

ORIGINAL ARTICLE

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Forecasting the start of the pollen season of *Poaceæ*: evaluation of some methods based on meteorological factors

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Abstract The pollen of anemogamous plants is responsible for half the allergic diseases, that is to say a prevalence of 10% in the French population. *Poaceæ* produce the first allergenic pollen almost everywhere. The work described in this article aimed to validate forecast methods for the use of physicians and allergic people who need accurate and early information on the first appearance of pollen in the air. The methods were based on meteorological parameters, mainly temperature. Four volumetric Hirst traps were used from 1995 to 1998, situated in two departments of Burgundy. Two of the methods tested proved to be of particular interest: the sum of the temperatures and the sum of Q_{10} values, an agrometeorological coefficient integrating temperature. A multiple regression, using maximum temperature and rainfall, was also performed but it gave slightly less accurate results. A χ^2 -test was then used to compare the accuracy of the three methods. It was found that the date of onset of the pollen season could be predicted early enough to be useful in medical practice. Results were verified in 1999, and the research must be continued to obtain better statistical validity.

Keywords Pollination · Forecast · *Poaceæ* · Meteorological factors · Temperature

Introduction

Towards the end of the last century Blackley (1888, first published 1873) revealed the role of *Poaceæ* in hay fever (Comtois 1995). Nevertheless, the scientific study of the aerobiological and more precisely palynological content of the air only started after the Second World War thanks to the development of high-performance traps. This method of sampling improved progressively and the vol-

umetric Hirst trap is now the technique most used in Europe; its accuracy with daily and even bihourly data allows correlations to be made with the weather. Pollen is greatly influenced by the meteorological conditions; before blossoming occurs, the sunshine (photoperiod) or temperature (thermoperiod) conditions, also called primary factors, influence the growth and development of vegetal species, and so control the pollen production. At the time of blossoming, the secondary meteorological factors (sunshine, rainfall, relative humidity) condition the opening of anthers and so the release of pollen grains, then tertiary factors (mostly wind) cause the grains to be scattered in the atmosphere (Laaidi K et al. 1997; Laaidi M 1997). More knowledge of the meteorological factors that act on the production, release and scattering of pollen grains is therefore essential to understanding the pollen counts and to any forecast of the biological content of the air (McDonald 1980; Spieksma 1983; Spieksma and den Tonkelaar 1986). With such forecasting in mind, primary factors that take effect before blossoming can be integrated into models in order to predict the date of the first arrival of pollen in the air. This is of particular importance for people allergic to a given pollen, who will then be able to start an antiallergy treatment several days before the beginning of pollination, to optimise its effectiveness. The forecasting methods set out in this paper involve grasses, which produce some of the most abundant pollen in the atmosphere (Guérin 1993) and represent the commonest allergen in Europe, affecting 20% of the allergic population in Denmark and 80% in France or in the Netherlands (Weeke and Spieksma 1991). In addition, the interannual variability of the start of pollination (up to 2 weeks in the area and period studied) makes it important to predict the event for a particular year. In practice, weekly pollen counts are issued 9 days after the first grains have impacted on drums (7 pollen-recording days followed by 2 others for analysing and sending data) so clinical symptoms have time to set in before allergists have the necessary information. Thus forecasting models would allow allergists, and hence their patients, to know several

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days in advance when pollen will appear, allowing them to initiate preventive treatment that will be more effective than a curative approach.

Materials and method

The pollen grains were sampled by a Lanzoni-Hirst-type (Hirst 1952) volumetric trap (VPPS 2000) placed on the flat roof of a building, 16–34 m above ground level. It was calibrated to handle a flow of 10 l air/min, which roughly corresponds to human breathing, and a built-in vein ensured that it was permanently oriented in the direction of the wind. Pollen grains sucked into the trap impacted on a cylindrical drum covered by a plastic film coated with a uniform layer of sticky substance (Vaseline, paraffin oil and toluene) and rotated by 7-day clockwork at a speed of 2 mm/h (Mandrioli 1990, 1994; Rantio-Lehtimäki 1991). Guérin (1993) reckoned that such a trap gives a representative picture within a 30-km radius. Four traps were used for this study, from 1995 to 1998 (the only years available); they were installed in Burgundy, France (Fig. 1), in the departments of Côte-d'Or (Montbard 47°37' N 4°20' E, Dijon 47°16' N 5°0' E) and Saône-et-Loire (Mâcon 46°18' N 4°50' E, Chalon-sur-Saône 46°47' N 4°50' E). The methodology employed is common for this type of sampling. Every week, the strip was removed and cut into seven equal segments corresponding to the 7 days of the week. Each segment was mounted between slide and coverglass. Then it was examined by light microscopy following the method described by Kämpylä and Penttinen (1981), which consists in reading 12 transverses. The results were expressed as the number of pollen grains per cubic meter of air. Meteorological data were recorded by Météo-France less than 2 km away from each sampling place. The variables used here were the ones that condition the growth and development of plants. Under natural conditions, development mainly depends on temperature, while the influence of other environmental factors, edaphic as well as climatic, is insignificant (Durand 1967; Richard 1985). In fact, temperature is the commonest parameter used to predict the pollination date of a plant (Niqueux and Arnaud 1967, 1981; Ashcroft et al. 1977; Lejoly-Gabriel 1978; Richardson and

Anderson 1986; Törnevik 1982; Linvill 1990; Andersen 1991; Frenguelli et al. 1991, 1993; Sutra et al. 1992; Larsson 1993; Lafont and Perret 1995; Besselat et al. 1995). The temperature action curve can then be considered to obey a linear law (by the method of summing temperatures) or an exponential law (by the method of summing Q_{10} , where Q_{10} is an agrometeorological index based on temperature and on the rate of growth of plants). Other parameters have also been used, such as solar radiation (Maurain 1933; Thornthwaite 1952, quoted by Durand 1967) but with unsatisfactory results, rainfall or relative humidity (Lejoly-Gabriel 1978; Subiza et al. 1992). Before establishing a method for predicting the starting date of the pollen season (SDP), one had to be precisely defined, and calculated on the basis of the years available. This calculated SDP could then be used to adjust a forecast model, which would allow the prediction of the SDP in the following years. Graphically, the pollination curve of a plant, plotted from accumulated daily percentages of pollen on the y-axis and the date of observation on the x-axis, is sigmoidal with two bends (Pathirane 1975; Lejoly-Gabriel 1978). These two points correspond to the onset and the end of the main pollination period, and can be arithmetically determined (Lejoly-Gabriel 1978). We used the arithmetic method to define the SDP, which corresponds to the day when the daily pollen concentration first reaches 1% of the annual sum, the accumulated concentration up to this day being at least 5% of the same annual sum. This procedure has the advantage of eliminating the long tails of very low values at the start of the season, which may not accord with local phenology and may introduce an error in the statistical analysis. In order to predict when the first grass pollen will appear in the atmosphere, three methods were established that used the meteorological and palynological data: summing the temperatures, summing the Q_{10} and a multiple regression using temperature extremes and rainfall.

1. The method of summing the temperatures consists of cumulatively summing the daily average temperatures from a statistically determined date, above a thermal threshold and until the SDP previously calculated. Several dates were tested in order to determine the best one for starting the sum of temperatures calculation. These dates ranged from 30 January to 10 May, in steps of 10 days. Different thermal thresholds, above which the daily temperature is effective, were also tested, from 0 to 9°C, in steps of 1°C. For each location, the result was 100 date/threshold combinations. For each combination, we calculated the mean μ and the standard deviation σ of the sum of the temperatures, for all the years. The best starting date and the more appropriate threshold were those that minimized the ratio σ/μ , which corresponds to the coefficient of variation.
2. The second method is based summing Q_{10} , which is an agrometeorological coefficient. It corresponds to the ratio between the growth rate of a plant at a particular temperature (T , °C), and that which would be observed at temperature $T+10$. This second method allows the growth and development of a plant to be adjusted to an exponential temperature law rather than a linear one. For perennial grasses, the onset of the reproduction process is conditioned by short days and low temperatures; the formation of the flower organs then depends on longer photoperiods (Niqueux and Arnaud 1967). In any one place, the photoperiod evolution is the same from one year to another. Between the two most distant towns in our study, Mâcon in the South and Montbard in the North, there is only 1°19' difference in latitude, which is not enough to cause significant differences in photoperiod. Cooper's work (1952, quoted by Niqueux and Arnaud 1967) showed that the beginning of flower initiation of English rye grass has an average interval of 1 day for 2 degrees of latitude. Now there is hardly more than 1° of difference between the latitudes of our most distant sites, so only the temperature variability can induce an earlier or later blossoming. From the end of dormancy to spike appearance, perennial grasses are mostly subject to quite low temperatures. In such a context, the growth, even if slow, depends primarily on the transformation of reserve substances; this transformation, and hence the growth, must follow the exponential relationship $Q_{10}^{(T/10)}$ (Niqueux and Arnaud 1981). In the case of perennial and early plants such as birch, Q_{10} enables the calcu-

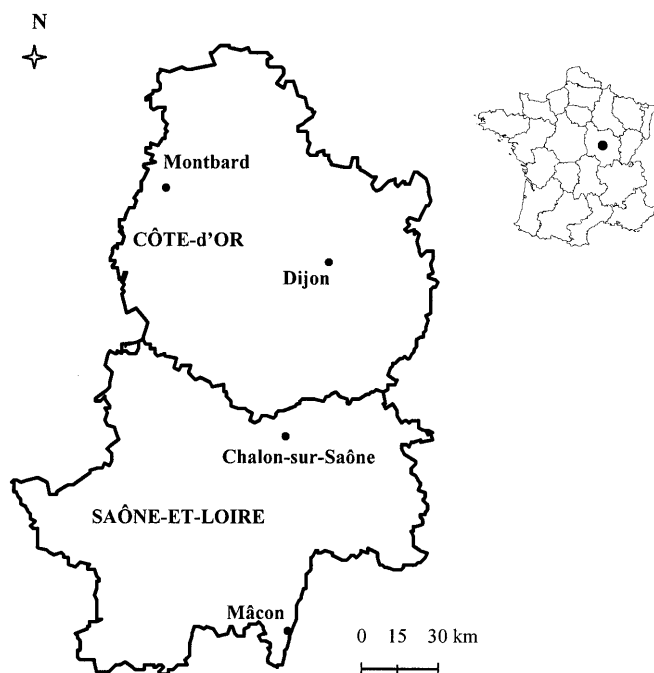


Fig. 1 Location map of the four Burgundian pollen traps

lation of a “sum of cold” necessary to end dormancy, and then a “sum of heat” leading to pollination. In that it is not possible, in pollen analysis, to distinguish between perennial and annual grasses, the latter not being affected by dormancy, the sums of cold cannot be used. We therefore tried to establish, for the whole *Poaceae* family and for each site, the values of Q_{10} , the necessary sums of $Q_{10}^{(7/10)}$ and the starting dates required for the calculation of these sums. The temperature used is a daily average and the sums are stopped when the calculated SDP is reached. The starting dates of the sums were tested every 10 days from 1 November to 30 April. Q_{10} values from 1 to 6 were tested by steps of 1 and then, more precisely, by steps of 0.1. For all the date/ Q_{10} combinations, the mean μ , the standard deviation σ and the variation coefficient σ/μ were calculated, as explained for the method of summing temperatures. The combination chosen is the one that minimizes the coefficient of variation.

3. The last method is multiple regression, which tries to predict the SDP from 10-day meteorological data. The regression performed is a forward stepwise regression, using SigmaStat software. After an analysis of variance, the most informative variable is entered into the model. The second variable entered is the one that significantly adds to the ability of the equation to predict the SDP. Other variables are then entered, and the model stops when no further independent variable adds any information to the equation. The multiple regression analysis was performed for the years 1995–1998, using rainfall and 10-day minimum and maximum temperatures for 10-day intervals from 1–10 January to 21–30 April, denoted 1 to 12, as independent variables influencing the SDP. Because of the small size of the samples in each site (3 or 4 years of pollen counts), it was necessary to consider the 13 observations as 13 independent sets of data, and hence to establish only one regression equation for all the towns. Sunshine duration, solar radiation and temperatures 10 cm and 20 cm under ground could not be kept as descriptive variables, because data were available for only two sites, Dijon and Mâcon. The regression method needs some correlations between variables to be calculated and Spearman’s rank-correlation coefficient was used, because data were not normally distributed. The three methods were adjusted for the available years, and the SDP was readily calculated. We then compared the predicted and observed SDP (that is the SDP calculated by the method of Lejoly-Gabriel) in order to choose the best method. This method can of course be used in future for predicting the SDP before the pollen season starts. In order to compare the three methods of forecasting the SDP, a χ^2 -test was performed (khi-2 of Bravais-Pearson). This allows the difference between the observed SDP and the predicted or theoretical SDP to be characterized for each value of the distribution.

Results

Determination of SDP for the years available

The SDP was calculated by the above-mentioned method (Lejoly-Gabriel 1978) for 1995 or 1996 (depending on the sites) to 1998, and the results are given in Table 1. It can be noticed that the spatial variability of the SDP for a given year is around 17–18 days, while the temporal variability for a given location ranges from 1 to 16 days. This interannual variability would probably be more important if we had longer data series. In fact a recent study carried out in the United Kingdom over about 30 years revealed an interannual variability of 25 days in the city of Derby, 37 days in Cardiff and 39 days in London (Emberlin et al. 1999). Grasses from our southernmost department (Saône-et-Loire) usually pollinate as

Table 1 Starting dates of the grass pollen season in Burgundy. Day and month are indicated by numbers in bold. The rank of the days is indicated in normal-type numbers. μ is the mean of the ranks and σ the standard deviation of these ranks

Location	1995	1996	1997	1998	μ	σ
Montbard		30/05 151	28/05 148	28/05 148	149.00	1.73
Dijon		29/05 150	17/05 137	15/05 135	140.67	8.14
Chalon/S.	09/05 129	24/05 145	11/05 131	12/05 132	134.25	7.27
Mâcon		12/05 133	11/05 131	11/05 131	131.67	1.15

early as the first 2 weeks of May (respectively 12 and 14 May, on average, for Mâcon and Chalon-sur-Saône), while those from the northernmost department (Côte-d’Or) begin their pollination later, during the last 2 weeks of May (respectively 21 and 29 May for Dijon and Montbard).

Forecasting the SDP by the sum of temperatures

The SDP was forecast by the method previously described, which minimizes the variation coefficient σ/μ . An example of the calculation of σ/μ is given in Table 2 for the location of Dijon. The results for all the cities are given in Table 3. The parameters determined for each site allow retroactive forecasts of SDP from available years to be carried out and the error estimated comparison with the observed SDP (Table 4). For all the years and sites, the average error, μ , did not exceed 0.31 day, the standard deviation of this error σ reaching 1.55 days. The method gives quite good results, with a maximum error of 4 days in Dijon.

Forecasting the SDP by summing Q_{10}

Results are given in Table 5. One can observe that the parameters differ greatly from one city to another, the dates as well as the Q_{10} values or their sum. After being determined, the parameters that emerged from the preceding analysis were tested for the years available and the results are presented in Table 6. For all the locations and years, the error mean μ is null while σ reaches 2.27 days. The Q_{10} values ranged from 1.2 to 1.6, except for Dijon where the value obtained seemed a little too high to characterize a biological phenomenon. The results are generally satisfactory, except for Chalon-sur-Saône where the maximum error reached 6 days. For this town, the summing begins very early, on 1 November, maybe because perennial grasses are more abundant, and Bidabe (1967) has shown that Q_{10} does not give better results than the sum of temperatures for very early varieties, unlike semi-early or late ones.

Table 2 The method of summing temperatures: example of calculations of the different parameters needed to predict the starting date of the pollen season (SDP) in Dijon (only three starting dates are represented)

Years	Sum of temperatures (°C) above a threshold of:									
	0°C	1°C	2°C	3°C	4°C	5°C	6°C	7°C	8°C	9°C
Starting date: 9 February										
1996	920.55	918.75	912.55	897.75	862.30	830.40	796.10	762.75	733.05	681.75
1997	978.40	978.40	978.40	975.75	972.55	967.95	934.65	881.35	776.65	673.45
1998	874.80	874.80	874.80	864.10	849.70	817.95	784.60	699.05	645.65	542.45
σ	51.92	52.00	52.43	57.27	67.58	83.24	83.51	92.52	66.71	78.14
μ	924.58	923.98	921.92	912.53	894.85	872.10	838.45	781.05	718.45	632.55
σ/μ	0.0562	0.0563	0.0569	0.0628	0.0755	0.954	0.996	0.1185	0.0929	0.1235
Starting date: 19 February										
1996	891.85	890.05	885.05	877.30	848.45	825.30	796.10	762.75	733.05	681.75
1997	915.20	915.20	915.20	915.20	915.20	915.20	893.50	840.20	758.40	663.70
1998	820.00	820.00	820.00	811.70	800.50	773.15	745.40	673.60	628.15	542.45
σ	49.62	49.33	48.65	52.36	57.61	71.86	75.27	83.37	69.06	75.75
μ	875.68	875.08	873.42	868.07	854.72	837.88	811.67	758.85	706.53	629.30
σ/μ	0.0567	0.0564	0.0557	0.0603	0.0674	0.0858	0.0927	0.1099	0.0977	0.1204
Starting date: 29 February (leap year) or 1 March										
1996	858.55	857.10	852.10	844.35	818.55	795.40	772.15	738.80	724.25	681.75
1997	827.70	827.70	827.70	827.70	827.70	827.70	816.90	763.60	697.15	611.30
1998	745.40	745.40	745.40	737.10	725.90	698.55	676.10	630.85	592.60	524.05
σ	58.49	57.90	55.91	57.72	56.32	67.21	71.94	70.58	69.52	79.00
μ	810.55	810.07	808.40	803.05	790.72	773.88	755.05	711.08	671.33	605.70
σ/μ	0.0722	0.0715	0.0692	0.0719	0.0712	0.0868	0.0953	0.0993	0.1036	0.1304

Table 3 Parameters chosen to predict the starting date of the pollination of grasses by the sum of temperatures

Location	Starting date of the sum	Threshold (°C)	Necessary sum of temperatures (°C)
Montbard	11/03	7	723
Dijon	19/02	2	873
Chalon/S.	30/01	2	830
Mâcon	31/03	4	482

Forecasting the SDP by regression analysis

Before running the regression analysis, we first made correlations between the observed SDP and meteorological factors. The only parameters correlated with the SDP were the maximum temperature for 1–10 April (Spearman's correlation coefficient $\rho = -0.606$; $P = 0.027$) and the rainfall for 21–30 April ($\rho = -0.589$; $P = 0.033$). These two variables were therefore used to establish the multiple regression equation. In addition, it was necessary to “force” the model because the correlation coefficients between these variables and the SDP were low. Therefore the equation must be used with the utmost caution because its power only reaches 0.684, which is under the minimum recommended power of 0.8:

$$Y = 163.992 - 1.293T_{\max,10} - 0.164P_{\text{mm},12}$$

with $T_{\max,10}$ = maximum temperature of the 10th decade (1–10 April) and $P_{\text{mm},12}$ = precipitation of the 12th decade (21–30 April). Our equation was tested on the years

Table 4 SDP calculated for grasses by summing temperatures. Values in parentheses are the error (in days) in the predicted SDP. μ is the average error and σ the standard deviation. For all the years and sites, $\mu = 0.31$ and $\sigma = 1.55$

Location	Predicted SDP					
	1995	1996	1997	1998	μ	σ
Montbard		30/05 (0)	29/05 (+1)	28/05 (0)	0.11	0.58
Dijon		29/05 (0)	15/05 (-2)	19/05 (+4)	0.22	3.06
Chalon/S.	09/05 (0)	24/05 (0)	09/05 (-2)	14/05 (+2)	0.00	1.63
Mâcon		13/05 (+1)	11/05 (0)	11/05 (0)	0.11	0.58

Table 5 Parameters chosen to determine the SDP from the Q_{10} value

Location	Starting date of the sum	Q_{10}	Necessary sum of Q_{10}
Montbard	11 March	1.6	132
Dijon	31 December	5.3	663
Chalon/S.	1 November	1.4	243
Mâcon	31 December	1.2	152

available for each site. Table 7 presents the results obtained and the difference between the real and predicted SDP (numbers in parentheses). For all the locations and years, the average error μ is much less than 1 day

Table 6 SDP calculated for grasses by the Q_{10} method. SDP. Values in parentheses are the error (in days) in the predicted SDP. μ is the average error and σ the standard deviation. For all the years and sites, $\mu = 0$ and $\sigma = 2.27$

Location	Predicted SDP				μ	σ
	1995	1996	1997	1998		
Montbard		30/05 (0)	28/05 (0)	28/05 (0)	0	0
Dijon		29/05 (0)	17/05 (0)	15/05 (0)	0	0
Chalon/S.	09/05 (0)	18/05 (-6)	16/05 (+5)	13/05 (+1)	0	4.55
Mâcon		12/05 (0)	11/05 (0)	11/05 (0)	0	0

Table 7 SDP for grasses calculated by multiple regression. The predicted SDP are shown as the rank of the day. Values in parentheses are the error (in days) in the predicted SDP. μ is the average error and σ the standard deviation. For all the years and sites, $\mu = 0.08$ and $\sigma = 6.42$

Location	Predicted SDP				μ	σ
	1995	1996	1997	1998		
Montbard		148 (-3)	136 (-12)	137 (-11)	-8.67	4.93
Dijon		146 (-3)	138 (+1)	135 (0)	-0.67	2.08
Chalon/S.	130 (+1)	145 (0)	131 (0)	137 (+5)	1.50	2.38
Mâcon		143 (+10)	137 (+6)	138 (+7)	7.67	2.08

($\mu=0.08$ day) and its standard deviation reaches 6.42 days. The maximum observed error is 12 days in advance, which is really quite high. We then worked on monthly values to see if this error could be reduced. The variables were then precipitation and maximum and minimum temperatures from October to April. Data from October to December were introduced to determine whether the meteorological conditions of the preceding autumn could influence grass pollination. But there was no correlation between these variables and the SDP. The 3-monthly meteorological parameters (October–November–December and January–February–March) did not give better results.

Discussion and conclusion

The SDP calculated by the method of Lejoly-Gabriel

The SDP calculated by the Lejoly-Gabriel method shows that this date is earlier in the south than in the north of the region. This could be due to the migration of the thermal equator, which, in spring, moves from south to

north at a mean speed of 3.5 days/degree of latitude (Guérin 1993). However, in this case, referring to the average SDP determined in Table 1, an SDP occurring in Mâcon on 12 May would give an SDP on 15 May in Dijon (0°98' difference in latitude) and on 16 May in Montbard (1°19' difference). In fact, these SDP occur later (respectively 21 and 29 May), suggesting that other parameters must be involved. As far as the altitude is concerned, there is not a big difference between the four stations: 216 m in Mâcon, 189 m in Chalon-sur-Saône, 222 m in Dijon and 298 m in Montbard. Meteorological parameters probably play a large part, such as the high frequency of fog and temperature inversions in Dijon, or particularly low temperatures occurring in one site for a given year. It should also be noted that grasses are represented by a lot of species pollinating at different dates, which can partly explain such differences.

The method of summing temperatures

Once more the errors, which are very low, are probably due to the fact that grasses are a family composed of a great diversity of species, either annual or perennial, each of them having a specific phenology. In the future, so as to inform physicians and allergists a few days before the arrival of the first grains, the method will have to use the observed temperatures and then, when approaching the necessary sum, the predicted temperatures, which are given by Météo-France at present 5 and soon 7 days in advance.

The method of summing Q_{10}

The differences observed when the different parameters are determined (the starting date of the summation, the Q_{10} and the sum itself) can be partly linked to climatic conditions; indeed, the starting date of the summation is earlier in Mâcon (31 December), located in the South of Burgundy, than in Montbard (11 March) located in the North. The much milder winter in Mâcon can enable perennial grasses to begin their growth from the “bad” season onwards, which could explain the earlier starting date of the summation. Nevertheless the starting date is the same in Dijon and Mâcon, and 2 months earlier in Chalon-sur-Saône, and this cannot be due to the climatic context, but probably rather to a geographically different distribution of the main grass species, wild as well as cultivated (Laaidi 1999). Another hypothesis can be suggested in the case of Montbard: the very late starting date of the summation could be linked to the predominance of annual species, which appear later. It should be noted in passing that all these assumptions must not conceal the fact that the observed differences probably have no other explanation than sampling fluctuations. In fact, Larsson et al. (1983) studied the correlations between the records obtained by two Hirst traps placed in the same site, and then between two traps located in different

towns. They concluded that the differences observed between the two adjacent traps are explained by the trap itself and randomness, while the differences between the two separate sites do depend on the trap and randomness, but also on the surrounding vegetation, the climatic context and the site. For the summing of temperatures as well as the Q_{10} method, we did not look for parameters (starting date, threshold, Q_{10}) that could be the same for all the stations. In fact, this research has been done for another taxa (*Betula*) for the same years and sites, and the results proved to be less accurate when the same parameters were used for all the stations (errors of up to 7 days for the sum of the temperatures) than when different parameters were used for each station (errors of up to 2 days). It is therefore preferable to use different parameters for each site, each of them having its own climatic context (Laaidi 1999). This shows the importance of having a dense network of traps in order to obtain more accurate forecasts.

Multiple regression

The coefficients of the equation variables are both negative, so the SDP even earlier, since the maximum temperature of the first 10-day period of April and the rainfall of the last 10-day period of this month are high. Heat and enough rainfall to satisfy the water requirements during the month before pollination allow a plant to complete its development, and in particular its pollen production, and so pollinate earlier. Even if temperature is an essential factor of flower development, the factor that is frequently used in forecasts, other meteorological parameters should not be neglected, such as rainfall in this case. Studying conditions in Melbourne, Ong et al. (1997) only used precipitation before pollination for its prediction; they used the rainfall sum of July to develop a regression equation that predicted the beginning of grass pollination (which takes place between 20 October and 24 November) with a satisfactory precision of 76%.

A comparison of the three methods

In order to compare the different methods used to forecast the SDP for grasses, we performed χ^2 -tests to measure the difference between the observed distribution and the theoretical ones (Table 8). The method using the sum of the temperatures and that using the sum of Q_{10} are reliable at 99%, the first with a χ^2 of 0.22 and the second with a χ^2 of 0.45. The Q_{10} method seems to give perfect results in three towns (no difference between forecast and reality), but the results for Chalon-sur-Saône are a little less good (a maximum difference of 6 days). For the method of summing temperatures, the maximum difference reaches 4 days in Dijon, and 0–2 days in the other cities. Such differences are satisfactory for a pollination period of 2–3 months on average. The multiple regression gives 97% reliable results, with a χ^2 of 3.63.

Table 8 Determination of χ^2 for the different methods of forecasting the SDP for *Poaceae*

Location and year	SDP (rank of the days) predicted by different methods			
	Observed SDP	Sum of temperatures	Q_{10}	Regression
Montbard 1996	151	151	151	148
Montbard 1997	148	149	148	136
Montbard 1998	148	148	148	137
Dijon 1996	150	150	150	146
Dijon 1997	137	135	137	138
Dijon 1998	135	139	135	135
Chalon/S. 1995	129	129	129	130
Chalon/S. 1996	145	145	139	145
Chalon/S. 1997	131	129	136	131
Chalon/S. 1998	132	134	133	137
Mâcon 1996	133	134	133	143
Mâcon 1997	131	131	131	137
Mâcon 1998	131	131	131	138
Calculated χ^2		0.22	0.45	3.63
P		0.99	0.99	0.975

But this apparently very good result must be qualified because the differences between the calculated and observed SDP can reach 12 days in Montbard and 10 in Mâcon. This method should therefore be used very cautiously. As it allows forecasts to be made at least 10 days in advance, it would be interesting to bring it up to date in the future, using data from more years. At present it can only be used in Dijon and Chalon-sur-Saône, where the maximum errors do not exceed, respectively, 3 and 5 days. Nevertheless, such errors are not negligible, so the method will always have to be supported (according to the city) by Q_{10} or sum of temperature calculation to achieve more precision.

The Q_{10} method will therefore have to be used preferably in Montbard, Dijon and Mâcon, while the method of summing temperatures will be better suited in Chalon-sur-Saône. Both methods can make forecasts 5 days in advance if predicted temperatures are used instead of the observed ones when approaching the necessary sum. These methods were applied in 1999 on the basis of only two traps (Dijon and Chalon-sur-Saône), because the other two were not viable for financial reasons. This forecast was then compared with the real SDP, which occurred on 24 May in Dijon and on 10 May in Chalon-sur-Saône.

1. With the method of summing temperatures, the difference between the real and predicted SDP was 6 days in Dijon and 2 days in Chalon-sur-Saône. This corresponds quite well to the results of the preceding years, where this method was more accurate in Chalon-sur-Saône.
2. With the method of summing Q_{10} , differences were higher and reached 6 days (in advance or late) in both sites.
3. With the multiple regression method, the error was reasonable in Dijon where the difference between the observed and predicted SDP did not exceed 5 days. This difference reached 10 days in Chalon-sur-Saône.

Applying these methods for 1999 therefore led to varied results, and the method of multiple regression remains of little interest. Differences between forecast and actual results are satisfactory for the two other methods, where the χ^2 -test indicated great reliability (99%) on the basis of the preceding years. These methods will have to be tested again over more years, in order to improve statistical validity, but they can be implemented already, and are very useful for allergists. They should also be used in other French or European sites, and so be adapted to local phytoclimatic conditions. Their values for preventing pollinosis fully vindicates the continuation of such research.

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