Aerobiological monitoring and mapping of Ambrosia plants in the province of Parma (northern Italy, southern Po valley), a useful tool for targeted preventive measures

R. Albertini¹,², M. Ugolotti³, L. Ghillani⁴, M. Adorni⁵, P. Vitali³, C. Signorelli¹,⁶, C. Pasquarella¹

Key words: Allergy, pollen, prevention, public health, ragweed

Parole chiave: Allergia, Ambrosia, polline, prevenzione, salute pubblica

Abstract

Background. Ambrosia is an annual anemophilous weed producing allergenic pollen affecting public health in European countries. In Italy, the most infested region is Lombardy where, in some areas, it is the major cause of hay fever. In the Parma district, until 2007, Ambrosia seemed to be very rare, despite an observed increase of Seasonal Pollen Index (SPI), of pollen peak value and of asthma among ragweed sensitized patients. The aims of this study were to calculate ragweed pollen season and trends from 1996 to 2015, to assess the relationships between pollen season characteristics and selected meteorological data, to map plants in the territory and to evaluate the presence of beetle Ophraella communa (Ophraella), known as an eater of Ambrosia leaves.

Methods. The following pollination parameters: start, end, duration, peak concentration date, peak values, SPI and the following climatic parameters: temperature, relative humidity, rainfall, were analyzed. The ragweed plants sites were mapped and the presence of Ophraella was assessed during naturalistic activities.

Results. Significant SPI and pollen peak value increase until 2011 were observed, but recently, 2012-2015 vs 2009-2011, a strong reduction (about 50%) of these parameters was observed. The spring average air temperature increased significantly. The results of the correlation analysis showed Ambrosia season characteristics significantly related. We identified the sites source of Ambrosia, even downtown at the confluence between Parma and Baganza rivers. Ophraella was observed for the first time in 2014.

Conclusions. The results showed the spread of ragweed plants over the territory and the risk of allergy increase that ragweed could cause. It remains to evaluate the role of the Ophraella in the reduction of Ambrosia pollen concentration. It is important to consider the potential risk Ophraella may represent for sunflower and other taxonomically related crop plants and other native and exotic species.

The lack of initiatives by the Health Authorities to prevent and to contrast the spread of Ambrosia in the Parma area could cause public health consequences and an increase in health expenditures.

¹ Department of Medicine and Surgery, University of Parma, Italy
² Medical Immunology Unit, University Hospital of Parma, Italy
³ Hygiene Unit, University Hospital of Parma, Italy
⁴ Popolar University of Parma, Italy
⁵ Freelance naturalist, Parma
⁶ School of Medicine, University Vita-Salute San Raffaele, Milan, Italy
Introduction

Ragweed is an annual invasive weed belonging to the Asteraceae family, originating from North America but later spread into Europe and Asia, causing public health related problems in many countries due to its anemophilous, very allergenic pollen (1). In Europe, its economic impact was recently estimated at several billions Euro annually, concerning effects on human and animal health, biodiversity, the environment, agriculture, horticulture, tourism, transport, building infrastructures, monitoring and control in urban areas too (1). Many European countries, characterized by continental climate, are infested by ragweed (2), which have late summer-early fall pollination. Five species of ragweed are common in Europe: *Ambrosia maritima* L. with Euri-Mediterranean native habitat, which grows in sandy soils close to the seashore causes minor allergic consequences, and *Ambrosia artemisiifolia* L., *Ambrosia tenuifolia* Sprengel, *Ambrosia coronopifolia* (*Ambrosia psilostachya*) Torr. et Gray, *Ambrosia trifida* L., originated from the American continent, locally naturalized, which grow in uncultivated fields, disused areas, railway embankments, road sides, sandy soils, and cause very important allergic consequences. In Europe foreign ragweed started expansion in the latter decades of the 19th century from Hungary (3), Austria (4), Croatia (5), some parts of France (6) and Italy (7). At present, this weed is spread mostly in Eastern Europe, in particular, in the Pannonian area and also in France, particularly in the Rhône-Alpes region, and the spreading is in progress in many countries (8, 9). The international trade and, in some case, the climatic changes are suspected to drive ragweed invasion (10). In Italy, the most infested regions by ragweed are in the Po Valley (11), especially in Lombardy, where the plant is widespread and where, in the Milano Province, 13,000 ha of crops (about 10%) were affected in 2005 (12). The species appears to be spreading toward South, with spreading rate calculated between 6 and 10 km/yr (1). Regarding the area of Parma, in our previous study (13) we found that *Ambrosia* pollen first appeared in the early ’90s, and since 1996 its presence has become regular during summer, just like the increasing trend of yearly total pollen and daily peak value. In the Parma area the plant was identified as sporadic until 2007. From 2007 up to 2011 the increasing concentrations of ragweed pollen recorded in Parma area anyway was lower than those recorded in other European and Italian areas [yearly total pollen <2,000 in Austria (4), <4,000 in Croatia (5) or <6,000 in France (14)]. Hungary showed even higher yearly total pollen, close to 20,000 (15). The ragweed pollen is transported over long distances (thousand kilometers) (16, 17) in our area too (18) and the analysis of weather charts and the calculations of back-trajectories over Parma, showed that during the peak periods the wind direction was often from North-North East, so from the most infested areas of Europe and Italy. The importance of transport of ragweed pollen over long distances has been also demonstrated in other European countries (19-21).

Aerobiological and clinical studies from various countries have documented the importance of ragweed pollen as an aeroallergen (7, 22-27). Positive results to ragweed allergens in the skin prick test (SPT) of allergic patients is more than 80% in Hungary, 30% in France, Austria and Czech Republic, 17% in Southern Switzerland (28-30). In Lombardy, in some areas, *Ambrosia* is the major cause of seasonal respiratory allergy (31). In Legnano, near Milan, the sensitization rate to ragweed of patients with pollinosis increased from 24% in 1989 to over 70% in 2008 (32). In 1989, about 45% of the ragweed sensitized patients suffered from respiratory symptoms (rhinitis, asthma). After five years, this percentage increased to
70% and finally reached 90%. In Parma we found a significant increase in the number of polysensitized patients with positive SPT to ragweed and, among these, a significant increase of asthma symptoms (33).

In Italy only the Lombardy region has been fightingAmbrosia spread for many years (34-37).

Recently, the beetleOphraella communaa(Ophraella), as Ambrosia native to North America, was accidently introduced into many countries in eastern Asia, where it is currently used as biological control agent against ragweed. At sites where the beetle was present, up to 100% of the plants were attacked with damages causing complete defoliation and death of ragweed before flowering. In 2013 this beetle was found in Europe and it is not clear the route Ophraella has followed. Where this occurred, it significantly reduced airborne pollen concentrations (38). Evidence has been provided that the presence of Ophraella may explain the lower levels ofAmbrosia pollen recorded recently in Northern Italy (39). Unfortunately, some plant tests conducted within the EU-COST action on sustainable management of Ambrosia artemisiifolia (40), including taxonomically related crop plants and other native and exotic species, concluded about a potential risk by Ophraella for sunflowers intended for oil production, as an ornament or as animal food and for closely related endangered species.

Aims of this study were to analyze the ragweed pollen distribution in the Parma area over twenty years from 1996 to 2015, to calculate the pollen seasonal parameters, the trends of selected meteorological data and the relationships between them. Correlation between pollen season parameters and selected meteorological data was calculated. In addition, the presence of ragweed plants and of Ophraella on the territory of the Province of Parma was assessed.

Materials and methods

Location of the study

The study was performed in the Province of Parma (500,000 inhabitants) which lies in the Po Valley between the right side of the Po River and the Apennines (Figure 1).

Aerobiological data

Airborne pollen was sampled using a Hirst type 7-day recording volumetric spore trap, the standard equipment used for aerobiological sampling worldwide (41), according to the methods of the Italian Aerobiology Association (AIL) (42). The pollen trap was placed at 18.2 m above ground level on the meteorological tower of the Parma University in the town center, 52 m above sea level, latitude 44°48'15” North, longitude 10°19’ East. We analysed pollen data collected over a 20-year period from 1996 to 2015. According to Jäger et al. (43), we examined pollination start, end, duration, date of peak, peak pollen value and Seasonal Pollen Index (SPI) as characteristics of the pollen season. The onset of the pollen season was defined as the first day when the cumulative pollen...
count exceeded 1% of the annual total, not followed by more than six consecutive days with zero values. The end of the season was defined as the day upon which 95% of the annual total was reached (44). The duration of the season was calculated as the difference in days between the start date and the end date of the season. Temporal variations in pollen seasons (i.e. start date, end date and date of peak) were displayed as the number of days from January 1st (Day of the Year, DOY). Pollen concentrations were expressed as the number of pollen/m³ and the SPI was expressed as grains (45).

**Botanical and entomological data**

During naturalistic activities performed from 2008 to 2015, the sites with presence of ragweed plants and *Ophraella* were mapped.

**Meteorological data**

Daily averages of temperature (°C), relative humidity (%) and total rainfall (mm), transformed into annual or seasonal averages, were taken into consideration. The meteorological data were obtained at the same site where the pollen data were recorded.

**Statistical analysis**

Statistical analysis were performed using Microsoft Excel and IBM SPSS 23 software. Kolmogorov–Smirnov and Shapiro–Wilk tests were used to assess the type of distribution of pollen parameters. The tests showed that the pollen data were not normally distributed and so Spearman’s “q” correlation tests (46) were used to establish whether any significant relationship existed between the different characteristics of the pollen season: start date/end date; start date/duration; start date/peak value; start date/SPI; start date/date of peak; end date/duration; end date/peak value; end date/SPI; end date/date of peak; duration/SPI; duration/peak value; duration/date of peak; SPI/date of peak; SPI/peak value; and peak value/date of peak. Simple linear regression analysis was carried out in order to investigate trends in certain characteristics of selected pollen seasons and meteorological data over time (47-49). The median, mean, standard deviation (SD), R² value, slope of the regression over time, standard error of the regression slope (SE), probability level (p) and number of years in the analysis (N) were calculated. Results were considered to be significant when p<0.05. To detect the presence of trend the Cox-Stuart test was applied.

**Results**

Variations over time in the *Ambrosia* season of airborne pollen characteristics recorded in Parma (between 1996 and 2015) are shown in Table 1. As median, *Ambrosia* pollen appears in the air of Parma with DOY 219 and as the pollen seasons end with DOY 262. The average duration of the pollination period was 46 days (Table 1). The pollen peak value was 36 pollen grains/m³, DOY 242. The median SPIs was 259. During the period studied, the lowest and highest amounts of variability for SPI were 6 and 793. The analysis of selected meteorological data, recorded over the same time period, showed a decrease in annual total rainfall and in annual relative humidity (Figure 2a) and a concurrent increase of annual and seasonal temperatures (Figure 2b). Only the average spring temperature increase was significant (p<0.05). We observed a significant increase of SPI and of the peak value until 2011 (peak value 128 p/m³, SPI 793 during 2010) (33), but a reduction of SPI (-52.6%) and of peak value (-58.6%) 2012-2015 vs 2009-2011 was observed. Figure 3 shows the comparison of average pollen per day and average annual peak value concentration. The SPI (Table 1) and the numbers of days with pollen concentrations over 10 pollen grains/m³ (Figure 4) over 20 years, significantly
Table 1 - Seasonal characteristics (i.e. start date, peak date and end date, duration, peak value and SPI) and trends of *Ambrosia* pollen recorded in Parma, Northern Italy, from 1996 to 2015

<table>
<thead>
<tr>
<th></th>
<th>1996 - 2015</th>
<th><strong>Ambrosia</strong></th>
<th>Median</th>
<th>Mean</th>
<th>SD</th>
<th>R²</th>
<th>Slope</th>
<th>SE</th>
<th>p</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start date (DOY)</td>
<td>219</td>
<td>214.95</td>
<td>20.49</td>
<td>0.00</td>
<td>0.08</td>
<td>0.82</td>
<td>0.92</td>
<td>20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peak date (DOY)</td>
<td>242</td>
<td>240.95</td>
<td>7.78</td>
<td>0.01</td>
<td>0.11</td>
<td>0.31</td>
<td>0.73</td>
<td>20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>End date (DOY)</td>
<td>262</td>
<td>265.65</td>
<td>14.13</td>
<td>0.07</td>
<td>-0.61</td>
<td>0.54</td>
<td>0.28</td>
<td>20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Duration (DOY)</td>
<td>46</td>
<td>50.90</td>
<td>19.40</td>
<td>0.04</td>
<td>-0.64</td>
<td>0.76</td>
<td>0.41</td>
<td>20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peak value (Pollen/m³)</td>
<td>36</td>
<td>42.20</td>
<td>30.60</td>
<td>0.16</td>
<td>2.10</td>
<td>1.11</td>
<td>0.08</td>
<td>20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPI</td>
<td>259</td>
<td>300.15</td>
<td>214.87</td>
<td>0.43</td>
<td>23.69</td>
<td>6.49</td>
<td><strong>0.00</strong></td>
<td>20</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The following statistics are included: the Median, Mean, Standard Deviation (SD), R² value, Slope of the regression over time, Standard Error of the regression slope (SE), probability level (p) and number of years in the analysis (N). Slope considered to be significant when p<0.05. We report in italic letters p<0.05, in bold letters p<0.01 and bold italic letters p<0.001.

Figure 2 - Variation and trends of selected meteorological data recorded in Parma during the study period: a) annual total rainfall (mm) and average of relative humidity (%); b) annual and seasonal mean temperatures (°C).
increased despite the great reduction observed in the last few years. No significant trends in season characteristics related in timing of pollen season (start, end, duration), but only in SPI, was observed (Table 1). There were also a large number of significant Spearman’s rank correlations between different pollen season characteristics (Table 2). Significant negative correlations between end dates and SPI, end dates and the peak value or start and duration, peak value and duration were observed (respectively $\rho = -0.541$, $\rho = -0.463$, $\rho = -0.589$ and $\rho = -0.447$). There was also a significant negative correlation between duration and SPI ($\rho = -0.552$). Significant positive correlations between end and duration ($\rho = 0.506$), and SPI and peak value ($\rho = 0.820$) were observed. There were also significant positive correlations between SPI and spring ($\rho = 0.582$) and summer temperature ($\rho = 0.490$). In addition, a positive correlation between relative humidity and the day of peak ($\rho = 0.538$) and a negative correlation between annual average temperature and the day of peak ($\rho = -0.508$) were observed.

On the ground we identified numerous sites with ragweed plants: *Ambrosia artemisiifolia* (42), *Ambrosia coronopifolia* (37) and *Ambrosia trifida* (5) (Table 3), even downtown, specially, at the confluence of the Parma river with the Baganza river. *Ambrosia* was observed up 660 m above sea level. 56.8% of the sites with *Ambrosia coronopifolia* were located in hilly areas South of Via Emilia and 27.1% in Parma.
Plants and pollen of *Ambrosia* spread and allergy prevention downtown; 39.1% sites with *Ambrosia artemisiifolia* were located in hilly areas South of Via Emilia and 22% in Parma downtown. *Ambrosia trifida* was observed North of Via Emilia (Figure 5). In Vignale, beetle *Ophraella* was observed for the first time in 2014 (Figure 6 a, b, c). In 14.5% of the sites involved with *Ambrosia*, presence of the beetles was observed (19% of sites with *Ambrosia coronopifolia*, 12.2% of sites with *Ambrosia artemisiifolia* and 0% of sites with *Ambrosia trifida*).

**Discussion and Conclusions**

Observations conducted in the early 1990s showed that *Ambrosia* pollen appeared sporadically in the air of Parma, but - since 1996 - there has been a significant increase in pollen as well as a corresponding growth in the number of patients with positive SPT to *Ambrosia* pollen allergens, and - among these - a significant increase of asthma (33). It is important to underline that allergic reactions significantly reduce the quality of life, interfere with both attendance and performance at school and work (50). The allergic diseases (rhinitis, hay fever, asthma, and atopic dermatitis), associated with exposure to aeroallergens, determine both substantial health effects and large economic costs (50, 51). The aims of this study were to quantify the regional pollen spectrum of *Ambrosia* observed over a 20-year period, the trends, and to evaluate the relationships between them and meteorological data. An additional goal was to map the ragweed plants in the area and to evaluate the presence of the beetle *Ophraella*, an eater of *Ambrosia* leaves which, inexplicably, has never been observed North of the Via Emilia. The results confirm the well-documented expansion of these invasive alien species in Northern Italy (26, 52) and the increasing trend of exposure data of previous study, despite the reduction in airborne pollen observed in the last few years. Concentrations in Parma are lower than in the province of Milan (Lombardy), where yearly total pollen is approx. 5,000, but higher than many other areas, e.g. Central Italy where yearly value is lower than 100 (data from R.I.M.A.®, Italian Monitoring Network in Aerobiology of the Italian Association of Aerobiology, AIA), anyway capable of determining sensitization and symptoms in allergic individuals (33). The significant negative correlation

![Figure 4 – Numbers of days per year with pollen concentration over 10 pollen grains/m³, N=10, r=1, p<0.01](image-url)
Table 2 - The results of Spearman’s rank correlation test between different parameters of the pollen season

<table>
<thead>
<tr>
<th>Seasonal and meteorological data</th>
<th>Start</th>
<th>End</th>
<th>Duration</th>
<th>Peak value</th>
<th>SPI</th>
<th>Day of Peak</th>
<th>Winter mean temperature</th>
<th>Spring mean temperature</th>
<th>Summer mean temperature</th>
<th>Autumn mean temperature</th>
<th>Relative humidity average</th>
<th>Annual total rainfall</th>
<th>Annual mean temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start</td>
<td></td>
<td></td>
<td></td>
<td>-0.589**</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
</tr>
<tr>
<td>End</td>
<td></td>
<td></td>
<td></td>
<td>ns</td>
<td>-0.506*</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
</tr>
<tr>
<td>Duration</td>
<td>-0.589**</td>
<td>0.506*</td>
<td></td>
<td>-0.463*</td>
<td>-0.541*</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
</tr>
<tr>
<td>Peak value</td>
<td>ns</td>
<td>-0.463*</td>
<td></td>
<td>-0.447*</td>
<td>-0.552*</td>
<td>-0.820**</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
</tr>
<tr>
<td>SPI</td>
<td>-0.541*</td>
<td>-0.552*</td>
<td>0.820***</td>
<td></td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
</tr>
<tr>
<td>Day of peak</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>0.538*</td>
<td>-0.508*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Winter mean temperature</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
</tr>
<tr>
<td>Spring mean temperature</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>0.582**</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>0.0456**</td>
<td>0.621**</td>
<td>ns</td>
</tr>
<tr>
<td>Summer mean temperature</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
</tr>
<tr>
<td>Autumn mean temperature</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>0.481*</td>
<td>ns</td>
</tr>
<tr>
<td>Relative humidity</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
</tr>
<tr>
<td>Annual total rainfall</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>-0.764***</td>
<td>ns</td>
<td>ns</td>
</tr>
<tr>
<td>Annual mean temperature</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>-0.508*</td>
<td>0.517*</td>
<td>0.621**</td>
<td>0.481*</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
</tr>
</tbody>
</table>

*p<0.05,  **p<0.01,  ***p<0.001,  ns: not significant

The table shows the results of Spearman’s rank correlation test between different parameters of the pollen season and meteorological data. The correlation coefficients are provided for various parameters such as start, end, duration, peak value, SPI, day of peak, winter mean temperature, spring mean temperature, summer mean temperature, autumn mean temperature, relative humidity average, annual total rainfall, and annual mean temperature. The table indicates the strength and direction of the relationship between these parameters, with significant correlations marked by asterisks. The table highlights the importance of monitoring and understanding the relationship between pollen parameters and meteorological trends to improve forecasting and control strategies.
At present, in our area, the situation is very similar to what occurred in Lombardy at the end of the last century (7). Local health authorities and public entities delegated to the control of the territory should work to coordinate monitoring and management, based on the experiences of Lombardy in order to fight the *Ambrosia* pollen and plants spreading. In the absence of legislative and managerial initiatives by the Institutions and the local Health Authorities to understand, to prevent and to reduce *Ambrosia* plants spread, serious consequences on public health should be expected and, in addition, also an increase of direct and indirect sanitary costs.

The public health authorities should organize dedicated teams, as the Lombardy Health Authorities have already done, for targeted preventive measures. In fact, the Lombard Department of Health has prepared guidelines (57) for many years, for the prevention of ragweed pollen spread, entrusted to the Prevention Departments of the Local Health Authorities and Municipalities, adopting...
Figure 5 – Province of Parma. Sites observed from 2014 with Ambrosia plants (different species). The beetle Ophraella communa was observed in the municipalities of Collecchio, Medesano, Parma, Sala Baganza, Traversetolo and Varano de Melegari (areas marked in gray).

Figure 6 - a) The beetle Ophraella communa in action on Ambrosia coronopifolia Torr. & Gray (left river-bed of the Enza river in Vignale of Traversetolo, Summer 2014); b) and c) ragweed plant with leaves badly worn.
Plants and pollen of *Ambrosia* spread and allergy prevention

A multidisciplinary approach. The goals were: studies of territorial expansion of the plant, containment activities of the spread of the plants on the territory, allergy epidemiology, restraint of sanitary costs, conferences of consensus on the ragweed allergies prevention guide, education and empowerment of the population. In addition to pollen, following the recent results of the European project HIALINE (Health Impacts of Airborne Allergen Information Network) (58-60), in the near future, it will be important to focus also on ragweed airborne allergen content (i.e. amb a1). This will lead to understand and better define the risk of exposure to airborne *Ambrosia* allergens in order to protect allergic patients and the entire population.

As in any environment where biological particles can pose a risk either to human health or to the integrity of materials, microbiological monitoring is a fundamental activity for the management of the problem (61-69), also for the prevention and control of *Ambrosia* allergy, monitoring concerning pollen, allergen and plants represents a useful tool for targeted preventive measures.

**Acknowledgments**

The authors would like to thank Paolo Fantini (Physics Department of the University of Parma) for providing meteorological data. The authors are also grateful to the Italian Aerobiology Association (AIA), which funded a Postdoctoral Fellowship in Aerobiology research at the University Hospital of Parma and the non-profit Catalano Foundation for its contributions. Special thanks to the Italian Network in Aerobiology (R.I.M.A.®) for the elaboration of the regional *Ambrosia* pollen data.

**References**


Plants and pollen of Ambrosia spread and allergy prevention


37. Local Rules of Hygiene (Milan). This order was issued in 2011 and requires supervision and mowing operations to reduce the spread of Ambrosia artemisiifolia. 2011.


