency of counted taxons established in comparison to the whole of the pollen and spores counted, the following quantitative parameters are evaluated for each taxon observed: the number of grains trapped cm^2 of the filter, the total number of grains transported by the flux on a 1 m^2 section, the average number of grains transported on a 1 m^2 section during 24 hr, the average number of grains transported by 1 m^3 of air according to the length of the air column filtered by an anemometer.

Computerization of the results

It was necessary to computerize the results because of the great amount of pollen collected each week in the flux, distributed most frequently within thirty to fifty taxons, depending on the seasons, with a total of over 170 for the total annual cycle studied and because of the need to exploit the data collected as rapidly as possible.

Quantitative parameters studied

On each curve, the average number of grains collected on a 1 m^2 filter surface/24 hr during a 1-week period is plotted on the ordinate.

Because of the great number of pollen grains collected, a semi-logarithmic scale is employed.

On each curve, the weekly predominant wind direction is indicated, as well as the average hourly volume of filtered air.

Taxons studied

In the results of this study, we have mentioned only the main allergenic pollen as found in both M.T.P.R. and F.R. They include gramineae, urticaceae, plantain and compositae with a special curve for artemisia and ragweed.

Trees studied include ash, plane and though mildly allergenic, cupressaceae and pine which are in great number in the local flora of the two stations.

Results

Analytic study (Fig. 2 Table 1a, b)

Gramineae. At M.T.P.R., 9,200,398 grains were trapped (representing 3.82% of the total) compared to 6,147,524 grains (representing 10.17% of the total) at F.R.

The curves show four periods (Fig. 3): (1) In mid-April, a first peak of low importance (165,017 grains/ m^2 per day at M.T.P.R. and 188,222 grains/ m^2 per day at F.R.) corresponds to the flowering of gramineae from Mediterranean 'guarrigues'. This influence is higher in F.R. because Mediterranean vegetation is important south of the Pyrenees.

(2) At the end of May, one notes a principal peak for M.T.P.R. (7,402,589 grains/ m^2 per day) and a secondary peak for F.R. These gramineae originate principally from non-mediterranean plains.

(3) In July, a secondary peak is observed in the beginning of the month at M.T.P.R. (2,484,979 grains/ m^2 per day) and a principal peak at F.R. is seen at the end of the

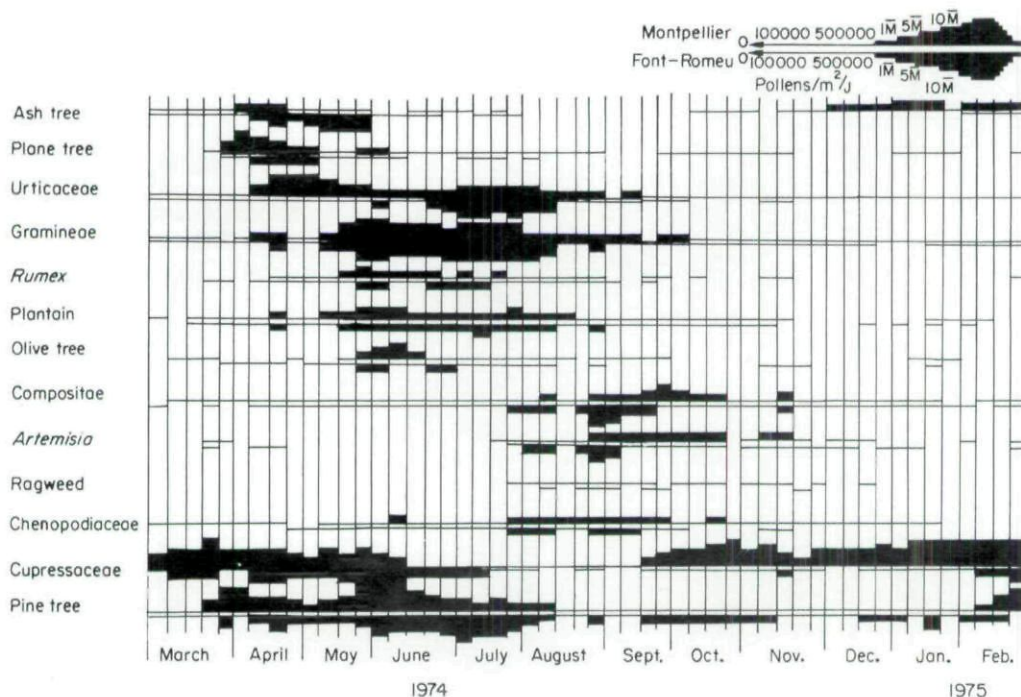


Fig. 2. Qualitative and quantitative confrontation between pollen calendars for plain (upper line) and mountain (lower line) during the climatological year 1974-1975.

month (3,871,379 grains/m² per day) resulting from the flowering of mountain gramineae.

(4) During August, September and October, the quantities fall slowly but remain late into the season.

Urticaceae-Moraceae. This group includes *Broussonetia* and *Parietaria*, which are highly allergenic, as well as nettles which are difficult to differentiate from the first ones under microscopic examination. At the M.T.P.R. station, large amounts of pollen are filtered each year (22,543,596 grains equal to 9.37% of pollen sampled). Two peaks are noted: the first occurring at the end of April and the beginning of May (reaching 20 million grains/m² per day) is mainly related to the flowering of *Broussonetia*. The second occurring during July (reaching 1,520,458 grains/m² per day) relates to nettles. At the F.R. station, only one peak of local origin is produced in relation to the flowering of mountain nettles. Contamination by *Broussonetia* and *Parietaria* pollen from the Mediterranean region is very low. A total of 2,324,793 Urticaceae grains were intercepted representing 3.84% of the total pollen trapped.

Plantain. Plantain is composed of a great number of species. Among the numerous recorded peaks, it is difficult to determine the different regional influences. However, three periods can be distinguished:

(1) The first period occurs during the third week in April and relates to Mediterranean plantains: 144,391 grains/m² per day at M.T.P.R. and 300,667 grains/m² per day at F.R.

(2) The second occurs during the first two weeks in June with 700,000 pollen grains/m² per day at M.T.P.R. and 453,303 pollen grains/m² per day at F.R.

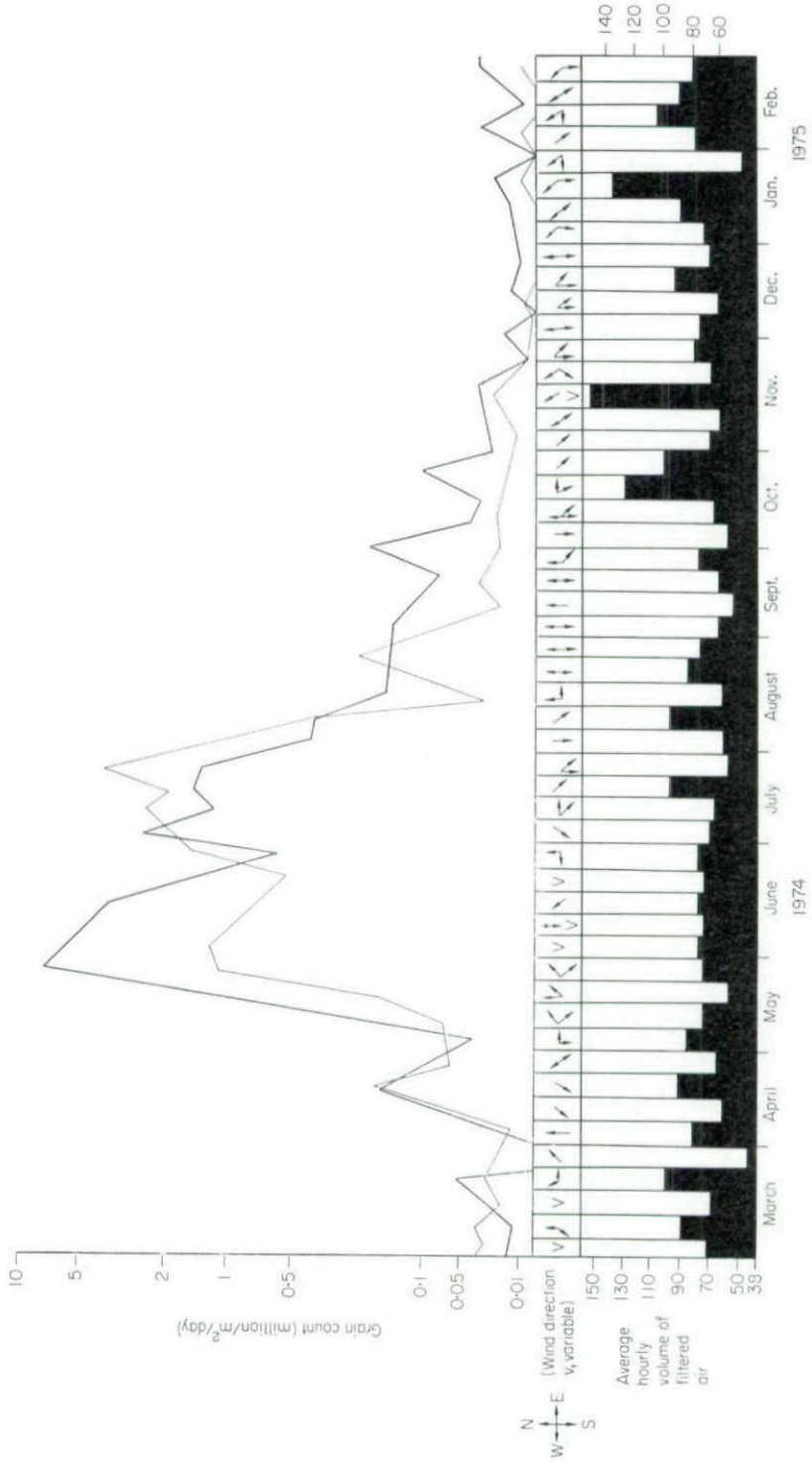


Fig. 3. Comparative calendar of gramineae for plain and mountain during the climatological year 1974-1975. —, Montpellier; — —, Font-Romeu.

Table 1a. Weeds. Qualitative and quantitative confrontation between calendars for plain and mountain

Weeds	Montpellier		Font-Romeu		Percentage of grains trapped in F.R./percentage of grains trapped in M.T.P.R.
	Number of grains/UFV	Percentage of annual total	Number of grains/UFV	Percentage of annual total	
Urticaceae	22 543 596	9.37	2 323 793	3.84	10.31%
Gramineae	9 200 398	3.82	6 147 524	10.17	66.82%
<i>Plantago</i>	1 738 915	0.72	1 177 240	1.94	67.70%
Compositae (total)	1 491 153	0.62	725 549	1.20	48.66%
<i>Artemisia</i>	1 112 989	0.46	544 919	0.90	48.96%
<i>Rumex</i>	876 171	0.36	465 549	0.77	53.13%
Chenopodiaceae	856 864	0.36	328 480	0.54	38.34%
Ragweed	44 666	0.02	1 699	0.003	3.80%

(3) The last, occurring in July and the beginning of August, corresponds to the flowering of mountain plantains (550,000 grains/m² per day at M.T.P.R. and 500,368 grains/m² per day at F.R.).

Compositae. These grasses are present in the atmosphere from the end of March until the end of November. At F.R., the entire quantity represents half of that found in M.T.P.R. The mountain *Artemisia* bloom 3 weeks earlier than those of the plains.

At F.R., the principal peak takes place at the end of August (1,112,165 grains/m² per day) and at M.T.P.R. not until the end of September (1,539,034 grains/m² per day).

Fortunately, ragweed pollen (which is highly allergenic) is rare in our region and is essentially present during August and September. The quantities recorded are higher at M.T.P.R. than at F.R. (44,000 grains/m² per day equivalent to 1.5/m³ at M.T.P.R. versus 3,440 grains/m² per day at F.R.).

Plane trees. At M.T.P.R., the pollination of plane trees is heavy from the third week of March until the end of April (representing 2.65% of total pollen trapped). The peak (greater than 10 million/m² per day) is reached at the beginning of April (200 grains/m²). A secondary peak is seen at the end of May, resulting from pollen coming from other regions.

At F.R., plane tree pollen is encountered even though this tree is absent in mountainous regions (240,000 grains were trapped equivalent to 0.4% of total pollen trapped). The trapping occurs from the second week of April until the first week of May).

A maximum higher than 450,000 pollen grains/m² per day is encountered during the third week of April. A delay of 2 weeks compared to the peak obtained at M.T.P.R. demonstrates that this pollen comes from plane trees situated in the low valleys of the Pyrenees.

Ash trees. At M.T.P.R., 1,142,000 grains were trapped during the year representing 0.47% of total pollen trapped. Ash trees often grow along the river banks and streams of the region.

Two periods of pollination are observed during the year: the first period occurs during April and May and relates to the late flowering of mountain ash as shown by

the F.R. curve. The second period corresponds to the flowering of local trees and extends from the end of November until the end of February.

The presence of high levels of ash tree pollen in the atmosphere during winter can account for allergic manifestations during a season of the year when a pollen aetiology is not expected.

At F.R., 1,974,000 grains were trapped during the year representing 3.6% of the total pollen. The pollination period extends from the end of March to the beginning of June with a peak during the third and fourth weeks of May.

Cupressaceae. This group is composed of numerous species which cannot be differentiated under microscopic examination. We have regrouped in this taxon the different species of cypresses and thujas as well as juniper trees which grow spontaneously in the 'guarrigue' on the hillsides in southern France and in the woods, plains, on the rocks and meadows of the mountain regions. These trees or bushes are present in the most diversified regions, thus proving that pollen is present in the atmosphere throughout the year.

At M.T.P.R., more than 120 million grains were trapped, representing nearly 50% of total pollen trapped. The curves indicate three principal periods: the first period occurs during the third week of March (12.5 million grains/m² per day, equivalent to an average quantity of 210 grains/m³) and relates to the flowering of Mediterranean juniper trees. The second peak occurring at the end of October (12.9 million grains/m² per day, equivalent to 1,380 grains/m³) relates to the flowering of some cypresses planted in parks and gardens and the secondary flowering of Mediterranean juniper trees. The third period takes place at the beginning of February and corresponds to the peak of the year (109 million grains/m² per day, equivalent to 2,390 grains/m³). It relates to the full flowering of local cypresses.

At F.R., 4,689,000 pollen grains were trapped during the course of the year representing 7.76% of the total pollen. A principal peak takes place at the beginning of June (3.5 million pollen grains/m² per day) due to the flowering of mountain juniper trees.

Pine trees. At M.T.P.R., 34.4 million pollen grains were trapped representing 14.29% of total pollen. The curve shows three principal periods: the first one occurs at the end of March (greater than 26 million grains/m² per day) and is related to the full flowering of Aleppo pine in the Mediterranean region. The second occurs from the end of May until the end of June (with a peak of 15 million grains/m² per day) and corresponds to the flowering of stone pines planted in neighbouring parks, as well as to that of maritime pines found in the Cevenne mountains and in more northern regions. The third period takes place from the first week of July and relates to the flowering of mountain pines as shown by the F.R. curve.

At F.R. (19.4 million grains representing 30.5% of the total pollen grains), three main periods are observed: the first one occurring at the end of April (600,00 grains/m² per day) relates to the flowering of Aleppo pines. The second occurring in the beginning of June (9 million grains/m² per day) relates to the flowering of pines planted in the lower valleys of the Pyrenees and the Roussillon. The third period occurring in the beginning of July (12 million grains/m² per day) corresponds to the flowering of local mountain pines (Norwegian and pitch pines).

Synthetic study (Table 2)

The VFU exposed weekly at M.T.P.R. between 25 February 1974 (ninth week of the

Table 1b. Trees. Qualitative and quantitative confrontation between calendars for plain and mountain

Trees	Montpellier		Font-Romeu		Percentage of grains trapped in F.R./percentage of grains trapped in M.T.P.R.
	Number of grains/UFV	Percentage of annual total	Number of grains/UFV	Percentage of annual total	
Cupressaceae	120 066 914	49.90	4 689 348	7.76	3.91
Pine	34 397 379	14.29	18 433 634	30.50	53.59
Plane	6 384 311	2.65	244 182	0.40	3.82
Ash	1 141 680	0.47	1 974 437	3.26	172.79
Olive	797 398	0.33	425 121	0.70	53.31

calendar year) and 24 February 1975 (eighth week of the calendar year) intercepted a total of 240 million pollen grains on their usable surface of 400 cm². Within the same time period, the total for F.R. reached only 60 million or 25.11% of the M.T.P.R. pollen. The average quantities recorded in a 1 m² section of flux per day (annual general average) are respectively 17,236,000 grains at M.T.P.R. and 4,088,000 at F.R.

Not only is the global pollen density lower in the F.R. atmosphere, but there also exist important significant variations in the monthly and seasonal distributions of the trapped pollen in the two regions. Thus, the average minimal collections at M.T.P.R. (Table 1) were observed at the end of the summer during August–September (barely more than 2 million pollen grains/m² per day or 10.1 pollen grains/m³) and in the winter at F.R. (December–January with only 90,000 grains/m² per day). The maximal collections, on the contrary, occurred at the end of winter (February) at M.T.P.R. with an average superior to 77 million pollen grains/m² per day. At F.R., maximal collections occurred more characteristically in the course of summer (July) with a daily average superior to 13 million pollen grains/m² per day (Tables 2 and 3).

Table 2. Seasonal confrontation between calendars for plain and mountain (1974–1975)

		Montpellier		Font-Romeu	
		Number of grains/m ² /day ($\times 10^6$)	% Mensual/annual total	Number of grains/m ² /day ($\times 10^6$)	% Mensual/annual total
Spring	March	13.4	6.51	4.5	9.29
	April	22.4	10.81	5.8	11.91
	May	31.8	15.39	9.8	19.99
Summer	June	15.3	7.40	11.1	22.73
	July	9.1	4.42	13.2	17.05
	August	2.2	1.07	2.0	4.21
Autumn	September	2.4	1.19	0.45	0.94
	October	8.0	3.90	0.23	0.47
	November	2.5	1.24	0.24	0.50
Winter	December	3.8	1.88	0.15	0.31
	January	18.2	8.81	0.09	0.18
	February	77.1	37.32	1.10	2.42

Discussion

The results obtained in M.T.P.R. and in F.R. at an altitude of 1,600 metres as well as those compiled by one of the authors in the Sahara desert permit the following observations:

(1) The technique of pollen sampling which we employ possesses quantitative and qualitative advantages. Quantitatively, the returns from this technique are very high since one vertical filtering unit intercepts a daily average of 410,000 pollen grains for 400 cm² with an average hourly flow of 40–100 m³ of air filtered depending on the force of the wind (it may be recalled that the suction force of the Hirst apparatus is 0.6 m³ of air/hr). The abundance of pollen samples is due to the large surface of the filters and to their construction design, as well as to their position on the weather-vane permitting a continuous orientation facing the wind.

The sample of pollen thus obtained is highly representative, because the smaller-sized pollen grains are not exposed to electrostatic phenomena which is not necessarily the case with other types of apparatus. Qualitatively, the identification of pollen fossilized by acetolysis is more precise than that of full pollen since the different structures of their exine become clearly visible. Furthermore, the technique is simple, not very costly and requires no source of energy. No special preparation of the filters is necessary before or after use, which facilitates their preservation and eventual transport.

(2) Atmospheric currents displace numerous spore–pollen fluxes from one region to another. The geographical origins of these fluxes as well as their trajectories are directly influenced by the general circulation of the atmosphere. Raynor, Hayes & Ogden (1974) reported similar results after studying the spore–pollen content of the atmosphere with samples taken by plane.

(3) The spore–pollen density of these fluxes can be very great. Thus, we have established at M.T.P.R. that each day these fluxes are able to transport more than 70 million pollen grains in a section of 1 m² and that during the last week of January, the average weekly density reaches 2,492 grains/m³ of air. Concerning those pollen grains capable of producing allergy, during the second week of April, 1974, 1 m³ of air was found to contain: 200 pollen grains from plane trees, 100 from pine trees, 30 from birch trees, 25 from cypresses, 100 from wall-pellitories, 20 from oak trees and 15 from yoke elm trees. Considering that every day a normal person inhales 10 to 12 m³ of air, this represents 5,400 pollen grains inhaled each day, a rather considerable quantity.

(4) In the course of their trajectory, the fluxes progressively lose their contents in the form of 'pollen falls' (average daily amount: 500,000 grains/m² at M.T.P.R.) which are deposited on the surface of the ground all along the trajectory.

(5) The taxons are not present in the same proportions in the spectrum of the flux and the 'pollen falls'. The differences noted in proportions of pollen content result from the great differences in degree of 'floatability' of the various species of pollen. This explains how the small-sized pollen with low density (such as the *Urticaceae*) are less frequently trapped by gravimetric pollen collectors (such as the Durham type of apparatus).

(6) The atmospheric transportation of pollen interferes considerably with the pollen content of the atmosphere of different floral domains. Thus, olive tree and plane tree pollen are present in the atmosphere of F.R. even when their plant sources are absent in the environment.

Conversely, numerous ash tree pollen grains were recorded at M.T.P.R., four

months after the local flowering period for these trees. This indicates that their pollen source is located in the mountain region as is also the case for pollen grains recorded from birch, chestnut and filbert trees, all of which are absent from the plain region. Moreover, the pollen transports clearly transcend the perimeter of the region, since, one or twice each year, during Sirocco episodes, pollen of *Argania*, *Calligonum* and certain types of *Acacia* (whose plant source are found only along the coastal regions of Morocco and Algeria) are found in the M.T.P.R. atmosphere.

(7) In the simplest cases, these interferences reveal themselves by the presence of two peaks of pollen concentration (Fig. 3). The principal peak corresponds to the local flora and the secondary peak is attributable to pollen transported from other regions.

(8) When the plant species of two regions are the same, there exists naturally a space of time between the flowering of the plain and mountain flora. It is this difference in flowering time which explains a common observation: certain allergenic persons who spend the summer in a mountain region experience not one but two exposures to the flowering of gramineae to mention an example. Similar findings were reported by Gueho, Cornillon & Touraine (1970).

(9) The chronological order of the phases of flowering on the plains and in the mountains is not always the same. Thus, during the first semester of the year, the mountain pollination experiences a delay of approximately 3–4 months in comparison to the plains (one can cite the case of ash trees as an example). During the second semester, the reverse occurs with a flowering of mountain flora several weeks before that of the plains, as exemplified by the case of *Artemisia*.

(10) In fact, often the phenomena are even more complex, thus making it impossible to propose a 'general rule'. Depending on the eventual intervention of diverse possible wind conditions, the pollen transfers can be multiple and comprise several types of successive fluctuations.

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