

Long distance transport of ragweed pollen as a potential cause of allergy in central Italy

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Background: *Ambrosia* pollen is an important allergen in North America and, as recently discovered, in some European countries. In Italy, the most affected area is the northeast, whereas ragweed has not been reported in the central and southern parts of the country.

Objective: To identify the source of ragweed pollen detected in Florence and Pistoia in central Italy.

Methods: Ragweed pollen data were collected in Florence and Pistoia for a 6-year period (1999–2004). The relationship between pollen counts and local ground prevalent wind directions was evaluated with analysis of variance and the least significant difference test. Weather conditions were also evaluated on a large-scale circulation pattern by analyzing weather maps and air mass back trajectories.

Results: A highly statistically significant relationship between daily prevailing wind direction and pollen count was found in the period under investigation; the ragweed pollen peaks were recorded when winds from northeast in Florence and north-northeast in Pistoia were observed. The synoptic weather situation and the path of back trajectories suggest an area around southern Hungary as a possible source of *Ambrosia* pollen. Furthermore, the pollen count was above the clinical threshold several times in both Florence and Pistoia.

Conclusions: Several factors indicate that the detection of ragweed pollen in central Italy is due to long distance transport. Taking into consideration the high allergenicity of *Ambrosia* pollen, the present findings, if confirmed, suggest that the number of sensitized individuals might significantly increase in the near future.

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INTRODUCTION

The genus *Ambrosia*, which includes both *Ambrosia artemisiifolia* (short or common ragweed) and *Ambrosia trifida* (giant ragweed), has long been recognized as a significant cause of allergic rhinitis. A large random skin test survey demonstrated that 10% of the US population was ragweed sensitive.¹ More recently, *Ambrosia* pollen levels were significantly related to asthma and rhinitis in a study based on a symptoms diary and peak expiratory flow rates.² The pollen of *A. artemisiifolia* is produced in enormous amounts and one single plant alone may produce millions of pollen grains. Since the pollen grains are small (18–22 μm), they are often involved in episodes of long distance transport.³

The most representative species, *A. artemisiifolia*, was first discovered in Europe in 1860.⁴ Since then, ragweed pollen has been increasingly important from an allergological point of view in parts of central and eastern Europe. The distribution of ragweed pollen covers the area at medium latitude,

which is characterized by a continental climate; it spreads from Hungary, the most ragweed-polluted country,⁵ to Croatia, certain parts of France,⁶ and Italy.⁷ Furthermore, ragweed has also been detected in Bulgaria,⁸ Austria,⁹ Switzerland,¹⁰ Czech Republic,¹¹ Slovak Republic,¹² Sweden,¹³ Poland,¹⁴ and Russia.¹⁵

Ragweed was found in 2 Italian regions, Piemonte and Liguria, for the first time in 1902. Currently, the most affected regions of Italy are Lombardia and Friuli Venezia-Giulia, located in the northeastern part of the country.^{3,16} To our knowledge, no published data exist on the distribution of ragweed plants in the central and southern parts of Italy.

Although no studies have been performed to evaluate the prevalence of ragweed sensitization among atopic patients in the area under study, the rate is presumably low; in fact, the clinical importance and the sensitization rate for the indigenous Compositae (eg, *Artemisia vulgaris*) are also low.¹⁷ In the last 6 years, the regional aerobiological network of Tuscany has noticed an increasing count of ragweed pollen, but the plants have not been found so far.

The aim of this study was to identify the source of ragweed pollen detected in Tuscany during a 6-year period (1999–2004). To investigate this phenomenon, weather conditions on a large-scale circulation pattern and local ground prevalent wind directions (the direction the wind is coming from) were analyzed. Although the impact on atopic people is currently still uncertain, the understanding of the pollen source might be useful for the development of an alert system for patients sensitized to ragweed.

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MATERIALS AND METHODS

Study Sites

Florence and Pistoia are Italian cities located in the region of Tuscany in a closed valley bottom at the foot of the Apennines. Florence (latitude = 11°11'E; longitude = 43°47'N) is at 50 m above sea level and is surrounded by hills to the south and mountains to the north, which rise to almost 1,000 m. Pistoia (latitude = 43°57'N; longitude = 10°57'E) is approximately 30 km northwest of Florence and is surrounded by hills to the south and southwest and mountains to the west and north, which rise to almost 2,000 m. Both cities have a Mediterranean semicontinental climate, with cold winters and hot summers.

Pollen Data

Ragweed pollen was detected in Florence and Pistoia between August 20 and September 20 during a 6-year period (1999–2004). The air was sampled by an instrument (VPPS 2000, Lanzoni, Bologna, Italy) that applies the principle initially proposed by Hirst¹⁸ and recommended by the International Biological Program.¹⁹ The instrument was located on the flat roof of 2 buildings situated in the cities of Florence and Pistoia 18 to 20 m above ground level and far away from walls and protection.

The sampler is regulated to handle air flows of 10 L/min and was at all times oriented into the wind by a wind vane. Pollen grains affected a cylindrical drum covered with a plastic strip coated with a uniform layer of adhesive solution. For this purpose, a 3% silicone fluid (polydimethylsiloxane) was used with 2,500,000 centistokes of viscosity in carbon tetrachloride.²⁰ It is extremely important to use this kind of silicone fluid, because different silicone solution, such as oil and fats, give completely different results.

Every week the strip was removed and cut into 7 equal segments, corresponding to the 7 days of the week. Each segment was mounted between the slide and cover glass with a mixture of glycerine jelly (10 g of jelly, 60 mL of water, 55 mL of glycerine, 2 g of phenol, and a few drops of basic fuchsin in an aqueous saturated solution).²¹

The prepared samples were examined with optical microscopes, with a magnification that varied according to the situation. For routine counts, a magnification of 40× is recommended. The pollen grains are generally counted not on the whole 14 × 48-mm sampled area but on a fraction of the entire deposit of particles (statistical count). For this purpose, the slide is examined on parallel (longer side of the slide) horizontal sweeps with the continuous sweeps technique. The minimum number of horizontal sweeps is the one that ensures a total observed area of not less than 18% of the sampled area. The results were expressed as the number of pollen grains per cubic meter of air.

Meteorological Data

Daily meteorological data of air temperature, relative humidity, wind velocity and direction, and rainfall for 1999 to 2004 were provided by the urban weather station located in the

western part of Florence (managed by the Institute of Biometeorology, National Research Council) and near the Experimental Center of Vivaism located in the southwest suburb of Pistoia. The weather stations were both approximately 3 km away from the pollen traps. There were no obstacles between weather stations and pollen samplers. The daily prevailing wind direction was obtained by calculating the most frequent class (ie, north, north-northeast, northeast, east) of wind direction in a day. Daily prevailing wind directions were tested for daily pollen count differences using analysis of variance (ANOVA) and the least significant difference test.

To determine the daily atmospheric circulation patterns with the aim of evaluating the origin of the air mass reaching Florence and Pistoia in the period under investigation, synoptic weather maps (isobaric levels of 500 and 850 hPa) were analyzed. Maps were generated by the Global Forecast System at the US National Center for Environmental Prediction (www.ncep.noaa.gov) and were used for the entire study period.

Air mass back trajectories starting from Florence and Pistoia were also computed to determine the real origin of air masses and the time needed to arrive at the studied area. Air mass back trajectories provide a useful means of establishing source-receptor relationships of air particles.^{22,23} The HYSPLIT version 4 transport and dispersion model^{24,25} provided by the National Oceanic and Atmospheric Administration Air Resources Laboratory was used for this purpose (www.arl.noaa.gov/ready/hysplit4.html). The path followed by the air masses for the previous 48 hours was determined in time steps of 6 hours.

RESULTS

The total pollen count (the sum of daily counts per cubic meter of air) in the periods taken into consideration, the date of the peaks, and the maximum daily count reached in the year for each city are given in Table 1. Only a small quantity of pollen was collected in both cities in 1999 and 2001, with 2002 and 2004 being the most polluted years; there is a clear increasing trend in the total ragweed pollen counts throughout the 6 years. No ragweed pollen grains were recorded outside the study period.

A statistically significant relationship between daily prevailing wind direction and pollen count was found in the period under investigation. The ANOVA showed statistically significant differences (from $P < .001$ to $P < .05$) between the pollen counts recorded when northeast and north-northeast wind directions occurred in Florence and Pistoia, respectively, and those recorded when most of the other wind directions occurred (Fig 1). The pollen count usually increased approximately 24 hours after a day characterized by prevailing north-northeasterly (Pistoia) and northeasterly (Florence) winds and decreased when the wind direction changed. Furthermore, pollen grains in the air samples persisted at high levels throughout several days according to the persistence of north-northeasterly and northeasterly winds (Fig 2).

Table 1. Characteristics of Ragweed Pollen Count in Florence and Pistoia in 1999–2004

Year	Total count, grains/m ³ *		Peak day		Daily maximum count, grains/m ³	
	Florence	Pistoia	Florence	Pistoia	Florence	Pistoia
1999	50	46	Sep 11	Sep 11	13	8
2000	58	59	Sep 9	Sep 9	28	31
2001	31	33	Aug 26	Aug 26	5	5
2002	218	235	Sep 2	Sep 2	76	83
2003	61	93	Sep 14	Sep 15	20	30
2004	184	250	Sep 6	Sep 6	60	140

* Total count is the sum of the daily counts between August 20 and September 20.

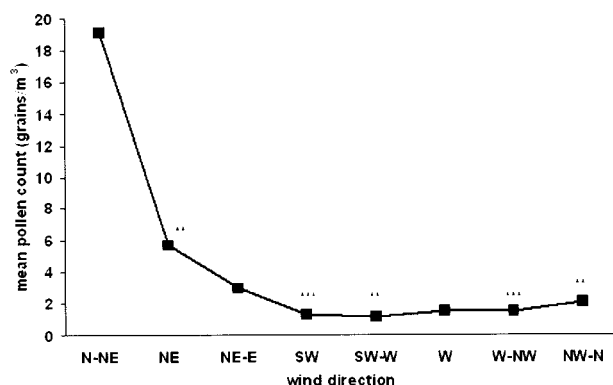
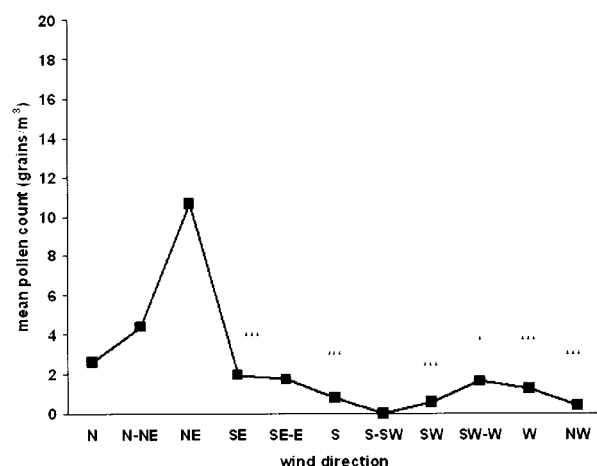


Figure 1. Plot of mean ragweed pollen count vs prevailing wind direction in Florence (top) and Pistoia (bottom). The asterisks show the significant variations between the mean pollen count in days with northeastern wind direction in Florence and north-northeastern wind direction in Pistoia and the other wind directions: * $P < .05$; ** $P < .01$; *** $P < .001$. N indicates north; N-NE, north-northeast; NE, northeast; SE, southeast; SE-E, southeast-east; S, south; S-SW, south-southwest; SW, southwest; SW-W, southwest-west; W, west; NW, northwest; W-NW, west-northwest; and NW-N, northwest-north.

The detection of *Ambrosia* pollen was always associated with days characterized by air masses coming from eastern or

northeastern Europe. This synoptic weather pattern occurred several days before the maximum pollen peak (from 1 up to 5 days before the pollen peak), and it was represented by well-developed anticyclonic systems having their center over northern Europe or Russia and persistent cyclonic systems centered on the southern Adriatic sea and over the Balkans. This system is characterized by low atmospheric pressure that induces air flow over Italy from the eastern and northeastern parts of the European continent (Fig 3, top). The relationship between pollen count and synoptic weather pattern was particularly evident during the highest pollen peaks, which occurred on August 31, 2002, September 1–2, 2002, and September 6–8, 2004.

The computation of back trajectories ending in Florence and Pistoia on the days characterized by high *Ambrosia* pollen count confirmed data obtained by the weather analyses of large-scale circulation patterns and local ground wind direction. Figure 3 shows the back trajectory of air mass ending at 23 coordinated universal time on September 2, 2002, in Pistoia (Fig 3, bottom) and the corresponding meteorological map (Fig 3, top). The path computed by the HYSPLIT model suggests an area around southern Hungary as a possible source of ragweed pollen.

DISCUSSION

All factors examined in the present study indicate that the detection of ragweed pollen in Florence and Pistoia during August and September 1999–2004 is due to long distance transport. First, as yet ragweed plants have not been observed in Tuscany or, to our knowledge, in central and southern Italy. Second, the pollen count was intermittent in 3 (1999, 2000, and 2003) of the 6 years under study, even taking into consideration the cleaning effect of rainfall (data not shown). In addition, pollens are suddenly detectable in the air, usually reach the highest peak in 2 to 3 days, and disappear in 4 to 5 days. Pollen of local origin is normally received continuously within a well-defined pollen season that usually lasts more than 5 days. The third factor is represented by the association between the presence of ragweed pollens and winds coming from northeast in Florence and from north-northeast in Pistoia. This observation is strongly supported by the statistical analysis, which also shows a low concentration of ragweed grains in days characterized by wind coming from any other

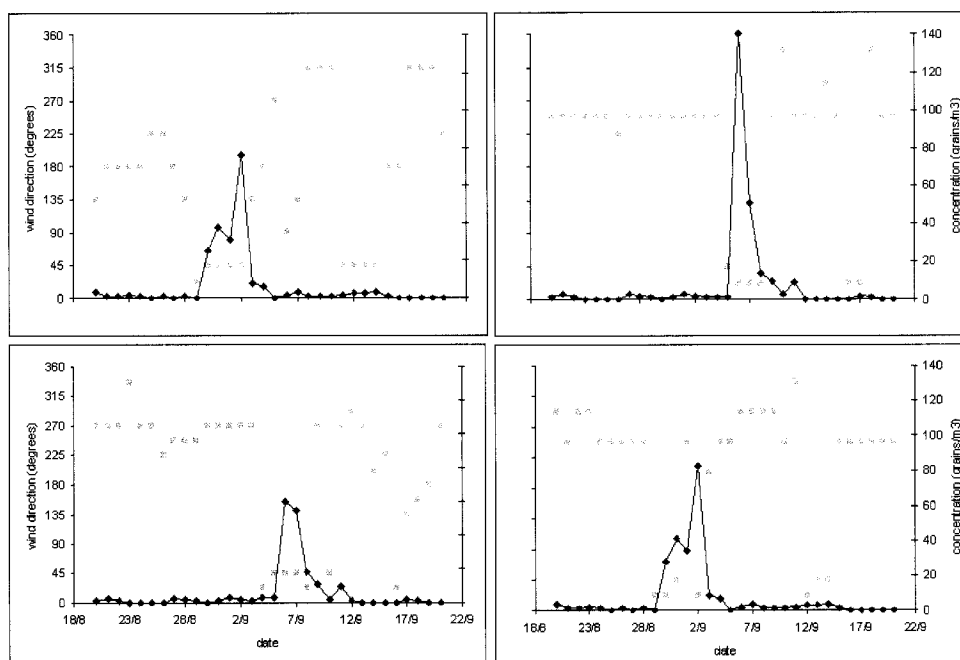


Figure 2. Daily count of ragweed pollen and daily prevailing wind direction (expressed in degrees) in Florence (top) and Pistoia (bottom) in 2002 (left) and 2004 (right). Note that northeastern direction corresponds to 45° and the north-northeastern direction corresponds to 22.5° .

direction. The difference regarding the wind direction associated with high pollen count recorded in the 2 cities that are relatively near each other might be addressed to geomorphologic reasons; Pistoia is surrounded by mountains that rise 1,300 miles to the northeast and by valleys to the north-northeast, whereas Florence is surrounded by mountains that rise 1,000 miles to the northeast. These characteristics may also explain the higher pollen count detected in Pistoia, because the mountains that surround Florence might reduce the pollen that reaches the city.

Both large-scale weather circulation patterns and back trajectories clearly showed air masses coming from central or eastern Europe, in correspondence with ragweed pollen detection; in particular, the meteorological situation concerning the highest peaks indicated southern Hungary as a possible source of origin of *Ambrosia* pollen. The finding is consistent with the ragweed pollen season that usually occurs in that region.²⁶

Different studies have tried to determine the threshold of ragweed pollen concentration able to induce symptoms in sensitized patients. Experimental studies showed that most people sensitive to *Ambrosia* pollen are symptomatic between 10 and 50 grains/ m^3 .²⁷ However, the clinical threshold was lower in a French²⁸ and an Austrian²⁹ study, being 13 grains/ m^3 and 20 grains/ m^3 , respectively. In our study, the ragweed pollen concentration was above 10 grains/ m^3 12 times in Florence and 10 times in Pistoia and above 50 grains/ m^3 3 times both in Florence and Pistoia during the 6 years under investigation. Furthermore, between 80% and

90% of the days had a concentration above 10 grains/ m^3 in the last 3 years (in particular, 83.3% in Florence and 90% in Pistoia), indicating the increasing trend of ragweed pollen in the air samples in this area. Taking into consideration the high allergenicity of *Ambrosia* pollen, present findings suggest that the number of sensitized individuals might significantly increase in the near future, prolonging the allergy season until late summer even in the areas where the species is as yet not established.

A few studies have shown that long distance transport of ragweed pollen has occurred in other European countries. In south Sweden, detection of pollens from 1995 to 1998 was associated with air streams coming from eastern Europe.¹³ A study performed in the Baltic States, a region close to south Sweden, confirmed that eastern European countries, namely, Russia, Hungary, and Ukraine, might be the possible source of *Ambrosia* pollen.³⁰ In this area, long distance transport seems to occur on a regular basis, but pollen levels are generally low. On the contrary, in Catalonia (Spain) the detection of ragweed pollen was due to an extraordinary meteorological situation and the source was identified in the north of France.³¹ The effect of increasing diffusion of *Ambrosia* species on sensitization rate in Europe might be enhanced by transboundary pollen movement; however, it is arguable that a transport on a regular basis and high pollen levels are needed to have an impact on the prevalence of allergy to ragweed pollen.

In conclusion, further research is needed to evaluate the true impact of ragweed pollen on atopic patients in areas

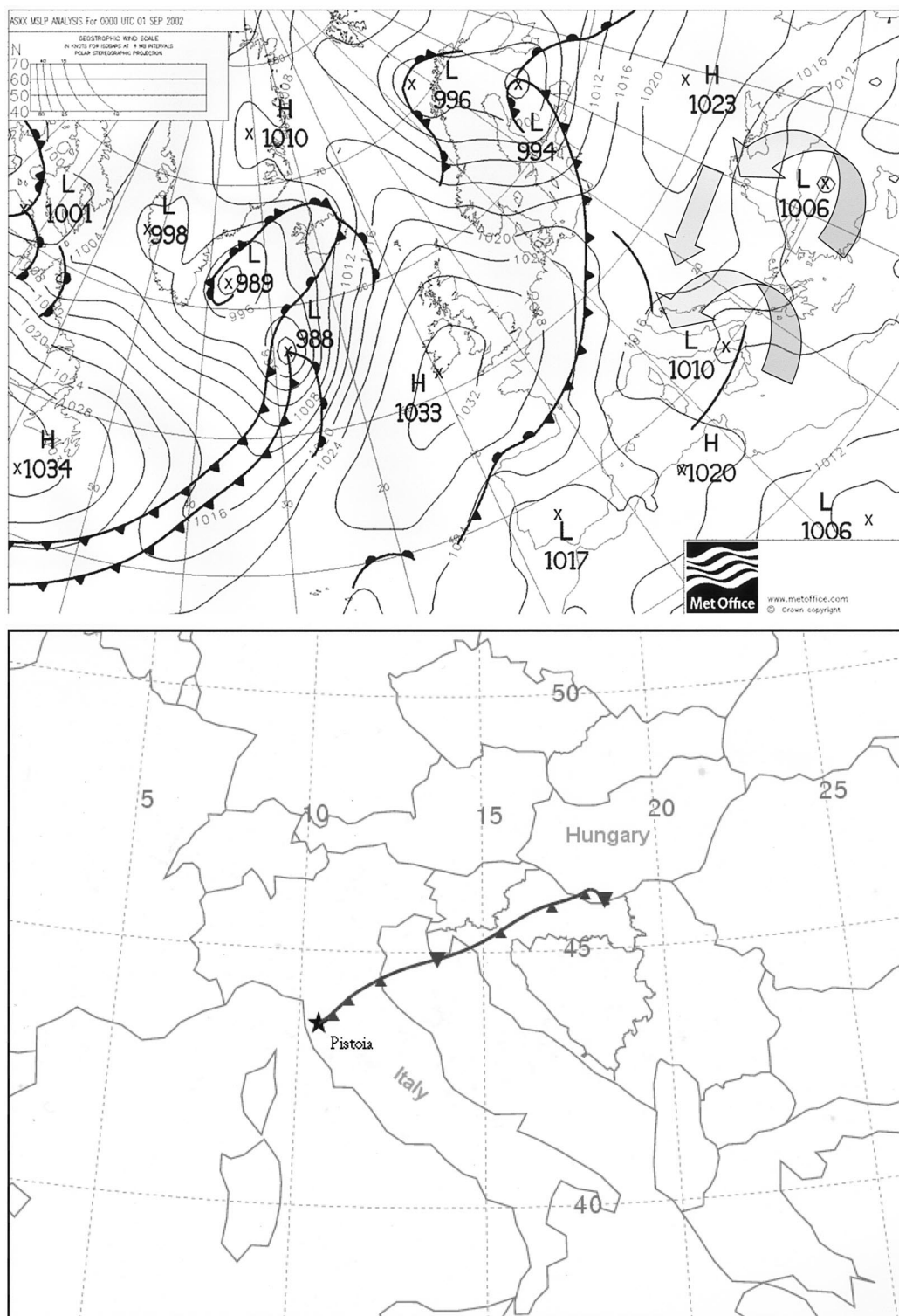


Figure 3. Top, Weather map for 00 coordinated universal time on September 1, 2002, the day before the peak of ragweed. The gray arrows indicate the direction the air flow is coming from on the basis of synoptic weather pattern. Bottom, Possible path of ragweed pollen, which reached Pistoia on September 2, 2002. Backward trajectory computed by using the HYSPLIT model version 4.0 provided by the National Oceanic and Atmospheric Administration. Markers on the line indicate a 6-hour interval.

affected by long distance transport, with the aim of foreseeing the clinical importance of ragweed sensitization in the next decades. Finally, an improvement in the European aerobiological network might be helpful to better identify the source of origin and the trajectory of pollen involved in long distance transport to develop a global forecast synoptic system for allergic patients.

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