Commentary

Discovery Medicine 2024; 36(191): 2468–2474
https://doi.org/10.24976/Discov.Med.202436191.228

Cortaderia selloana or the Disregarded Impact of Worldwide Expanding Plant Invasions on Human Health

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Published: 20 December 2024

Invasive alien plant species (IAPS) are well known to disrupt biodiversity, natural ecosystems, and infrastructures, resulting in a significant worldwide economic cost. However, the impact of IAPS on human health has been generally disregarded, despite a significant potential risk. Currently, due to new evidence and the concept of *One Health*, this concern is gaining strength. The spread of invasive plants at a global scale can profoundly affect human health through pollen and toxin production. Allergic respiratory diseases caused by pollen are likely the primary risks posed by IAPS. Because of the frequent invasion of populated areas and their different pollination period throughout the year, IAPS might further contribute to the current striking increase in allergies. Respiratory allergies significantly affect the quality of life of patients, along with associated economic impacts. In this study, we focus on a paradigmatic IAPS that is invading considerable areas of the globe, *Cortaderia selloana* (Pampas grass), to illustrate the increasing and widely disregarded human health risk posed by IAPS. Our aim is to raise awareness of the IAPS concern among the medical community and health policymakers, suggesting rapid action to address associated concerns.

Keywords: invasive alien plant species; allergy; pollinosis; One Health; *Cortaderia selloana*

Introduction

Alien species include plants, animals, microorganisms, or fungi that are transported, either intentionally or accidentally, by human activities to ecosystems beyond their natural distribution range and historical biogeographical limits [1–4]. These species become invasive when they establish themselves, proliferate uncontrollably, and dominate that new location. In their new habitats, they often lack their native competitors, enabling them to reach high abundance. Similarly, their rapid growth, high reproduction rates, high dispersal capacity, and adaptability to the new environmental conditions further support their spread. The introduction and proliferation of these species adversely impact the local ecosystems, causing significant economic losses and biodiversity reduction by outcompeting native species. Due to this phenomenon, they are referred to as invasive alien species (IAS). Globally, IAS are considered the second leading cause of biodiversity loss, exceeded only by habitat destruction [3,5]. The disastrous impacts of IAS included biodiversity decline, destruction of ecosystem functions, and significant economic burden associated with control, reduction, and restoration attempts [2]. IAS can reduce agricultural crop and grassland yield, alter infrastructure usability, increase restoration costs, and diminish the aesthetic and recreational value of natural landscapes [3,4,6,7].

The synergistic relationship of IAS with other factors makes them a key driver of ecosystem degradation across the world [8,9]. Moreover, their impacts and associated risks vary among ecosystems and are particularly more pronounced in coastal areas, inland waters, Mediterranean climate zones, and islands [9]. To grasp the magnitude of the issue, approximately 17,000 IAS introductions have been recorded worldwide over the past few centuries, with over 7500 being plant species. Alarmingly, the number of alien species continues to increase without any sign of saturation [2,5,6].

While some animal IAS, such as rodents and insects, have become significant medical concerns, the impact of invasive alien plant species (IAPS) has been widely disregarded in medicine. Therefore, this article aims to address this issue. First, we will highlight how little we know about IAPS and human health. Second, we will discuss the increasing significance of pollen allergies in medicine. Third, we will focus on the invasive grass *Cortaderia selloana*, reviewing historical and recent evidence indicating its crucial role in extending allergy seasons throughout the year. Finally, we will highlight that the risk posed by IAPS is expected to increase in the context of climate change unless urgent and effective control measures are adopted.

IAPS and Human Health

In addition to the aforementioned concerns, IAPS presents an additional, largely disregarded threat to human health. Currently, the impact of IAPS on human health is emerging as a rapidly growing issue, underscoring the need for closer collaboration between biological and health sciences, improved surveillance efforts, and coordinated policy development [2]. This aligns with the *One Health* concept, which is promoted by various international agencies and organizations such as the Food and Agriculture Organization of the United Nations (FAO), the World Organisation for Animal Health (OIE), the UN Environment Programme (UNEP), and the World Health Organization (WHO). Their website states: *'One Health is an integrated, unifying approach that aims to sustainably balance and optimize the health of humans, animals, plants and ecosystems'* (https://www.unep.org/topics/chemicals-and-pollution-action/pollution-and-health/unep-one-health).

IAPS indirectly impacts human health by changing environmental quality and ecosystem structure, potentially resulting in exposure to toxins and allergens that can cause diseases, injuries, or even deaths [4]. It has been reported that the global spread of invasive plants can profoundly affect human health, mainly through the production of allergens and toxins [4,8,10,11]. However, a limited number of species have been investigated for their impact on public health, primarily due to their production of large amounts of allergenic pollen [1].

The adverse impact of invasive plant species is expected to intensify in the near future due to the increasing number of introduction pathways and opportunities for invasion, both of which are augmented by climate change [8]. Several studies underscore that climate change benefits invasive species, causing additional pressure on human health. For example, increasing temperature is expected to expand the distribution range and increase the abundance of allergenic plants like *Artemisia annua* and *Ambrosia artemisiifolia* [1]. The predicted change in climatic conditions might boost the spread of invasive species across both terrestrial and freshwater ecosystems. However, predicting the influence of climate changes on IAPS is challenging, as these species can develop adaptive approaches, such as changes in physiognomy, anatomy, and biochemistry [4].

Pollen Allergies

Pollen production is likely the primary human health concern linked to IAPS. The pollination process in the most allergenic plants occurs mainly through wind (anemophilous species), releasing huge quantities of pollen into the air to reach a successful reproduction [12,13]. While IAPS does not induce unique mechanisms of allergy they trigger well-known pathways. Pollens are a major cause of type I allergies due to various allergens [14], with vulnerability often influenced by genetic or familial factors [15]. In Western Europe, native grass pollen peaks during spring and early summer, resulting in a rise in allergic conditions such as rhinitis, conjunctivitis, and asthma. However, non-native grass species often deviate from this pattern. In this way, Belmonte *et al.* (2004) [16] analyzed the diversity, abundance, and phenology of non-native airborne pollen across seven Spanish Mediterranean sites. Their results indicated that pollen from allochthonous species poses a substantial health concern, due to its ability to provoke allergic reactions outside the usual allergy season. Furthermore, they reported that non-native taxa reached their peak pollen concentrations in late March, whereas native species peaked in mid-May. This earlier flowering phenology of non-native species, along with some alien species flowering later than native plants, extends the overall period of allergy risk throughout the year. Additionally, they showed that even some intentionally introduced non-native plants, which may not invade natural ecosystems, can negatively affect human health.

Pollen allergy (pollinosis) was first described in the 19th century [17]. The prevalence of respiratory diseases caused by pollen allergy significantly increased during the late half of the 20th century [18]. Various conditions such as allergic rhinitis, rhino-conjunctivitis, and asthma affect a significant portion of the global population, with a higher prevalence reported in developed countries [2,19]. Research indicates that the prevalence of allergenic rhinitis ranges from 5% to 50% worldwide [20], with about 20–30% of the population experiencing allergies to grass pollen [14].

The Cost of Pollinosis

Allergic diseases and asthma have evolved from relatively rare conditions to emerging prominent public health concerns, with their prevalence continuing to increase globally [21]. Asthma is the most common chronic paediatric disease in Europe, affecting approximately 30 million children and young adults who also suffer from allergic rhinitis caused by pollen [22]. Allergic rhinitis is the most prevalent allergic condition, affecting up to 40% of young adults [23]. Moreover, allergies are often associated with severe comorbidities, including asthma, sinusitis, or conjunctivitis [19,24]. According to the World Health Organization 2013 update of the WAO White Book on Allergy, over 300 million individuals globally were living with asthma at this time, which is expected to reach 400 million by 2025. Furthermore, asthma causes an estimated 250,000 deaths annually [25].

Allergies can severely affect patients' quality of life, impairing their mental health and compromising education and professional careers through presentism (reduced productivity at work) and absenteeism (absence from work).

Zuberbier *et al.* (2014) [26] revealed that in the European Union, the estimated cost of absenteeism was €528 per worker annually, while presentism costs ranged between €845 and €1690 per worker .

In the Netherlands, the total annual cost of allergic rhinitis is €4827 per patient [27]. Colás *et al.* (2017) [28] assessed data from allergic patients recruited randomly in 101 health centers throughout Spain over 12 months. They found that the mean annual cost of allergenic rhinitis per patient (n = 498) was €2326.70 (direct cost €553.80 and indirect cost €1772.90) [28]. In the United States, García-Mozo (2017) [14] observed that around 50 million people suffer from nasal allergies, costing the US healthcare system around $17.5 billion annually. Therefore, due to the high prevalence, ubiquitous diffusion, and significant social and economic burden of pollen allergies, their management is of global priority and imposes considerable costs not only on the healthcare system but also through their impacts on education, workplace, productivity and healthcare resource utilization [12,14,24,28].

Diagne *et al.* (2021) [29], employing the InvaCost database, calculated that the total reported cost of plant invasions in the US was $8.9 billion between 1970 and 2017. Moreover, they highlighted that the database likely underestimated the costs associated with plant species compared to mammals or insects [29].

Cortaderia selloana

To indicate the increasing health risk posed by IAPS, we discuss a striking example: the grass *Cortaderia selloana* (CS), commonly known as Pampas grass (Fig. 1A,B, Ref. [11]). Native to South America, CS is rapidly spreading worldwide (Fig. 1C). It belongs to the Poaceae family, which includes about 12,000 wind-pollinated species (anemophilous). Poaceae species release a significant amount of pollen, making their pollen one of the primary airborne biological pollutants and a leading cause of pollen allergy worldwide [14]. In addition to their significant health concerns, CS imposes negative impacts on socio-economic status, such as reducing the productivity of tree plantations, decreasing the recreational value of invaded areas, and causing respiratory allergies [12,30]. This species has become naturalized on every continent except Antarctica [30]. Over the past few decades, it has extensively colonized areas where it is not autochthonous, establishing itself as a worldwide invasive grass with a great potential for further expansion, particularly under climate change conditions [31]. CS has successfully colonized Western Europe, North America, Australia, New Zealand, and South Africa [31].

As it occurs with many other IAPS, studies assessing the allergenic potential of CS remain limited despite the substantial impact of grass allergies on human health. Some research findings have been communicated at scientific meetings and publicly available. Reported at the 1979 Annual Meeting of the Academy of Allergy in New Orleans, Street *et al.* [32] observed an association between increased symptoms among grass-sensitive patients and the flowering season of *Cortaderia jubata* (CJ), a species closely related to CS. Utilizing skin tests, the study analyzed two hundred patients from California, where CJ had been introduced thirty years before, and ten patients geographically isolated from the plant. Among patients sensitive to Poaceae pollen, only one patient reacted exclusively to CJ, suggesting that this plant possessed at least one unique antigen while sharing others with common grasses [32].

Gálvez *et al.* (2014) [33] assessed the allergenic potential of CS pollen extract on atopic patients, obtaining positive reactions that revealed the plant's allergenic capability. The authors highlighted the need for further investigations on this issue [33]. In 2015, Gálvez *et al.* [34] investigated the allergenic relationship between CS and *Lolium* species in grass-sensitized patients. Analysis of cross-reactivity showed values less than 50% for inhibitory concentration, suggesting distinct antigenicity of CS pollen, which emphasized the significance of future studies for enhancing allergy diagnosis and developing immunotherapy of allergic individuals [34].

Rodríguez *et al.* (2021) [11] were the first to reveal the potential allergenicity of CS. They monitored sensitization to CS in patients allergic to native grass pollen in northern Spain, where CS is highly abundant [11]. Skin tests and analyses of IgE specific to CS in 100 patients demonstrated that most patients allergic to native grasses were also sensitized to CS. By assessing air pollen data from the Basque Country, collected by the regional Health Department, the researcher found a major grass pollen peak around May, corresponding to the flowering season of native grasses, and a secondary peak between August and October. This later peak was attributed to IAPS, which coincided with a reactivation of allergy symptoms in most patients (Fig. 1D). Note that CS pollinate from August to October in Western Europe, extending the allergy season by about three months in these regions. These findings pose important public health implications as they exhibit an extended period of allergic reactions in affected individuals. These results are consistent with the previous observations by Street *et al.* [32] for CJ in California. They suggested cross-reactivity and common antigens between CS pollen and local grass pollen, which likely contributed to positive skin reactions and allergy symptoms during the pollinating season of CJ in patients without prior exposure to the plant [32]. Similarly, Galán *et al.* (2024) [8] recently found that ornamental exotic grass species such as CS and *Pennisetum villosum*, which flower later than native grasses, create an unusual second grass pollen peak in autumn in Madrid (Spain). Although further research is required, CS is thought to trigger pollinosis through mechanisms similar to those of local grasses. Studies, including our outcomes, have shown that CS pollen shares allergenic antigens with local grasses [11].

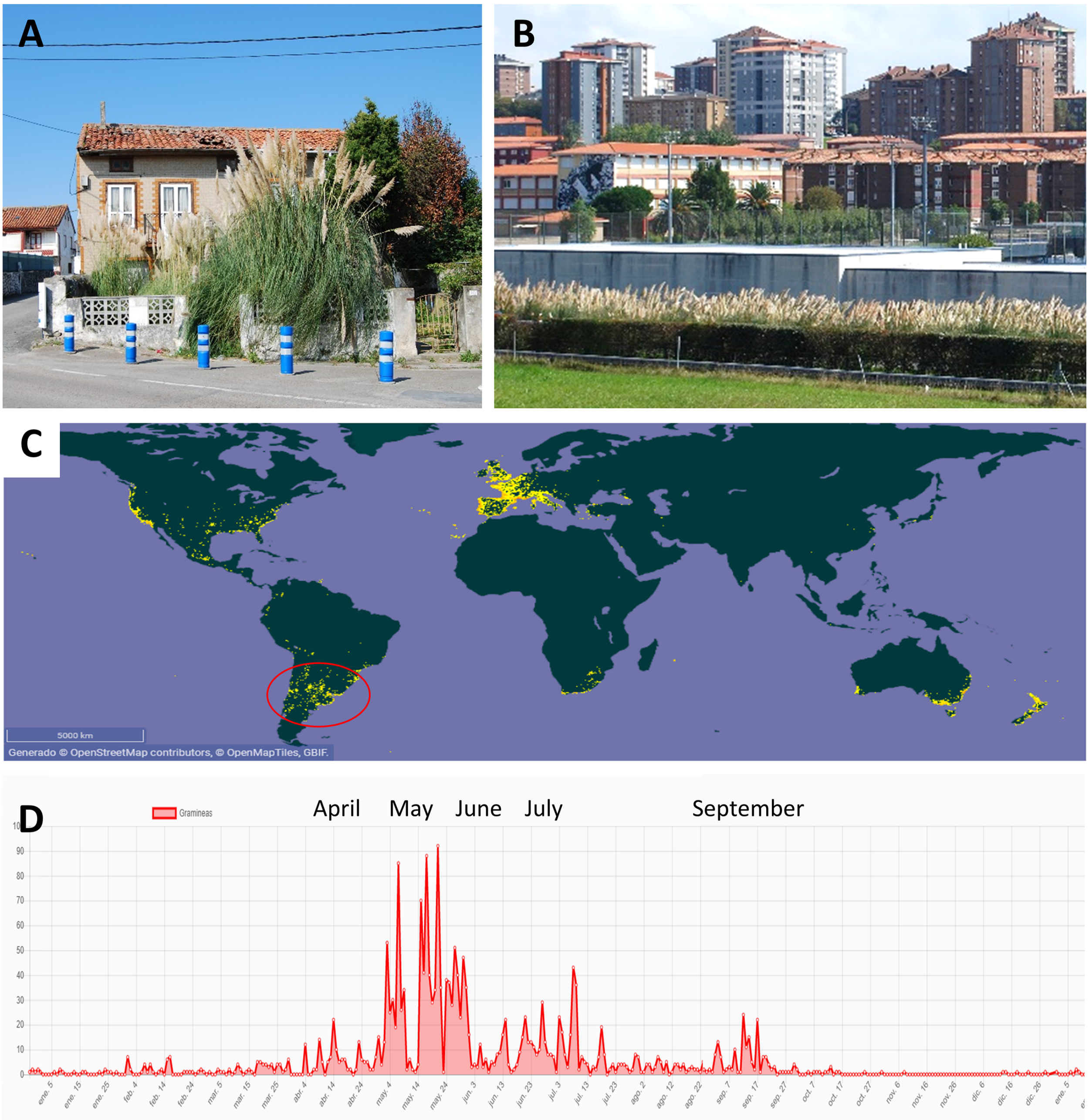

Fig. 1. Worldwide invasion of *Cortaderia selloana* strikingly impacts urban areas. (A,B) *Cortaderia selloana* invasion in urban sites (Santander, Spain; September 2024). (C) *Cortaderia selloana* worldwide invasion (From: *Cortaderia selloana* (Schult. & Schult.f.) Asch. & Graebn, GBIF Secretariat (2023). GBIF Backbone Taxonomy. Checklist dataset https://doi.org/10.15468/39omei; GBIF.org, September 2024). Red circle: original habitat. (D) Concentration of grass pollen in the air in 2019 in Bilbao (Spain; Laboratorio de Salud Pública, Gobierno Vasco, Bilbao) [11].

Grass pollen allergens are classified into 13 groups, each different in allergenic potency. Groups 1 and 5 provoke the highest allergenic responses, affecting 65–90% of patients [35]. Group 1 allergens are found across all Poaceae subfamilies, while Group 5 is specific to the Pooideae subfamily [14]. In 2018, Galvez *et al*. [36] analyzed serum from 16 patients utilizing Western blotting and found a profile of 15 allergens CS. They demonstrated that these allergens belong to groups 1 and 4 of grass pollen allergens [36]. Rodríguez *et al*. (2021) [11] found no evidence of group 5 allergens in CS. However, they observed proteins consistent with the grass group 1 grass allergens [11].

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CS is also a striking example of economic costs associated with IAPS. According to the InvaCost database, a total of €1,307,949.62 has been invested in research and control efforts for CS between 2011 and 2020 [37]. Significant resources have been dedicated to eradicating this species from Natural areas in recent years, implemented by specific European Union initiatives. For example, the *Stop Cortaderia Life* project (2018–2022), spent, €3.57 million, while the ongoing *Coop Cortaderia Life* project (2023–2028) invested €6.36 million [38].

In summary, most efforts to remove CS have primarily focused on areas of ecological significance. However, given the potential impact of CS on human health through allergenic pollen and its highest density in degraded urban coastal regions, there is a demand for targeted action in these urban areas. Furthermore, strategies to combat its invasion must be expanded to cities where the plant poses a significant threat to human health. Moreover, CS must be included in all international and national invasive species to ensure its planting, maintenance, and trade are strictly forbidden. Despite the substantial economic investments by the European Union to control CS, it has not yet been included in the list of invasive alien species of Union concern.

IAPS, Pollution, and Climatic Change

IAPS constitute a significant additional factor contributing to the increasing worldwide incidence of allergic respiratory diseases and bronchial asthma, with urban dwellers being affected more frequently than people living in rural areas, as air pollution and climate change both play a crucial role in worsening allergic responses [39]. These factors qualitatively and quantitatively influence pollen production by allergenic plants. Chemical pollutants from human activities, now present at unprecedented concentrations, further interact with respiratory allergic diseases [14]. In the case of CS and other IAPS, urban areas experience higher invasion rates than rural areas since the plant takes advantage of degraded soil and is vastly dispersed by human industrial and construction activities usually concentrated in urban settings [11].

Climate change also alters the concentration and distribution of airborne pollutants, prolonging the pollen season, and extending the duration of exposure to allergenic pollens. This trend negatively impacts the incidence of allergic rhinitis and asthma. Additionally, introducing exotic species with pollination peaks that differ from native flora can extend the pollen allergy season to most of the year in some areas [40]. Katelaris and Beggs (2018) [41] showed that the increased air temperature and carbon dioxide concentrations are causing some plant species to increase pollen production and allergenicity. The combined effects of climate change and pollutants create plant stress conditions, further increasing pollen production and allergen concentrations. Furthermore, the worldwide spread of IAPS, such as CS, is being favored by climate change. Warmer winters allow these species to expand into inland and northern areas previously unaffected, as young CS plants are susceptible to winter frosts [30].

Biological invasions progress through several stages, including introduction, establishment, expansion, and impact on the natural ecosystem, each represented by distinct ecological characteristics [4]. The establishment period is particularly crucial, as it offers the highest chance of successful eradication efforts. Therefore, it is essential for authorities to evaluate and identify species with the highest potential threat to support effective decision-making [2]. So far, eradication plans for most IAPS have primarily focused on conserving nature and biodiversity. However, given the significance of IAPS for human health, eradication efforts must be extended to urban areas that host a higher-density of population.

Conclusion

To assess the impact of IAPS on health, clinical departments, and researchers must perform serological and/or cutaneous tests using pollen extracts from these plants to determine the sensitization levels within the allergic population. Furthermore, the pollination period of IAPS must also be characterized in every region to identify if they cause allergies beyond the pollination seasons of the native plants. Distinguishing pollen from allochthonous and autochthonous species within the same family of plants is often challenging. Advanced biochemical or molecular tests should be implemented to detect IAPS pollen in urban environments.

The social and economic benefits of managing IAPS, including a reduction in medical care costs, have been underestimated. More careful estimations are needed as accurate information on human health and the economic impact of IAPS is crucial in justifying resource allocation and ensuring coordinated management actions [42]. The economic cost of implementing IAPS control measures is far lower than the medical and social costs resulting from plant invasions. It is, therefore, peremptory that the medical community, governments, and society recognize the health concerns posed by IAPS. Adopting the *One Health* concept is crucial to developing comprehensive strategies to quantify the impact of IAPS on the populations and to adopt measures for their control or eradication outside of their native habitats. Thus, the global spread of IAPS harms not only biodiversity and ecosystems but also human health, highlighting the urgent need for action.

Availability of Data and Materials

Data discussed are available in the publications cited or, when maps, institutions or databases, in the specific web sources.

Author Contributions

ML and AG: Conceptualisation, Data Curation, Investigation, Validation, Visualisation. AG: Supervision, Funding. Both authors were involved in the drafting and critical revision of the manuscript. Both authors have read and approved the final manuscript. Both authors have participated sufficiently in the work and agreed to be accountable for all aspects of the work.

Ethics Approval and Consent to Participate

Not applicable.

Acknowledgment

We thank Anna Solinís for critical reading. We thank members of the Life-Coop Cortaderia project, in particular Santiago García-de Enterría, for discussions and support. María Lucas is funded by the Life project. The project is co-funded by the Government of Cantabria.

Funding

Stop Cortaderia +. Development and implementation of a transnational alliance against Cortaderia. LIFE22-NAT-ES-Coop-Cortaderia/101113757, European Union.

Conflict of Interest

Alberto Gandarillas is serving as one of the Editorial Board members of this journal. We declare that Alberto Gandarillas had no involvement in the peer review of this article and has no access to information regarding its peer review. María Lucas has no conflicts of interest.

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