
Ragweed in France: an invasive plant and its allergenic pollen

Mohamed Laaidi, PhD*; Karine Laaidi, PhD*; Jean-Pierre Besancenot, PhD*; and Michel Thibaudon, PhD†

Background: Ragweed is an annual, herbaceous, wind-pollinated plant that is responsible for strong allergies. In France, it is mainly present in the region of Lyon, where it threatens the health of the population.

Objective: To analyze annual, daily, and bihourly pollen concentrations in the air to determine the characteristics of ragweed pollination and in particular its diurnal rhythm.

Methods: Ragweed pollens were sampled from 1987 to 2001 by a Hirst volumetric trap calibrated to handle a flow of 10 L/min of air, which roughly corresponds to a human breathing rhythm. Pollen counts were performed on a daily and bihourly basis, which is of particular importance in allergologic practice.

Results: Ragweed pollination occurs from the beginning of August to the end of September. Annual and daily levels of pollen have increased significantly since 1987. The pronounced diurnal periodicity shows a peak from 9 to 11 AM. Pollen counts increased from the early morning with temperature increase and relative humidity decrease.

Conclusions: Daily pollen counts of this strongly allergic plant are above the allergic thresholds commonly defined, limiting the interest of eradication campaigns. Thus, prevention of ragweed allergy depends on informing and educating the public through reports and updates. Diurnal variations seem to be the most crucial part of such a report, allowing allergy patients to adapt their daily outdoor activities in respect to the pollen peaks and off-peaks.

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INTRODUCTION

The short ragweed (*Ambrosia artemisiifolia* L) is an annual herbaceous plant that belongs to the Asteraceae family. Unlike several other plants of this family, usually pollinated by insects, ragweed is wind pollinated and produces high pollen quantities (2.5 billion grains per plant per day¹). Apart from *Ambrosia maritima* L, a native of Mediterranean regions, most species of *Ambrosia* come from the United States and Canada, where they are widespread^{2,3} and where their allergenicity is now well established.^{4,5} They were introduced into France with potato plants in the 1930s, then with the American war supply in 1944, and in cereal sacks during the 1960s.^{6,7} Ragweed has invaded many countries around the world and is now considered a vegetal plague responsible for severe allergies. In Asia, ragweed grows in China⁸ and Japan.⁹ In Europe,^{10,11} the most ragweed-polluted countries are Hungary,¹² Italy,¹³ Croatia, and certain parts of France. In France, invasion especially affects the Rhône-Alpes region¹⁴ and Burgundy¹⁵ but also the surrounding areas of Clermont-Ferrand, Saint-Etienne, Grenoble, Annecy, and Montluçon.^{16,17} *Ambrosia* is also found in Bulgaria,¹⁸ Switzerland,¹⁹ the Baltic States,²⁰ and Spain²¹ and even reached Sweden in 1996.²²

Highly allergic ragweed pollen causes several troubles in humans and animals.²³ It contains numerous powerful allergens. Among these allergens, 22 are already well known and 6 are considered major.²⁴ These allergens are mostly found in entire pollen grains but also in submicronic fractions below 5 µm. Allergens are present in the air not only during the seasonal period of ragweed pollination²⁵ but also before and after pollination, when they come from various parts of the plant, especially the inflorescence.²⁶ Skin prick tests or radioallergosorbent test reactions to ragweed allergens in pollen allergic European patients,²⁷ performed in the late 1990s, gave positive results of more than 80% in Hungary, nearly 70% in northern Italy, 30% to 40% in the Rhône area (France), approximately 35% in Prague, 25% to 30% in Vienna (Austria),²⁸ and approximately 19% to 25% in Brno (Czech Republic).²⁹ In the southern part of European Russia, ragweed is considered the most important allergen, even before house dust.³⁰ *Ambrosia* pollen and allergy are also documented in Australia,³¹ and *Ambrosia* is the second most important pollen allergen in Japan.³²

Because of the strong allergenicity and the increase in *Ambrosia* in Europe and especially in France, we chose to study its pollen to provide allergists and allergy patients with pertinent information about its pollination. Such information is in great demand, even from the authorities, and will soon lead to the creation of a ragweed watchdog in Lyon. The objective of this article is to analyze annual, daily, and bihourly pollen concentrations in the air. This approach allows the determination of the characteristics of ragweed pollination and in particular its diurnal cycle, which is im-

* Climat et Santé, Centre d'Épidémiologie de Populations, Faculté de Médecine, Dijon Cedex, France.

† Réseau National de Surveillance Aérobiologique, Chemin des Gardes, Saint Laurent de Chamousset, France.

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portant for allergy patients. To our knowledge, analyses, performed throughout many years, using a volumetric trap that provides data at short intervals, have never been undertaken in the main French region affected by ragweed allergy. The pollen trap is situated in an urban area, so pollen levels are those sampled in the city center, where most patients live.

MATERIALS AND METHODS

Airborne pollen was sampled with a volumetric Hirst trap,³³ which is now, in Europe, the most commonly used aerobiologic measurement instrument. The sampler, which belongs to the French aerobiological network (Réseau National de Surveillance Aérobiologique), was set up in the city of Lyon (France) on the roof of a building at a height of 28 m on the east side of the Rhône River in the south of the city³⁴ (Fig 1). Monitoring has been performed continuously since 1987. The sampler was calibrated to handle a flow of 10 L of air per minute, which roughly corresponds to a human breathing rhythm. It was permanently oriented in the direction of the wind and would be representative within a 30-km radius.³⁵ Sucked-in pollen grains were impacted on a cylindrical drum covered with a plastic film coated with a uniform layer of a sticky substance and rotated by a 7-day mechanism at a speed of 2 mm/h.³⁶ Every week the strip was removed and examined by light microscopy ($\times 40$) according to the 12 transverse transects method³⁷ so that results could be obtained

every 2 hours. The transverses were 4 mm apart, which corresponded to an analysis of 15 minutes every 2 hours. The bihourly counts were summed every day and then a corrective factor of 0.6 was applied to convert the daily values into grains per cubic meter of air (grains/m³).³⁸ The corrective factor depends on the whole surface area of the strip, the analyzed surface area, and the sucked air volume per day. Each year, the daily concentrations were summed from the beginning of August to the end of September to estimate the annual pollen levels. Daily concentrations were also averaged throughout the 15-year series to show the day-to-day evolution of concentrations. Regarding the diurnal rhythm of ragweed, it was established using the 2-hour pollen counts averaged throughout the 15-year series and transformed into a percentage of the daily amounts.

Pollen data used in this study cover the period from 1987 to 2001. Meteorologic data, for this same period, were provided by the National Meteorological Office (Météo-France) and included temperature, relative humidity, and wind speed measured every 3 hours, which is the lowest interval commonly used in France.

Spearman correlation coefficients (r) were calculated between pollen counts and the corresponding sequence of years to express the trend in ragweed pollen abundance. The P value retained as the risk threshold was 0.05.

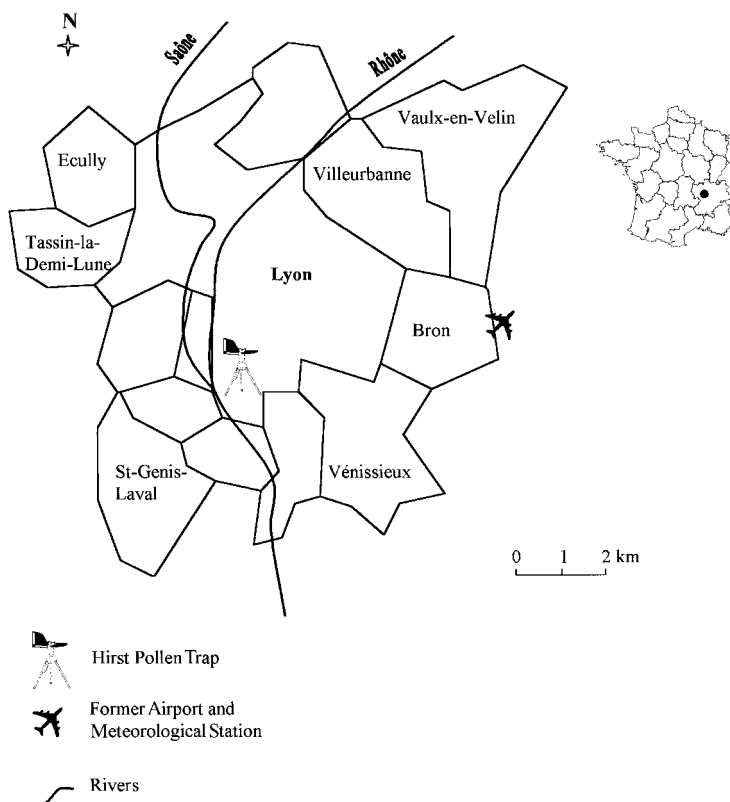


Figure 1. Geographical situation of the pollen sampling location of Lyon, France.

RESULTS

Annual Pollen Levels

Annual pollen levels since 1987 (Fig 2) showed a well-marked rising trend: they increased from 203 grains/m³ in 1987 to 2,176 grains/m³ in 1999, with a maximum of 2,574 grains/m³ in 1997. Pollen levels decreased sharply in 2000, reaching a total of only 728 grains/m³ and then increased again in 2001, reaching 1,561 grains/m³. Daily maxima (Fig 2) followed the same trend. Between 1987 and 1993 they ranged from 19 to 126 grains/m³, whereas between 1994 and 2001 they reached higher values ranging from 143 to 403 grains/m³. In both cases, the trend toward higher ragweed pollen counts is significant for this period ($r = 0.764$, $P < 0.001$ for annual levels; $r = 0.739$, $P = 0.001$ for daily maxima), annual and daily values also being correlated ($r = 0.864$, $P < 0.001$).

Daily Pollen Counts

Daily average of pollen concentrations from 1987 to 2001 (Fig 3) showed that ragweed pollination took place from the beginning of August to the end of September, with a maximum between mid-August and mid-September. Another Asteraceae, mugwort (*Artemisia*), pollinates twice before and after this period, *Artemisia vulgaris* L from the end of July to mid-August and *Artemisia annua* L in the last 2 weeks of September. These 2 species prolong and/or reinforce the allergic-risk period because 65% of the patients allergic to ragweed are also allergic to mugwort.⁶

Bihourly Pollen Counts

The diurnal rhythm of ragweed pollen counts (Fig 4A) in the city of Lyon varied little from one year to the next. The hours accounting for more than 10% of the total pollen collected during the 24-hour period ranged on average from 9 AM to 3 PM. However, the peak, which recorded 21% of the pollen

counts on average from 1987 to 2001, occurred precisely between 9 and 11 AM. However, pollen counts were low in the evening and during the night. Concerning mugwort, whose pollination surrounded that of ragweed, pollen grains were collected during the same hours (ie, between 9 AM and 3 PM), with a peak recorded a little later than that of ragweed during the day (ie, between 11 AM and 1 PM).

Bihourly pollen data were compared with the 3-hourly meteorologic data. The ragweed pollen off-peak, most marked between 9 PM and 5 AM, corresponded to a relative humidity ranging from 71% to 85%, a temperature of 15.4° C to 18.8° C, and a wind speed of 1.4 to 1.6 m/s (Fig 4A, B). As soon as temperature and wind speed rose and relative humidity decreased, pollen counts increased. The pollen peak, from 9 to 11 AM, coincided with an average relative humidity of 58% to 67%, a temperature of 19.8° C to 22° C, and a wind speed of 2.2 to 3.2 m/s.

DISCUSSION

Ragweed pollen counts collected by the Lyon trap have shown a clearly increasing trend since 1987. This evolution has resulted from plant proliferation in the region, originally on the bare soils of wastelands or building sites but also more recently in crops such as maize, sunflower, or even wheat. The year 2000 was an exception in that there was a noticeable decrease in pollen levels. This could be in part a result of the eradication campaign conducted by the French Ragweed Study Association but mostly due to the unfavorable meteorologic conditions. Abundant precipitations during August (25% above the normal) prevented anthers from opening and led to the washout of pollens soon shed. However, the low levels recorded from 1987 to 1990 cannot be explained by such meteorologic conditions, since during these years August and September rainfall was 12% to 73% below normal.

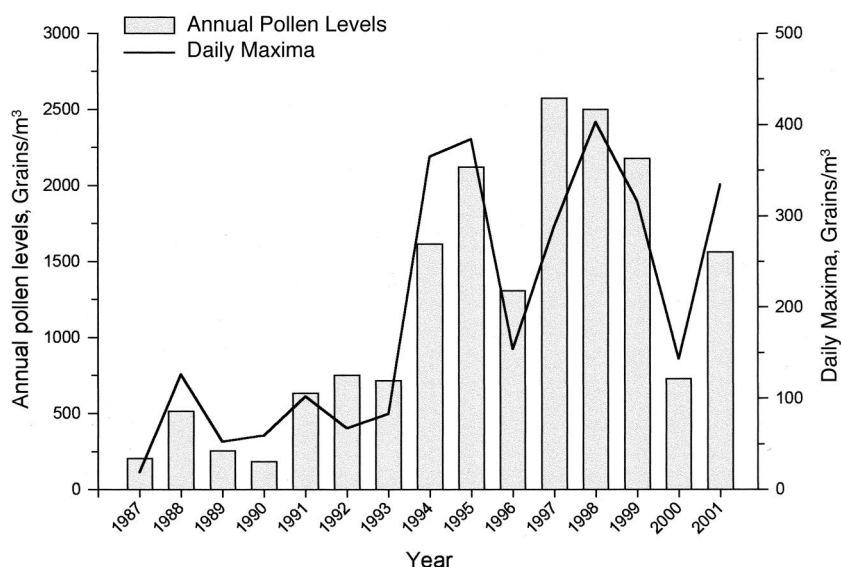


Figure 2. Annual *Ambrosia* pollen counts from 1987 to 2001 in Lyon, France.

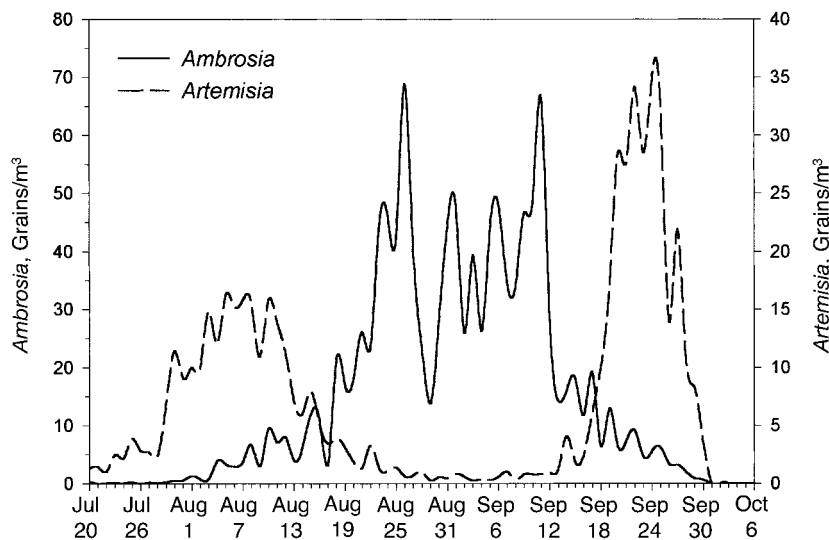


Figure 3. Daily average (1985–2001) pollen counts of *Ambrosia* and *Artemisia*.

Even though meteorologic conditions can influence pollen levels in a particular year, the general increasing trend has another origin. In 1992, the European Common Agricultural Policy (ECAP) reform required farmers to leave part of their fields lying fallow, and the area of fallow land particularly increased in 1994. In 1994, *Ambrosia* pollen levels increased considerably. This was not the case for *Artemisia* pollen levels, for which the peak year was 1992, even though, like ragweed, the overall trend is upward. *Ambrosia* and *Artemisia* have close ecologic preferences. Both grow on disturbed lands, with a predilection for nitrogenous soils, but one species of *Artemisia* is native (*A. vulgaris* L), whereas the other (*A. annua* L) was introduced at the same time as *Ambrosia*. The ECAP also favored the development of sunflower crops, where ragweed grows well. Since the 2 species belong to the same Asteraceae family, it became difficult to treat with herbicides, which would have killed not only the ragweed plants but also the sunflowers. So it seems that the increase in the area of fallow lands and sunflower crops enhanced ragweed proliferation, which also found favorable lands around Lyon on the bare soils of wastelands or building sites and along railroads and roadsides. In Canada where *Ambrosia* is native, fossil pollen grains have been found in sediments older than 60,000 years. Larger quantities have been found in late glacial deposits, and this is due to open barren land suitable to the plant development. It is only within the last 200 years that ragweed pollen has again become abundant. This increase has coincided with recent settlement by western Europeans, the removal of trees in favor of intense agricultural development, and thus the increased disturbance of natural habitats.² Similar human factors also seem to have influenced the development of *Ambrosia* in France. It has also been suggested that global warming has had an influence on the increase in ragweed pollen production,³⁹ but this hypothesis will have to be evaluated in another study and probably for a period longer than 15 years.

In parallel with the annual trend, the data also revealed an increasing trend in daily pollen maxima, with values ranging from 143 to 403 grains/m³ during the most recent years (1994 to 2001). These values are far above the clinical thresholds determined by the epidemiologic studies that state that the most sensitive patients begin to develop allergy symptoms⁴⁰ between 1 and 3 grains/m³, whereas between 10 and 50 grains/m³ almost all patients with a ragweed allergic rhinitis were symptomatic.⁴¹

Regarding bihourly concentrations, the peak was recorded between 9 and 11 AM. Because our trap was set up in an urban zone, there could be an interval between the recorded peak and the shedding peak near the pollen sources. The study of Bianchi et al⁴² on the diurnal pattern of *Ambrosia* pollination in fields revealed that extension and opening of the anthers occur between 6:30 and 8 AM, which correlates with rise in temperature and reduction of relative humidity. Then pollen grains are ejected and many of them adhere to adjacent vegetation, from which they could be blown by the wind after drying. Thus, pollen emission from *Ambrosia* occurs in 2 stages: the release from anthers governed by temperature and relative humidity and the transfer of the pollen from plant surfaces to the atmosphere governed by wind speed and turbulence. Actually, measurements made by various authors^{43,44} indicate a diurnal rhythm consisting of a significant emission near sunrise, a peak a few hours later, a gradual decline during the afternoon hours, and minor amounts during the night: this model is close to ours. In a similar way, Barnes et al⁴⁵ showed that the lowest pollen counts occurred at 6 AM, with peak pollen exposure occurring at noon for both urban and suburban locations. After sunrise, when *Ambrosia* pollen is released, solar energy increases air temperature and air movement and decreases relative humidity; the atmosphere becomes unstable and turbulent, so that pollen grains are rapidly dislodged and wafted away from plant surfaces. For other plants, such as *Ailanthus*, *Cicca*, or *Embllica*, the

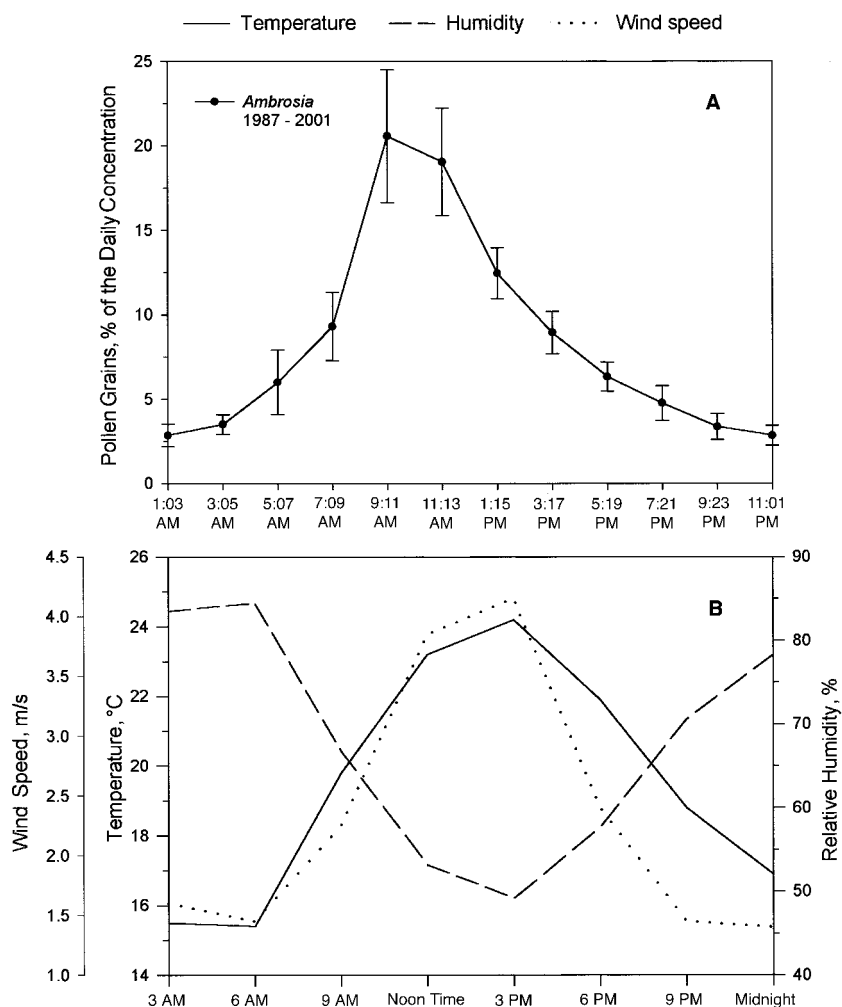


Figure 4. Bihourly *Ambrosia* pollen counts and meteorological conditions. A, Diurnal pollination rhythm (average 1987 to 2001) of *Ambrosia* in Lyon, France. B, Diurnal evolution of temperature, wind speed, and relative humidity (average 1987 to 2001).

pollen release takes place during the evening or the night when turbulence is low, so there is a wide gap between pollen release and the pollen peak in the air, air movement being required to disperse the discharged pollen.⁴⁶ For *Ambrosia*, pollen release takes place in the morning, just before moderate turbulence and wind begin, so the lag between pollen release and pollen peak is shorter. Then pollen dispersal throughout the day greatly depends on air movement, which varies according to variations in air temperature.

Even though the rhythm of ragweed pollination is well marked, it is not the case for other taxa. A French study⁴⁷ revealed a clear chronobiologic component for *Alnus*, *Corylus*, *Carpinus*, *Platanus*, *Urticaceae*, *Rumex*, *Plantago*, *Artemisia*, *Cupressaceae-Taxaceae*, and *Poaceae*, whereas *Populus*, *Fraxinus*, *Betula*, *Quercus*, or *Castanea* pollinated randomly throughout the day. In Spain, *Olea europea* L.^{48–50} and *Cupressaceae*^{48,51} were also found to have a well marked diurnal periodicity. The diurnal pollination pattern thus depends not only on the endogenous rhythm of the plant but also on the meteorologic conditions prevailing during anthesis and pollen

shedding. Our study revealed that increase in temperature and wind speed with a concurrent decrease in relative humidity correspond to an increase in pollen counts during the morning. However, the temperature and wind speed peak and the humidity off-peak were a little later (3 PM) than the pollen peak (9 to 11 AM), whereas in other species they coincide exactly. For hazel⁴⁷ the pollen peak ranged from 1 to 3 PM when temperature is the highest (10° C) and relative humidity the lowest (below 60%); this tree pollinates in winter, when temperature is usually low, whereas ragweed pollinates in August and September under milder conditions. Furthermore, the influence of relative humidity on pollination during the day was observed for *Olea*.⁴⁹ Regarding wind speed, pollen levels were low in the early morning when the wind was less than 2 m/s, which is the meteorologic threshold for calm wind, and they were at their highest when the wind was between 2.2 and 3.2 m/s, since such values are high enough to carry the pollen away from plant surfaces to the atmosphere. However, a stronger wind (3.8 to 4.1 m/s at noon and 3 PM) did not correspond to higher pollen levels, probably

because it contributes to the dispersion of the pollen through a deeper air layer so that the catch near the surface is reduced, as Davies and Smith⁵² showed for grasses.

CONCLUSION

As indicated by recordings made continuously for 15 years in Lyon, both seasonal concentrations and daily maximum ragweed pollen counts greatly increased. Eradication campaigns have been initiated, even though they are still limited geographically. However, ragweed clinical thresholds are low, and we think, like Banken and Comtois,⁵³ that such eradication campaigns are insufficient for preventing allergic risk. To prevent ragweed pollinosis, people must be informed and educated. The knowledge of the ragweed diurnal rhythm will allow individuals to manage their disease better each day by adapting their activities to the peak or off-peak periods: by closing the windows at home, at work, or when driving during the pollen peak and by avoiding going out if possible or at least avoiding open-air physical activities that increase the inhaled air volume, thus increasing allergen contact. This daily management of their pollinosis will allow allergy patients to alleviate their symptoms and/or to reduce their drug consumption. Knowledge of the diurnal pollination rhythm is a preventive tool that has to be accompanied by early information on the beginning of ragweed pollination. Within this framework, precise forecast models, established to predict the start, duration, and severity of the pollen season, based on meteorologic parameters, have been available since 2000.

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Requests for reprints should be addressed to:
Mohamed Laaidi, PhD
Climat et Sant  
Centre d'  pid  miologie de Populations
Facult   de M  decine
BP 87900
21079 Dijon Cedex, France
E-mail: mohamed.laaidi@u-bourgogne.fr