

Forecast of pollination dates and relation to onset of allergic pathology

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Abstract

Forecasting pollination would help allergists to establish an appropriate prevention for allergic patients. Previous studies have related meteorological variables to airborne pollen counts; patients suffer allergy episodes before the peak of pollen is reached. A 10-year study was done in Saint-Etienne (France) by a multi-disciplinary team (medical doctors, meteorologists, plant biologists). The frequency distribution of patients with pollinosis was obtained from mid-January to August every year. The meteorological station recorded the temperatures daily; pollen counts were obtained with a pollen trap. The maturation stages of trees (ash, birch) and graminaceae (dactyl and meadow grass) were followed by weekly sampling and provided the exact date of pollination. Mathematical models were built to predict the developmental stages of plant growth and the values were compared with the exact dates obtained every year. The frequency distribution of allergic patients was either mono or biphasic according to the evolution of daily temperatures. The maximum peak of patients always preceded the peak of graminaceae over the 10-year period. Different models were found to adequately predict the pollination dates: a Q_{10} -based algorithm best described the pollination date of trees; a weighted Q_{10} algorithm best reflected the pollination of graminaceae.

Abbreviations: CV = Coefficient of variation; D_p = Day of pollination; D_s = Day from which we start to make the sum of the temperatures; Q_{10} = A well-known estimation derived from the Arrhenius' equation; T_{cum} = Cumulated temperature; T_{cum6} = Cumulated temperature taking into account the values above 6 °C; T_d = Average temperature at day d ; Y = Temperature to reach at the stage phenologic of pollination

1. Introduction

The incidence of pollinic allergic is increasing in the general population. Several studies agree to correlate the strong association between the increase in pollen in the atmosphere and the increase in allergic diseases in relation to the sensitizing (Banken and Comtois, 1992; Ross and Fleming, 1994). The observed symptoms include: rhinitis, conjunctivitis, tracheitis, asthma but also cutaneous signs. All these manifestations significantly alter the quality of life of allergic patients (Bousquet et al., 1994; Didier et al., 1999). In France,

there are three main pollinic seasons: (1) trees, in February-March; (2) graminaceous, from April to June; (3) herbaceous, from July to September. The duration of the pollinic season explains the variations of the periods of allergy episodes reported by allergic patients.

Technical studies of pollinic pathology aimed to educate and inform the medical profession, but also of the allergic patients themselves. A network of stations in charge of the collection of pollen (Réseau National de Surveillance Aérobiologique – RNSA) was developed in France (Le Goaster et al., 1997; Thibaudon, 1997). Now, forty-six

stations collect pollen weekly on French territory from February to September. This makes it possible to know, for each station and each year, the nature of pollen present, their period of emission, and the quantities released in the atmosphere. It has been noted that pollination periods are variable from 1 year to the next and depend on the average temperature (Ariano et al., 1994; Glassheim et al., 1995). Several studies have compared the number of patients referred for a pollen-related pathology and the data obtained from pollen collecting. They have shown that the maximum peak of pollen is always delayed regarding the maximum peak of patients (Pehkonen and Rantio-Lehtimäki, 1994; Dechamp et al., 1997; Laaidi et al., 1997). This implies that pollen collecting is of little interest for a preventive action for allergic patients. The climatic conditions have been identified for a long time as being able to modify the number of pollen grains in the atmosphere, and consequently, to modify the incidence of allergic symptoms. Celenza et al. (1996) studied the influence of storms on the asthmatic episodes and on the graminaceous pollen in London. Singh and Babu (1980) in India, Ruiz de Clavijo et al. (1988) in Spain, Glassheim et al. (1995) in Colorado studied the influence of temperature, atmospheric pressure, wind, sun and rain on pollinic counts. McDonald and O' Driscoll (1980) showed the influence of the wind direction in Galway. In Madrid, Subiza et al. (1992) have studied the influence of hygroscoy on the maturation of graminaceous pollen.

The overall aim of this work was to determine if it were possible to define new agrometeorologic parameters predictive of the arrival of tree and the graminaceae pollen before a pollen air sampler detected them. This study was coupled with the collection of patients presenting an allergic pathology. A multi-disciplinary study associating doctors, meteorologists and plant biologists was initiated in 1990 in Saint-Etienne (a town of 200,000 citizens in the centre of France).

2. Materials and methods

2.1 Patients

From 1990 to 2000, an annual collection of patients referred for pollinic allergy was done by a

group of volunteer doctors from February to August. Each doctor had to fill in grids containing the first three letters of each patient's name, the date of the medical examination and the date of onset of symptoms, the nature of the symptoms and the results of the skin tests done with the most representative allergens (ash, birch and graminaceae). Data were transmitted to a medical referent and collected into a single 'patients/symptoms' file. Software was written in Visual BASIC, Microsoft, to exploit these data: for each day of the year, starting from 1st January, the software calculated the number of patients complaining of allergic signs. By convention, patients were retained in the database until the day of the medical examination where they were supposed to have received an effective treatment. So, the date of beginning of the symptoms constituted the key factor for classification, rather than the date of the medical examination itself which would have involved a statistical bias (time varying according to the patients and doctors). This new 'days/symptoms' file was then merged with the file containing the pollen counts and the meteorological parameters (*cf. infra*) to obtain a 'days/symptoms/pollen/meteorology' file.

2.2 Pollen sampling

A Hirst type volumetric pollen air sampler (Lanzoni s.r.l., Bologna, Italy) was used to trap pollen on a moving, adhesive-coated slide. It was placed on the roof of a building 600 m above sea level situated downtown, away from any factory or botanical park which could have biased the data of collecting (Subiza, 2001). The filter paper was collected every week and the pollen grains counted by a RNSA technician qualified in palynology. The exposed tape was treated with a dye (phenylated glycerol-gelatine and fuchsine) to more easily determine pollen grains, and examined under a microscope. The number of pollen grains was counted with a $\times 40$ lens, in accordance with the recommendations of the International Aerobiology Association. The count was reported as grains of pollen per cubic metre of air.

2.3 Botanical sampling

Five samples of plants were harvested each year from mid-January to the end of May: the gram-

inaceae were collected in a plain near the Departmental Meteorological office, the samples of trees were collected near the Faculty of Plant Biology. Samples were taken weekly during the first weeks of the study, then twice weekly at periods close to pollination. Pollen of two types of trees were considered: ash (*Fraxinus excelsior*) and birch (*Betula alba*). The following graminaceae were studied: meadow grass (*Poa pratensis*) and dactyl (*Dactylis glomerata*). The samples were analysed at the laboratory of Plant Biology (Faculty of Science, Saint-Etienne). The morphological examination of stamina provided the exact date of pollination of the plants *a posteriori*.

2.4 Agrometeorologic data

The growth of a plant and its date of pollination being strongly related to the duration of the day and the energy received, the following meteorological parameters were measured:

- temperature measured under a shelter placed at +1.5 m above the ground-level,
- temperature measured at +0.1 m above the ground-level,
- temperature measured to -0.5, -0.2, -0.1 m inside the soil.

Mathematical models for determination of the date of pollination of plants (D_p) have been described in the literature (Perarnaud and Raynal, 1991). In the present study, the plants considered were perennial with a winter growth and their development can be modelled by an exponential approximation (this method is referred as the Q_{10} approximation adapted from the Arrhenius' law) (Perarnaud and Raynal, 1991). For a given plant, a developmental phase (also called the phenologic stage, P_s) is obtained for a characteristic cumulated temperature obtained by the formula:

$$P_s = \sum Q_{10}^{T_d/10} \quad (1)$$

where Q_{10} is a coefficient by which is multiplied by the speed of development of the plant for every rise of 10 °C in temperature; T_d is the average temperature at day d . If we define: Y , the temperature to reach at the stage phenologic of pollination, D_p , the day of pollination, D_s , the day from which we start to make the sum of the temperatures, then the exponential approximation gives:

$$Y = \sum_{D_s}^{D_p} Q_{10}^{T_d/10} \quad (2)$$

We can see that, for a given plant, it is necessary to determine the value of the constant Q_{10} and the parameters D_s and Y . According to the experimental work of Niqueux and Arnaud (1967, 1981) on the development of fodder crops Q_{10} values should be close to 2 for perennial plants. A simulation technique for determining these parameters was developed on Excel software. By using dynamic spreadsheets, the effect of changing one variable in the model desired in Equation (2) was compared with the observed results obtained in the different years under observation. In that way, the values that best fitted the observed measurements were selected.

3. Results

3.1 Patients curves in relation with pollen count

In the present study, the curves plotting the number of patients with pollen counts confirmed the occurrence of the patients' peak before the peak of graminaceae pollen in all the 10 years of study: a 20 ± 16 days advance on average was observed. Figure 1 depicts the occurrence of the patient's peak occurring before the maximum of the graminaceae pollen count in 1997. This occurred whatever the pathology studied: rhinitis, conjunctivitis or asthma. The curves of these different symptoms were perfectly superimposed and differed only by amplitude (rhinitis and conjunctivitis being more frequent than asthma). The shape of the curves of clinical data can be either a monophasic (Figure 2) or a biphasic curve (Figure 3). The biphasic curves corresponded to years when a period of cold occurred in April, delaying the rise in temperatures and the maturation of the graminaceae (i.e., 1991, 1992 and 1994–1998). A reduction of the number of consultations was then observed between the patients suffering from allergy to pollen of trees (first peak) and the patients allergic to the graminaceae pollen (second peak) (Figure 1). During the years when this period of cold did not occur (1990, 1993, 1999 and 2000), no break was observed in the curve of the temperatures. Consequently, the frequency repartition of

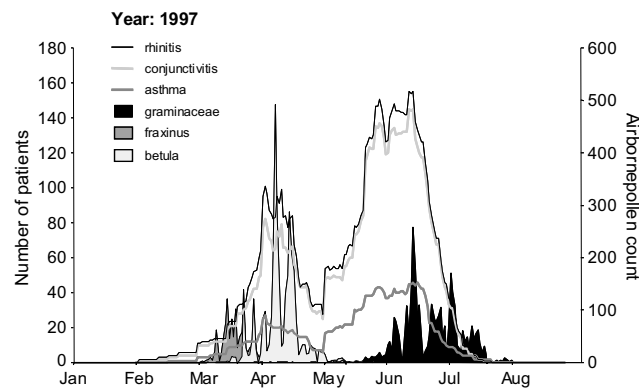


Figure 1. Number of patients with allergic symptoms compared with graminaceae pollen count in 1997. The patients' peak occurs before the maximum peak of graminaceae pollen. The curves of the three symptoms have a strictly parallel evolution. The peaks of the tree pollen (birch and ash) correspond to the first peak of patients who consulted in March–April.

the pathologies had a monophasic form. Throughout the study, the curves for patients and for pollen of trees (ash and birch) started simultaneously.

3.2 Determination of agrometeorological parameters

The observations of the laboratory of Plant Biology provided the exact dates of pollination of the trees and graminaceae (Table 1). In our simulation process, we started by arbitrarily selecting D_s as

January 1st for each plant under evaluation; various values for Q_{10} were also entered in the spreadsheet and the different values for Y were computed until D_p was obtained. For each Q_{10} , the average m and the standard deviation σ of Y over the 10 years of study were calculated. The coefficient of variation of Y was derived as: $CV = \sigma/m$. For each type of plant, the value of Q_{10} that was found to minimize CV was retained.

In a second step, computations were done by using this optimal Q_{10} , but making D_s to vary. The value of D_s providing the minimal CV was then

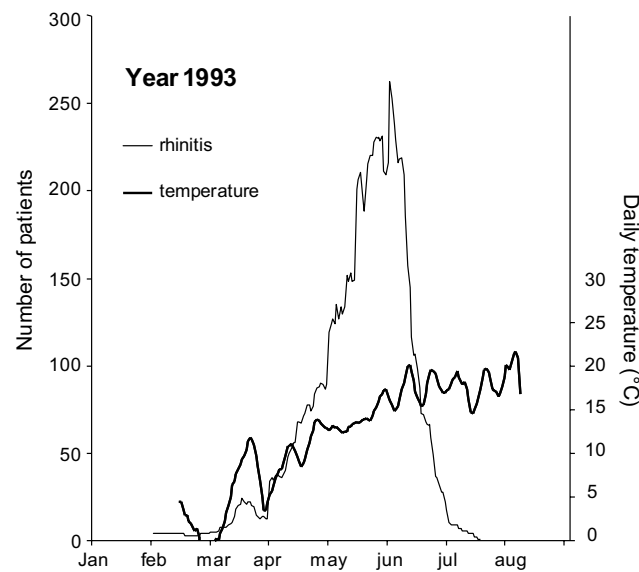


Figure 2. Number of patients with allergic rhinitis compared with the daily temperature. The 1993 curve is monophasic as temperature regularly increased over time.

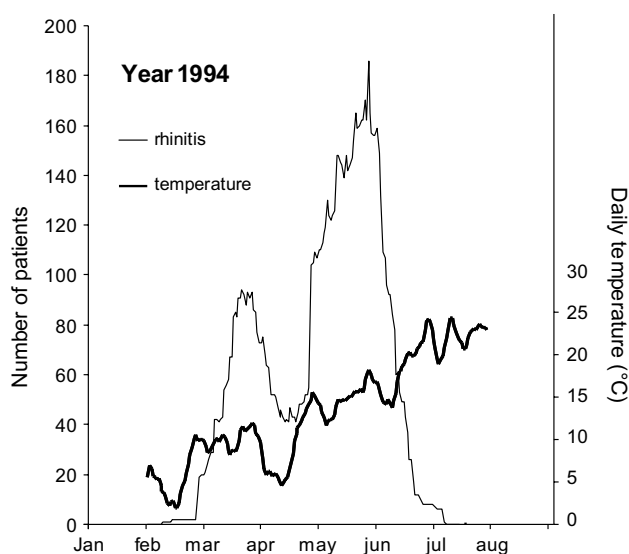


Figure 3. Number of patients with allergic rhinitis compared with the daily temperature. The 1994 curve is biphasic as a marked temperature fall was observed at the beginning of April.

retained in this second step. The average value of Y was then re-computed. A combination of all the possible values of Q_{10} and D_s was done. The values of the pair $[Q_{10}, D_s]$ providing the most belated D_s were selected. Finally, the Q_{10} value having the smallest σ was retained.

In a third step, D_p was determined by a new simulation based on a stepwise method. The values of 1 year were arbitrarily excluded from the file (each year was excluded sequentially). All the possible values of the pair $[Q_{10}, D_s]$ were tested and the theoretical values for D_p were calculated year per year. The difference between calculated D_p and observed D_s values were then derived. The pair

$[Q_{10}, D_s]$, which minimized the mean absolute value of these differences, was selected and data from the excluded year were reconstituted; the difference with the observed D_p was noted. This step was repeated for each year of the file; the column containing the differences between calculated D_p and observed D_p of the table allowed the control of the method's accuracy. The determination of the optimal pair $[Q_{10}, D_s]$ was done with the file including every year and by using the smallest σ . The calculated agrometeorologic parameters for the different plant species appear in Table 2. For birch, Equation (2) was found to provide the most reliable results. It minimized the variations of the

Table 1. Dates of pollination (D_p) determined by the Laboratory of Plant Biology

	Ash (<i>Fraxinus excelsior</i>)	Birch (<i>Betula alba</i>)	Meadow grass (<i>Poa pratensis</i>)	Dactyl (<i>Dactylis glomerata</i>)
1991				May 21st
1992			May 6	May 21st
1993			May 6	May 11th
1994			April 25	May 16th
1995	Beginning of April	Beginning of April	April 15th	May 9th
1996	Beginning of April	Mid-April	April 12th	May 24th
1997	Beginning of March	Beginning of March	April 10th	May 5th
1998	End of March	End of March	April 21st	May 11th
1999	March 20th	March 20th	<May 3rd	May 3rd
2000	Beginning of April	End of March	April 20th	May 5th

Table 2. Calculated agrometeorologic parameters

	Q_{10} optimal	D_s	Y	Average difference (days) (calculated D_p – observed D_p)	Maximum variation (days) (calculated D_p – observed D_p)
Ash (<i>Fraxinus excelsior</i>)	9	February 10th	128	4.1	8
Birch (<i>Betula alba</i>)	9	February 10th	278	2.6	7
Meadow grass (<i>Poa pratensis</i>)	8.6	October 1st	3620	3	7
Dactyl (<i>Dactylis glomerata</i>)	2.2	November 1st	965	3.5	9

calculated D_p vs. the observed D_p . The temperature used T_d is that measured at 1.5 m and daily averaged.

For ash, Equation (2) was also found to be the best method of Q_{10} , with D_s fixed on February 10th, with optimization of the difference between calculated D_p and observed D_p . The temperature used T_d is that measured at 1.5 m and averaged daily.

The best model for graminaceae was the model of Q_{10} balanced by a weighting factor. A linear weighting method giving threefold more importance to the temperatures close to D_p around the 200th day than D_s = October 1st was retained. It minimized the variations of the calculated D_p vs. the observed D_p . The temperature used T_d is that measured at 0.1 m in the soil at 6 P.M. The following equation (3) was found to best apply to the graminaceae:

$$Y = \sum_1^d Q_{10}^{(T_d/10) * (1+2d/200)} \quad (3)$$

4. Discussion

In this approach, only the temperatures were taken into account. Other parameters such as rainfall, daily evolution of moisture, reserves of water in the soil are also known to influence the plant growth and thus the D_p . The importance of our database is limited to 10 years of measurement for the determination of D_p . It is a short time study to validate agrometeorologic data with a high degree of accuracy, but few clinical studies of such a duration have been published in the literature (Spieksma et al., 1995; Leuschner et al., 2000).

That clinical signs precede the detection of pollen is well known. Various hypotheses have been advocated:

- (1) Concentration of pollinic antigens has been found significantly increased in the air before the period of pollination. These pollinic antigens were observed in air samples containing only particles smaller than the micron, therefore without pollen grains (Pehkonen and Rantio-Lehtimäki, 1994). These tiny particles can thus penetrate in the respiratory tract and cause reactions before pollination. This antigenic material could come from catkins, but also from bark, leaves and buds of the plant (Pehkonen and Rantio-Lehtimäki, 1994).
- (2) The priming effect is a phenomenon that was identified several years ago (Connell, 1969; Rosenthal et al., 1975). For a given taxon, the allergic reactions begin once a certain concentration in the air is reached; for example 40 grains/m³ for the pollen of ambrosia (Dechamp et al., 1997; Laaidi et al., 1997). This is in agreement with our clinical observations. When a period of cold occurs between the pollination of trees and that of graminaceae, the clinical curve of collection is biphasic. It remains monophasic if there is no fall in temperatures delaying the pollination of graminaceae.

Several papers in the literature have concerned the relationships between meteorological parameters and pollen counts. Correlations between temperatures and pollen antigenic concentrations have regularly been reported. However, no method for measuring temperature is unanimously accepted as a predictive parameter (maximum, minimal or average temperature, temperature of the three days before, temperature of the previous pollinic season...) (Koivikko et al., 1986; Galan et al., 1989; Ariano et al., 1994). Cumulated temperatures (T_{cum}) have been reported as a potentially interesting predictor. For birch, a T_{cum} of 300 °C above 0 °C was reported between February 1st in the north of France; in Paris, the T_{cum} value is

260 °C above 3 °C as from February 11th (Sutra et al., 1992). For the graminaceae, T_{cum} above 6 °C ($T_{\text{cum}6}$) could be regarded as a predictive value of release of the allergic symptoms (Taira et al., 1992; Antepara et al., 1995). In the present study, evolution of $T_{\text{cum}6}$ was found to follow a x^2 polynomial type increase in every year studied. The peak of graminaceae occurred for $T_{\text{cum}6}$ values ranging over a considerably large interval (644 ± 133 °C) making $T_{\text{cum}6}$ a non suitable predictor.

The Q_{10} method used in this study provided the most accurate results. The comparison of the predictive value obtained with this model to the statistical value mean of D_p would make it possible to see whether it allows a significant improvement of the score. Similar studies should be carried out in other geographical areas to validate these models. The use of such mathematical models and prediction of the dates of pollination appear a more accurate and simple technique than a true botanical study of plant growth. In the future, this method should enable us to obtain preventive information by providing a pollen concentration forecast to allergy sufferers.

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