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REVIEW PAPER

Ragweed in South America: the relevance of aerobiology stations in Latin America

Ivan Cherrez-Ojeda · Karla Robles-Velasco · German D. Ramon · Laura Barrionuevo · Oscar Calderon Llosa · Denisse Cevallos-Levicek · Marco Faytong-Haro · Andrés Espinoza-Maticurena · Patricio Alvarez-Muñoz · Ivan Tinoco · László Makra · Áron József Deák

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Abstract Pollen, particularly from the *Ambrosia* genus, plays a pivotal role in triggering allergic rhinoconjunctivitis symptoms. This review delves into the global background of *Ambrosia*, focusing on its origins, invasive potential, and spread to South America. The ecological niche for *Ambrosia* species is explored, emphasizing its stability globally but exhibiting unique and dynamic features in South America. Information on *Ambrosia* pollen concentration in South America is summarized, revealing varying levels across countries. The establishment of new aerobiology stations, as highlighted in the latest findings, contributes valuable data for understanding allergen risk management in the region. The health perspective addresses the rise in allergic diseases due to climate change, emphasizing the need for continuous monitoring, especially in South America. Agricultural damage inflicted by *Ambrosia* is discussed, emphasizing its invasive potential, high seed production, and negative impact on crops, forage quality, and livestock. The review also positions *Ambrosia* as a marker of climate change, discussing the effects of global warming on pollen seasons, concentrations, and allergenic characteristics. The importance of expanding aerobiology stations in South America is underscored, requiring collaborative efforts from government, scientific societies, and academic institutions. The review concludes by advocating for increased monitoring to address potential challenges posed by *Ambrosia*, offering a basis for tailored interventions and future research in South American regions.

I. Cherrez-Ojeda (✉) · K. Robles-Velasco · D. Cevallos-Levicek · M. Faytong-Haro · A. Espinoza-Maticurena
Universidad Espiritu Santo, Km. 2.5 Vía La Puntilla, 0901-952 Samborondon, Ecuador
e-mail: ivancherrez@gmail.com

I. Cherrez-Ojeda · K. Robles-Velasco · D. Cevallos-Levicek · M. Faytong-Haro · A. Espinoza-Maticurena
Respiralab Research Group, Guayaquil, Ecuador

G. D. Ramon · L. Barrionuevo
Instituto de Alergia e Inmunologia del Sur, Buenos Aires, Argentina

O. Calderon Llosa
Clínica SANNA el Golf, San Isidro, Lima, Peru

P. Alvarez-Muñoz
Universidad Estatal de Milagro, Milagro, Ecuador

I. Tinoco
Centro de Alergias Tinoco, Machala, Ecuador

L. Makra · Á. J. Deák
Faculty of Agriculture, Institute of Economics and Rural Development, University of Szeged, Andrássy út 15, Hódmezővásárhely 6800, Hungary

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1 Introduction

Pollen plays a significant role in triggering the seasonal symptoms of allergic rhinoconjunctivitis. Since pollen seasons can fluctuate according to temperature and location, it is crucial to monitor the quantities of pollen and the predominant species in different areas. *Ambrosia* commonly referred to as ragweed, has been identified as a major allergenic pollen genus with a strong invasiveness capability (Montagnani et al., 2017, 2023). *Ambrosia* has been now described in approximately 80 countries across all continents, including South America (Hufnagel et al., 2015; Sun et al., 2017), with the majority of them finding it as a casual, invasive, and naturalized alien species and only a few as the native species of the described area (Montagnani et al., 2017). This strong invasive potential has been primarily attributed to human influences that allowed their introduction into new regions during the previous century (urbanization, agricultural intensification, and improved transportation networks) (Marselle et al., 2019).

This review will primarily examine the worldwide background of ragweed, including its origins, initial documentation, and its spread to South America. The first section will further elaborate on the wider ecological niche of *Ambrosia*, highlighting its significance. The following section will discuss the primary discoveries documented in the literature on the occurrence of *Ambrosia* in several South American nations, including Venezuela, Colombia, Peru, Argentina, and Chile, as well as the latest results from newly established stations in Ecuador. Subsequently, the last sections will outline the primary issues that occur as a result of the existence of ragweed in various places, particularly in the domains of health, agriculture, and climate change.

2 Origin, occurrence, climate conditions, and resilience in a worldwide context

Carl Linnaeus initially introduced the botanical name *Ambrosia* in volume 2 of Species Plantarum in 1753, as an annual wind-pollinated monoecious weed species belonging to the Asteraceae family, with three documented habitats being Virginia, Canada; Virginia, Pennsylvania; and Etruria, Cappadocia (Linné & Linné, 1753). Based on the best information we have; the genus *Ambrosia* comprises 49 species (Hufnagel et al., 2015). Of them, 31 species are native to North America, while 8 come from South America (Hufnagel et al., 2015).

In every continent, the most frequently occurring *Ambrosia* species is *A. artemisiifolia*. However, besides Europe, there is no information on its estimated distribution compared to the other available *Ambrosia* species. For Europe, *A. artemisiifolia, A. trifida, A. psilostachya,* and *A. tenuifolia* are the most common species (Montagnani et al., 2023). Despite this, the most widespread of them is *A. artemisiifolia*. Its estimated distribution rate vs. other ragweed species in Europe is approximately 90:10 (Bartha et al., 2019; Makra, 2022).

Very few areas in South America have a climate similar to that of the ragweed's homeland. In addition, the climates of South America and North America differ significantly. Consequently, ragweed in South America cannot occupy the climatic range found in North America (Guisan et al., 2014). Furthermore, it should be noted that *A. artemisiifolia* has also spread to new climate areas in South America that are not found in North America (Guisan et al., 2014). A study showed that 450 species of insects, mites, and fungi are associated with *Ambrosia* species in North and South America (Gerber et al., 2011).

3 Ecological niche for *Ambrosia* species

Each species exhibits a spectrum of environmental conditions conducive to favorable population growth, defining its ecological niche (Takola & Schielzeth, 2022). This niche encompasses two interconnected components: (1) the range of biotic and abiotic factors influencing a species' persistence in a specific habitat, and (2) the species' influence on these factors (Scheiner & Willig, 2011).Based on these principles, Song et al. mapped the current and potential distribution of *A. artemisiifolia* for every continent by ecological niche models to identify areas with the highest potential risk of *A. artemisiifolia* invasion (Song et al., 2023). The great ecological niche stability in Africa, Australia, China, Europe, and South America suggests that *A. artemisiifolia* was ecologically conservative during the invasion. Ecological niche growth with a value of 0.407 was seen exclusively in South America (Song et al., 2023).). This suggests that *A. artemisiifolia* has undergone notable changes in its ability to inhabit and adapt to different conditions in South America.

According to the niche dynamic index, *A. artemisiifolia* is steady throughout its global invasion area, save for significant growth in South America. The climatic niches of the invading areas on all continents, save South America, are not significant. South America's climate niche stands out among all invading regions because of its unique characteristics: a low Schoener's D value and a very unstable climate niche (Unfilling = 0.846, Expansion = 0.407). In non-native areas, the climatic niches of *A. artemisiifolia* remained consistently steady, particularly in Europe. (Song et al., 2023). These findings suggest that A. artemisiifolia has a generally stable ecological niche globally, but South America stands out with a unique and highly dynamic climate niche, indicating substantial changes and expansion in the species' ecological preferences in that region underscoring the importance of studying ragweed in these regions.

4 Information available on the *Ambrosia* pollen concentration in South America

South America is composed of thirteen independent nations: Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador, Guyana, Paraguay, Peru, Suriname, Trinidad and Tobago, Uruguay, and Venezuela. Additionally, it includes French Guiana, which is an overseas department of France, and five dependent territories belonging to other countries (*América Latina y el Caribe*, no date). The diverse geography of South America results in a wide range of biomes throughout the continent. South America's coastal lowlands' desert habitat transitions to the harsh alpine biome of the Andes mountains within a few hundred kilometers. The Amazon River basin is characterized by lush, tropical rainforests, whereas the Paraná River basin consists of extensive grasslands. South America possesses an exceptional variety of plant and animal species, making its biodiversity stand out compared to other continents.(Echeverría-Londoño et al., 2018).

Even though the information available on the pollen concentrations measured at individual aerobiological stations in South America is still limited, we can describe the concentration of *Ambrosia* pollen in South America as follows:

Hurtado and Riegles-Goihman conducted air sampling in Caracas, the capital of Venezuela with a tropical climate (Hurtado & Riegles-Goihman, 1984). They found a very low concentration of *Ambrosia* pollen. In Bogota, the capital of Colombia, *Ambrosia* spp. were found very rare in 1966 (*A Geographical Atlas of World Weeds—Holm, LeRoy; Pancho, Juan V.; Herberger, James P.; Plucknett, Donald L.*, n.d.; *EPPO Global Database*, n.d.). However, small quantities of pollen grains were detected in July (Medina & Fernandez, 1966). During a measurement period in June 1986–May 1987, the aggregated pollen count of altogether 72 pollen types was 7,626. Among these, 24 taxa have been identified. Weed pollen counts, including *Ambrosia* spp., were very low (4% of the total, i.e., a mere 304 pollen grains) (Hurtado et al., 1989). This number assumes a very low annual ragweed pollen concentration in Bogota, (Table 1).

Calderón et al., identified and registered the most important aeroallergens in the atmosphere of Lima, the capital of Peru (Calderón et al., 2015). They found that the ratio of *Ambrosia* pollen concentration in the annual aggregated pollen integral was a mere 0.15%. In Talca, Chile, Mardones et al. (2013) found significant concentrations of *A. artemisiifolia* were detected from February until April during the measuring period from May 2007 to April 2008. However, the specific value of the concentration was not mentioned in the paper. Toro et al. studied the concentrations of 39 different pollen types in the Santiago de Chile metropolitan area over the period 2009–2013 (Toro A. et al., 2015). From the ten different weed taxa that were identified in the pollen samples the contribution of *A. artemisiifolia* to the average annual weed pollen grains was 267 ± 39 grains/m^3 per year, which means 7.0% of relative contribution.

In Argentina, Murray et al. described in 2010 the findings of 200 grains/m^3/year (0.5%, share in comparison with annual pollen concentrations) of ragweed pollen in Bahia Blanca (Murray et al., 2010). In 2018, Torres et al. described 171 grains/m^3/year (0.7%) of ragweed pollen in San Salvador de Juyuyuy (Torres et al., 2018). Ramón et al. studied the annual aggregated pollen concentration in

Table 1 Summary of *Ambrosia* pollen reports in six countries of South America over time

Year	Author	City, Country	Grains/m^3/year	% of total pollen
1942	Greco et al. (1942)	Belo Horizonte, Brazil	0	0
1966	Medina et al. (1966)	Bogota, Colombia	0	–
1984	Hurtado et al. (1984)	Caracas, Venezuela	Rare observations of ragweed pollen	–
1989	Hurtado et al. (1989)	Bogota, Colombia	304	4%
2010	Murray et al. (2010)	Bahia Blanca, Argentina	200.72	0.5%
2013	Mardones et al. (2013)	Talca, Chile	189	1.75%
2015	Calderon et al. (2015)	Lima, Peru	–	0.15%
2015	Toro et al. (2015)	Santiago, Chile	267	7%
2018	Torres et al. (2018)	San Salvador de Juyuy, Argentina	171	0.7%
2020	Ramon et al. (2020)	Bariloche, Argentina	7	0.8%
		Córdoba, Argentina	97	11.3%
		Santa Rosa, Argentina	14	2.8%
		Bahía Blanca, Argentina	34	12%

Argentina for four cities, from September 2018 to September 2019 (Ramon et al., 2020). They classified the pollen concentrations into three categories: tree, grasses, and weed pollen. The following weed pollen concentrations (grains/m^3/year) and their ratio in the aggregated annual pollen concentrations (in bracket) were measured: Bariloche: 7, (0,8%), Cordoba: 97, (11.3%), Santa Rosa: 14, (2.8%), and Bahía Blanca: 34, (12.0%), (Table 1). Although ragweed is in the weed category, there are many other types of weed pollen in that category. Based on this alone, we can say that the concentration of ragweed pollen in the aforementioned cities is not significant, but more research is needed. Greco et al. didn't find ragweed pollen in Belo Horizonte, Brazil, and its surroundings, during their measurements, from January 1940, up to July 1941 (Greco et al., 1942).

The establishment of new aerobiology stations in countries such as Ecuador, Chile, and Peru has significant importance in advancing the comprehension of allergic disorders within these geographical regions. These stations will serve as permanent sources of data on the behavior of pollen and fungal spores, therefore contributing to a deeper knowledge of allergic conditions. The significance of achieving the purpose of the National Allergy Bureau across the United States and globally is underscored by the potential novelty of the findings, which may have not been previously documented. As an example, we present the latest findings of the surveillance of pollen and fungal spores' levels in the atmosphere.

Figure 1 offers a visual representation of these initial findings, laid out in the form of a map overlaid with proportional circles that correspond to the maximum daily *Ambrosia* pollen counts per cubic meter, recorded from 2019 to 2023. The varying sizes of these circles clearly illustrate the discrepancies in pollen counts among the cities. Guayaquil's (Ecuador) circle is the largest, signifying the highest recorded count at 26 particles per cubic meter, while smaller circles represent Bahía Blanca and Buenos Aires (Argentina) with their respective counts of 5 and 8 particles per cubic meter. Lima (Peru) and Santiago de Chile are depicted with moderately sized circles, both marking a peak daily count of 10 particles per cubic meter.

Ecuador reports, in addition to *Ambrosia artemisiifolia*, 3 other species of *Ambrosia*: (1) *A. arborescens*, with the widest distribution in the country, (2) *A. artemisioides* and (3) *A. cumanensis* (*Tropicos—NameSearch*, no date). Ecuador is a territory highly vulnerable to the effects of climate variability and changes in temperature are projected to continue to rise through the end of the century (*World Bank Climate Change Knowledge Portal*, no date). Clearly, Guayaquil has the highest particle count recorded. For instance, this cartographic depiction highlights the geographic spread or intensity of *Ambrosia* pollination in South America, providing valuable insights

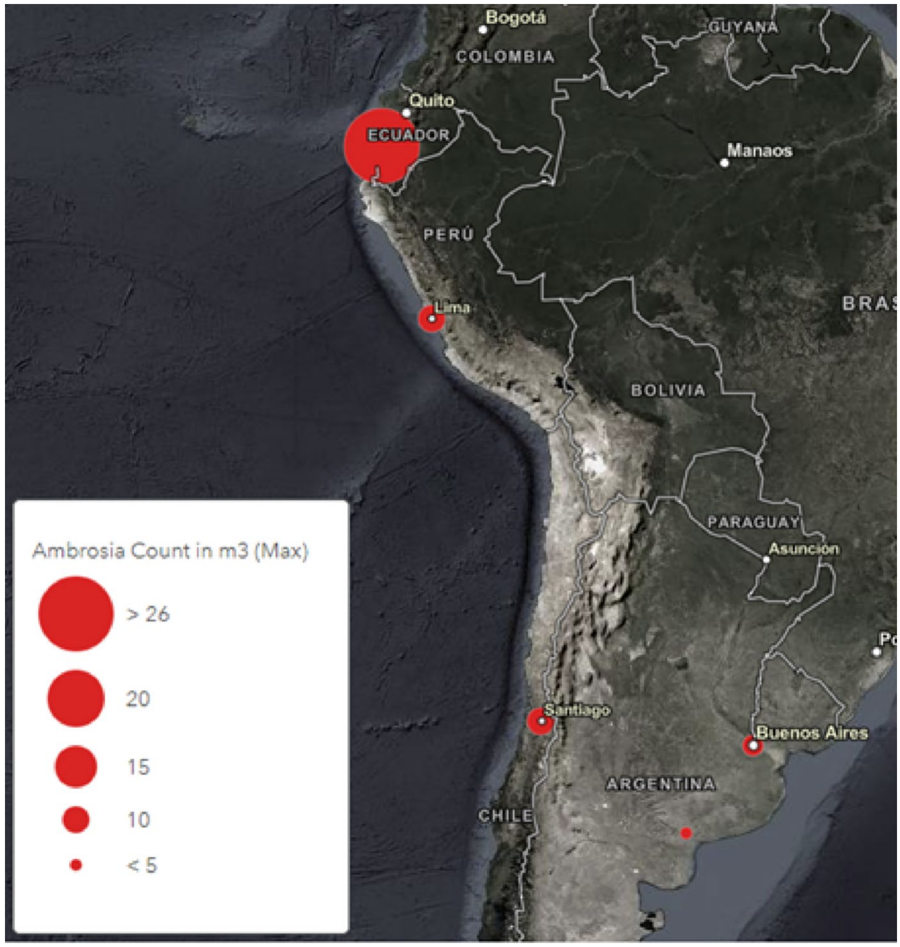

Fig. 1 Comparative analysis of maximum daily *Ambrosia* volume (m.[3]): city-wise distribution from 2019 to 2023

for public health planning and allergen risk management in the region.

5 Health perspectives

Due to global climate change, according to model calculations (e.g., Storkey et al. (Storkey et al., 2014); Chapman et al. (Chapman et al., 2016)), the pollen concentration of *Ambrosia* species increases, the pollen season becomes longer, and the habitats of allergenic taxa, including *Ambrosia* species, expand higher latitudes. Consequently, more and more people are exposed to and becoming sensitive to ragweed pollen. Therefore, the number of allergic diseases is increasing globally, and the global public health risk is increasing (Hess, 2019; Ziska et al., 2019). The contribution of human forcing on the climate system – due to the accumulation of anthropogenic greenhouse gases, especially CO_2 and methane, accounted for ~50% of the trend in lengthening pollen seasons and ~8% of the trend in increasing pollen concentrations (Anderegg et al., 2021).

Identifying the presence or absence of *Ambrosia* in a specific area is crucial from a medical standpoint due to its well-known status as one of the most allergenic pollen. This is mainly due to Amb a 1, a 38-kDa non-glycosylated protein classified as a pectatelyase protein. It is a highly allergenic molecule that is recognized by 90% of individuals sensitized to ragweed. (Gadermaier et al., 2008).

Existing studies have shown that the threshold value for clinical symptoms is below 20 ragweed pollen grains/m^3/daily (Jäger, 2000; Taramarcaz et al., 2005). In the USA, it has been estimated that allergic reactions to ragweed pollen are found with concentrations as low as 5–20 pollen grains/m^3/daily, and in the Midwest, the typical pollen count during the ragweed season is about 200 pollen grains/m^3/daily (Oswalt & Marshall, 2008). The information for Europe suggests that very sensitive people can be affected by as few as 1–2 pollen grains/m^3 (Chapman et al., 2016).

People allergic to ragweed appear generally to show allergies to other pollen. For example, Yankova et al. showed that all patients with positive skin prick tests for ragweed were highly allergic to other pollen types - mostly to Poaceae and Asteraceae (Yankova et al., 2000). Moreover, serious allergy to ragweed pollen can result in allergic asthma, allergic rhinitis, conjunctivitis, and various respiratory diseases (Anees-Hill et al., 2022; Taramarcaz et al., 2005).

Continuous monitoring is imperative to ascertain three key aspects. Firstly, it enables the identification of the progression of ragweed infestation within a particular region. Secondly, it provides empirical evidence regarding the effectiveness or ineffectiveness of the implemented measures aimed at reducing the infestation. Last, but not least, it aids in facilitating medical decision-making about pathologies associated with the allergenic pollen in question (Leru et al., 2019).

Pollen and fungal spores monitoring is being conducted in several nations worldwide, encompassing diverse stations and long-standing aerobiological initiatives. In Europe, the European Academy of Allergy and Clinical Immunology has available a web page where they provide a "Worldwide Map of Pollen Monitoring Stations" (*Worldwide Map of Pollen Monitoring Stations – EAACI Patients*, no date). In the environment of the Americas, the division of the American Academy of Asthma, Allergy, and Immunology AAAAI's Aeroallergen Network known as the National Allergy Bureau (NAB)(*AAAAI*, no date), is the organization in charge of providing updates on pollen and fungal spore levels. There are 84 stations in North America. In South America, there are only six certified aerobiology stations up to 2022 (*AAAAI*, no date; *Alergia y polinosis—Red Latinoamericana de Aerobiología*, 2023). The expansion of accredited stations throughout South America will facilitate the acquisition and dissemination of information in the field of Aerobiology at both continental and global scales.

6 Damage in agriculture

Ragweed has an enormous invasive potential through the production of large quantities of seeds with very high germination capacity. Each ragweed plant produces 3.000–62.000 seeds, which can remain dormant for up to 39 years if the environmental conditions allow (Montagnani et al., 2017). Moreover, because ragweed is an anemophilous (wind-pollinating) species, it generates small (18–22 microns) pollen grains with small air chambers between layers of the outer pollen wall, which is unique in the Asteraceae plant family (Mandrioli et al., 1998). A single *Ambrosia* plant may yield 1.19 ± 0.14 billion pollen grains every year (Makra et al., 2005). As a result, these features enable it to travel large distances, ranging from 60 to 200 km (de Weger et al., 2016) and, in some circumstances, up to 1000 km in ideal meteorological conditions (Cecchi et al., 2007). In addition, the absence of natural enemies of ragweed plants facilitated its spread in similar climatic conditions. *A. artemisiifolia* can significantly reduce the yield of cereals and other field crops (e.g. sunflower) and cause harvesting problems. Its presence greatly impairs the forage quality of meadows and pastures (*A. artemisiifolia* is unpalatable to livestock) and, if fed by cattle, contaminates dairy products.

7 *Ambrosia* as a marker of climate change

Climate change poses a serious risk to airborne bioparticles like pollen grains and fungal spores (Pacheco et al., 2021), making them more vulnerable to factors such as greenhouse gas emissions, humidity, air pollution, and high UV radiation (Schiavoni et al., 2017). This can disrupt the natural cycle of pollen seasons, leading to changes in the timing and amount of pollen released, as well as alterations in the composition, concentration, and allergenic properties of pollen. (Glick et al., 2021).

Global climate change is predicted to cause an increase in *Ambrosia* species pollen concentration, lengthen the pollen season, and spread the habitats of allergenic taxa, such as *Ambrosia* species, to higher latitude (Lake et al., 2017; Storkey et al., 2014). As a result, an increasing number of individuals are developing a sensitivity to ragweed pollen. Consequently, the prevalence of allergy disorders is on the rise worldwide, posing an escalating global public health threat (Hess, 2019; Ziska et al., 2019). Human activities, particularly the buildup of man-made greenhouse gases like CO_2, were responsible for around 50% of the extension of pollen seasons and about 8% of the rise in pollen concentrations (Anderegg et al., 2021).

Climate change's impact on *Ambrosia* distribution can boost anemophilous plant abundance, resulting in more pollen emissions into the atmosphere. This can elevate the population's exposure to aeroallergens and enhance sensitivity. Pollen gathered in northern Italy from ragweed plants in urban parks and near busy highways, which are heavily affected by pollution, exhibited higher allergenicity compared to pollen from plants in rural regions.(Moitra et al., 2023). However, the allergenicity level of ragweed from South America remains unexplored.

8 Conclusions

The aforementioned information provides substantial evidence to advocate for the expansion of accredited aerobiology stations in additional South American nations. To obtain accurate information on the ragweed situation, it is imperative that various stakeholders, including the government, scientific societies specializing in allergy, immunology, biology, and palynology, as well as academic institutions (not limited to universities) involving individuals of all ages, actively participate in monitoring efforts. The implementation of this collaborative approach will facilitate the dissemination of knowledge regarding potential challenges related to ragweed and guarantee the accessibility of precise data. This, in turn, can contribute to the formulation of interventions from environmental, botanical, and health standpoints. Furthermore, it may pave the way for future research endeavors focused on investigating the extent of allergenic sensitization among individuals residing in South American regions, as well as the potential development of tailored immunotherapy approaches that cater to the unique requirements of these areas.

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Declarations

Competing interests The authors declare no competing interests.

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