

# Urban Greening and Pollen Allergy: Balancing Health and Environmental Sustainability



Katarina Stevanovic, PhD<sup>a,b</sup>, Aki Sinkkonen, PhD<sup>c</sup>, Ruby Pawankar, MD, PhD<sup>d</sup>, and Torsten Zuberbier, MD, PhD<sup>a,b</sup>  
Berlin, Germany; Turku, Finland; and Tokyo, Japan

Urban living requires a careful balance between human health and environmental sustainability when selecting urban vegetation. Public gardens and green roofs offer significant environmental benefits, including air filtration, exposure to health-associated microbiota, and mitigation of the urban heat island effect. However, prioritizing allergy-friendly species is crucial to prevent the exacerbation of pollen allergies. This review highlights 3 primary criteria for selecting vegetation that supports these ecosystem services while minimizing allergy risks. First, reducing the use of many wind-pollinated plants, such as birch trees and grasses, is crucial due to their high pollen production and cross-reactivity with other species, which can exacerbate allergies. In contrast, insect-pollinated plants are generally safer for allergy sufferers. Secondly, cultivating multispecies plant communities with minimal maintenance supports habitats for microbiota and invertebrates, further

providing ecosystem services. Lastly, balancing plant gender ratios in urban spaces can help control pollen levels. Together these criteria provide a framework for urban planners to create green spaces that are both environmentally beneficial and allergy friendly. Although this review focuses on European data, the principles discussed have global relevance, reinforcing the need to integrate environmental sustainability with public health considerations in urban planning. Future studies should also investigate the health impacts of plant volatile emissions, explore heat-resistant plant varieties, and assess the ecological risks of invasive species to support sustainable, allergy-friendly urban environments. © 2024 The Authors. Published by Elsevier Inc. on behalf of the American Academy of Allergy, Asthma & Immunology. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>). (J Allergy Clin Immunol Pract 2025;13:275-9)

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<sup>a</sup>Institute of Allergology, Charité—Universitätsmedizin Berlin, corporate member of Freie Universität Berlin and Humboldt-Universität zu Berlin, Berlin, Germany

<sup>b</sup>Immunology and Allergology, Fraunhofer Institute for Translational Medicine and Pharmacology ITMP, Berlin, Germany

<sup>c</sup>Natural Resources Institute Finland, Turku, Finland

<sup>d</sup>Department of Pediatrics, Nippon Medical School, Tokyo, Japan

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Corresponding author: Torsten Zuberbier, MD, PhD, Institute of Allergology, Charité—Universitätsmedizin Berlin, Campus Benjamin Franklin, Hindenburgdamm 30, Haus II, 12203 Berlin, Germany. E-mail: [torsten.zuberbier@charite.de](mailto:torsten.zuberbier@charite.de). 2213-2198

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Environmental health is intrinsically linked to human health. Every environmental factor, whether natural or man-made, affects our bodies, as it does all living organisms, including microbes on and within our body. Although the human body can adapt to changes and stressors, this adaptability has its limits, especially concerning the immune system, which is our primary defense against external, internal, or perceived threats. As our world becomes increasingly more urbanized, industrialized, and digitalized, it is crucial to optimize policies to minimize negative impacts on both human and planetary health.

Prolonged exposure to low-dose immunotoxins or allergens can primarily target the immune system, potentially leading to secondary damage to organs such as the lungs, skin, nervous system, and thyroid.<sup>1</sup> This exposure may initially manifest as hypersensitivity, autoimmunity, or immune deficiency, subsequently increasing susceptibility to further damage such as infections and neoplasia. Allergens and immunotoxins sensitize the host to future exposure and may also act as an immune-response modifier, inhibiting or enhancing immune reactivity.

A historical perspective reveals significant correlations between industrialization and the rise of immunological and respiratory diseases. For example, a surge in occupational asthma was documented in the 1920s among workers exposed to inorganic agents in platinum salts and later among those handling coffee and castor beans.<sup>2</sup> During World War II, the increased use of organic and inorganic chemicals in synthetic materials closely correlated with occupational and environmental asthma.<sup>2</sup> Also, the widespread use of asbestos, known for their thermal-resistant properties, across various industries such as construction and textiles, may be linked

*Abbreviations used*

ECARF- European Centre for Allergy Research Foundation  
VOC- Volatile organic compound

to immune disturbances.<sup>2,3</sup> Interestingly, along with widespread use of anthropogenic contaminants, the incidence of immune-system disorders multiplied in industrialized democracies but not in the former socialist block in Europe, despite equal and often higher air pollution levels in the latter countries.<sup>4</sup> A plausible reason for the discrepancy was connected to decreasing contacts with microbial biodiversity in everyday life among urbanites outside the former socialist countries.<sup>5</sup> These historical insights underscore the necessity for urban planners, industry leaders, and policymakers to develop strategies that mitigate the public health impacts of urban and industrial development.<sup>6</sup>

Although urbanization and industrialization are beneficial for the economy and societal development, they have often resulted in environmental degradation, including air, water, and soil pollution, biodiversity loss, and increased greenhouse gas emissions, which in turn contribute to global warming and eventually climate change.<sup>5,7</sup> These environmental changes have significant health implications, particularly for individuals with asthma and other respiratory diseases, as well as other noncommunicable diseases, and those who cannot access nature on an everyday basis.<sup>5</sup> The World Allergy Organization has highlighted that heat waves, extreme weather events, increased ground-level ozone, transboundary particle pollution, and altered distributions of allergens (such as pollen, molds, and mites) have all increased due to climate change.<sup>7</sup> Many measures and initiatives have been undertaken to counter these adverse effects, but it remains essential to integrate environmental sustainability with public health goals, especially in managing allergy risks.

This review examines the role of plants in urban areas, emphasizing the need for a careful balance between increasing and rewilding urban vegetation to combat biodiversity loss and climate change and minimizing the pollen load to promote allergy-friendly environments. Urban centers urgently require resilient plant species that can withstand climate change, provide niches for consumers and decomposers, and promote microbial diversity, yet these species should not contribute significantly to pollen pollution or production of allergenic volatile organic compounds (VOCs). Virtually all plants release VOCs, but only a fraction of VOCs released by plants are associated with asthma and allergic symptoms.<sup>8,9</sup> Although the parameters considered in this review are specific to European urban environments, the principles discussed are potentially applicable globally. The review aims to outline solutions to integrate these 2 goals: selecting climate-resistant plants for sustainable urban environments and ensuring allergy friendliness.

## POLLEN ALLERGY IN EUROPE

Pollen allergy prevalence is on the rise and already affects up to 40% of the European population.<sup>10</sup> This issue is very significant as it is associated with a strong impact on patients' quality of life and high economic burden.<sup>11</sup> Pollen allergies occur when antigens present in pollen are released on contact with the mucous membranes of the mouth, nose, or eyes. This release can trigger hay fever, asthma, and oral allergy syndrome symptoms in sensitized individuals. Consequently, the severity of symptoms

experienced by those with pollinosis is directly influenced by the concentration of airborne pollen.<sup>10</sup>

Studies indicate that the pollen landscape in Europe is evolving due to various cultural and environmental factors. The importation of plants such as birch and cypress for urban landscaping has altered the regional flora, while increased international travel has facilitated the spread of allergenic species such as ragweed, as revealed by data spanning countries between Bulgaria, France, and Sweden.<sup>10</sup> In addition, climate change is exacerbating these changes by increasing the frequency of extreme weather events, such as thunderstorms, which can elevate the concentration of airborne pollen.<sup>12</sup> Mechanistically, the moisture in the clouds causes these pollen grains to rupture, breaking them down into much smaller particles—typically around 2.5  $\mu\text{m}$  in size.<sup>13</sup> These fine particles then descend to the ground level, where they can be inhaled by individuals with pollen allergies and asthma. In susceptible people, this phenomenon can worsen issues such as seasonal pollen overload.<sup>7,14</sup> An illustrative example of the use of allergy-causing plants in public spaces is the widespread planting of birch trees. Birch trees produce pollen containing the major allergen Bet v 1, which is a common cause of seasonal allergies in North America, Europe, and parts of Asia.<sup>15</sup> Public data on urban tree distribution in major German cities report an average of 36.2 birch trees per square kilometer in Berlin, with the highest concentration in Rostock at 129.4 birch trees per square kilometer.<sup>16</sup> In Europe, the prevalence of positive skin prick tests to birch allergens ranges from 5% in the Netherlands to 54% in Switzerland.<sup>10</sup> Meanwhile, birch, the ornamental plant of choice for architects, particularly in northern Italy, has led to a notable rise in allergic sensitization to this allergen.<sup>17</sup>

These shifting patterns in pollen distribution and allergen exposure highlight the need for careful urban planning and environmental policies to prevent well-intentioned green initiatives from exacerbating allergic reactions among urban populations.

## URBAN GARDENS

The planetary health and aesthetic benefits of urban gardens and rewilded yards are many. In a 1-month-long intervention trial made among 3- to 5-year-old daycare children, microbially oriented rewilding of urban daycare yards enriched skin microbiota and enhanced immune modulation, measured as a change in the blood IL-10 level.<sup>18</sup> When the same children were followed for 1 year, the microbiological changes persisted.<sup>19</sup> Because the clinical trial was performed using forest floor vegetation and planting boxes, it was not possible to separate the impact of microbes from the possible effects of sensing green.<sup>20</sup> This weakness was overcome in 2 placebo-controlled, double-blind intervention trials, in which volunteers were in daily contact with microbiologically diverse soil or placebo soil that contained microbiologically poor peat.<sup>21,22</sup> In both trials, the immune modulation of the placebo group deteriorated, while it enhanced in the intervention group similarly to Roslund et al.<sup>18</sup> Unfortunately, long-term trials that target disease prevention are not finished yet. However, the frequency of forest visits was inversely associated with the use of antihypertensive, asthma, and psychotropic medication among Finnish urbanites in a cross-sectional survey of over 7000 participants. In addition, exposure to farm-like microbiota in nonfarm homes is known to protect children from asthma development.<sup>23</sup> However, a recent study showed that newer outdoor gardens during colder seasons

**TABLE I.** Examples of common plants in Europe unadvisable for urban gardens due to allergy-causing effects

Plant species	Distribution within Europe	Pollination mechanism	Allergy concern	Cross-reactivity
Birch ( <i>Betula</i> spp.) <sup>10</sup>	All	Wind	High pollen production; Bet v 1 allergen	Fruits, other tree pollen
Hazel ( <i>Corylus</i> spp.) <sup>28</sup>	All	Wind	High pollen production; Cor a 1	Birch
Cypress ( <i>Cupressus</i> spp.) <sup>29</sup>	Mediterranean	Wind	Produces highly allergenic pollen	Other conifers
Olive ( <i>Olea europaea</i> ) <sup>30</sup>	Mediterranean	Wind	Ole e 1 allergen; highly allergenic pollen	Other Oleaceae plants
Plane ( <i>Platanus</i> spp.)	Eastern Europe	Wind	Common urban tree; produces significant allergenic pollen	Limited cross-reactivity
Grasses (all species) <sup>26,31</sup>	All	Wind	High pollen count; includes many allergenic species	Other grass species

show reduced microbial diversity and the increased presence of respiratory disease-associated microbes, which may contribute to increased respiratory disease prevalence.<sup>24</sup> Taken together, existing data on garden and yard microbiota point out that urban green spaces should be designed in a way that ensures rich microbiota that have been demonstrated to provide substantial allergy-related health benefits.

Also, many government policies and subsidies worldwide promote the construction of green roofs, which offer many benefits such as air filtration, urban heat island effect mitigation, habitat and safe crossing for certain insects and bird species, and providing building insulation and stormwater capture.<sup>25</sup> However, whether designing a green roof or an urban garden, certain parameters should be considered when selecting plants for these green spaces for allergy-friendly options.<sup>26</sup>

Plant monocultures provide less niches to soil and above-ground microbiota and invertebrates than multispecies plant communities, and therefore composted or otherwise microbiologically rich and diverse soil and multispecies plant communities are recommended.<sup>27</sup> Table I lists some examples of common plants found in Europe that are unadvisable for planting in urban gardens due to potential to cause allergies, based on their pollination mechanism and cross-reactivity, reported in available literature. For instance, the potential pollen load produced by trees can be quite high, with a single tree producing up to  $550.9 \times 10^8$  pollen grains per season.<sup>32</sup> In addition, pollen cross-reactivity is common among all grass species<sup>31</sup> and can also occur between unrelated species, such as the Fra a 1 protein in strawberries and Bet v 1 in birch trees, leading to cross-reactivity in individuals with birch pollen allergies.<sup>33</sup>

In man-made gardens, the diversity of plant species is often limited, promoting high production of monospecific pollen.<sup>34</sup> To mitigate these issues, it is advisable to plant species in balanced ratios, avoiding the over-representation of any single species. Moreover, the phenomenon of “botanical sexism,” which refers to the preferential planting of pollen-intensive male plants over fruit-producing female plants, should be avoided by correctly calculating and balancing the gender ratio of plants.<sup>35</sup>

Thus, careful planning and species selection in urban green spaces are essential to minimize allergenic impacts while maximizing the environmental and aesthetic benefits.

### INDOOR ENVIRONMENTS AND ALLERGIES

Several initiatives have emerged to mitigate the impact of allergy-causing factors, especially in indoor environments where density of urban populations can exacerbate allergy risk. To address these concerns, the European Centre for Allergy Research

Foundation (ECARF) has established allergy-friendly criteria for building construction.<sup>36</sup> However, challenges persist in public spaces such as schools, where large numbers of people gather in confined areas and where children are typically exposed to miniscule levels of biodiversity due to scarcity of diverse yard vegetation.<sup>18,19</sup> The interactions of many individuals in these enclosed spaces have not been extensively studied concerning their contribution to allergies and asthma. For instance, indoor allergens such as pet hair can be inadvertently introduced on clothing, potentially exacerbating allergy symptoms or asthma.<sup>37</sup> In addition, increased oxygen consumption and changes in room humidity can promote mold growth, further worsening respiratory conditions. Indoor green walls may be beneficial in these settings as they can provide air filtration and may even promote immune modulation.<sup>38</sup> The European project SynAir-G, involving the Global Allergy and Asthma Excellence Network, is currently taking the lead in this field to investigate the role of indoor spaces in maintaining healthy environments.<sup>39</sup>

Prioritizing allergy-friendly, sustainable design in indoor urban environments is essential for creating healthier spaces. Enhanced insulation and natural climate control, combined with features such as green walls and diverse vegetation, can improve air quality, regulate indoor humidity, and provide immune support. Such approaches reduce allergen exposure and promote sustainability, contributing to comfortable, resilient urban living spaces for all ages.

### DISCUSSION

In the context of urban living and environmental sustainability, the choice of plants in urban areas requires careful attention to health impacts and should be an integral plan of urban development. Urban centers urgently need robust vegetation and microbiologically live soils to mitigate the impacts of climate change and maintain biodiversity, while supporting both human and planetary health. The focus on allergy-friendly options is essential to ensure that urban environments remain healthy and comfortable for all residents, especially in areas where air pollution is a significant concern. The main selection criteria for allergy-friendly urban vegetation discussed in this review are summarized in Table II. Selecting allergy-friendly plants (non-wind pollinating), establishing multispecies plant communities, and balancing plant gender ratios for green roofs and urban gardens are crucial. Recently described examples of such plants can guide landscapers in making informed choices.<sup>26</sup> However, in light of positive developments, such as the ECARF Foundation’s recent allergy-friendly island of Borkum, a German island in the North Sea, it is evident that allergy-friendly green

**TABLE II.** Allergy-friendly urban vegetation selection criteria

Criteria	Description	Benefits
Minimize wind-pollinated plants	Avoid plants such as birch, grasses, and cypress that produce high pollen counts	Reduces pollen-induced allergies and associated health burdens
Promote multispecies plant communities	Avoid concentrated planting of single species in a single green area to avoid single high concentration of particular pollen types	Enhances biodiversity and provides ecosystem services such as air filtration and soil enrichment while reducing single pollen load
Balance plant gender ratios	Avoid overplanting male plants that release excessive pollen (“botanical sexism”)	Helps control pollen levels and ensures balanced ecosystem functioning
Select heat-resistant and nonallergenic plants	Use plants that withstand urban heat and avoid allergenic volatile organic compounds	Supports urban sustainability while mitigating allergic reactions
Incorporate microbiota-enriching elements	Design with microbiologically rich soils and farm-like microbes	Boosts immune modulation and reduces asthma/allergy risks

landscaping, parks, and green spaces can be effectively implemented.<sup>40</sup> Borkum’s exceptionally clean air, rich in iodine and aerosols, and low pollen count provide ideal conditions for a healthy and relaxing holiday for guests with allergies.

### POTENTIAL FUTURE DIRECTIONS

For future health conscious and sustainable design studies, several directions are proposed. One relatively unexplored field is the production of plant volatiles; there are cases in which people have experienced severe allergic symptoms due to VOC exposure released by plants.<sup>41</sup> In addition, prioritizing research into heat-resistant varieties that comply with the health considerations is essential. This research should also carefully evaluate the ecological risks of introducing non-native species. For instance, *Ailanthus altissima*, commonly known as “The Tree of Heaven,” is a major allergen source in China and has already spread to Europe where a notable increase in positive skin tests is occurring.<sup>42</sup> Similarly, although olive and hazel trees are valuable for their fruit in rural agricultural regions, their pollen becomes more aggressive when combined with urban dust particles, making them less suitable for city environments.<sup>43,44</sup>

In parallel with allergy-friendly decision-making that allows currently sensitized people to enjoy life, it is crucial to design environments that prevent sensitization and development of noncommunicable, particularly immune-mediated diseases. This covers 2 air filtration aspects: the pollutant absorbing ability of plants and the enhanced pollutant degradation in organic soils.<sup>19,45–51</sup> There is space for new innovations and the search and development of plant species and cultivars that withstand trampling and, in some cases, heavy cutting. For example, the ability to sprout quickly is an advantage in high-traffic areas such as daycare yards. In summary, advancing allergy-friendly and resilient plant options can enhance urban sustainability and public health.

In conclusion, this review underscores the necessity of balancing the need for robust urban vegetation with the imperative of minimizing allergenic pollen. The principles discussed, although focused on European urban environments, have global applicability. Future research and urban planning efforts should continue to integrate these dual goals to create sustainable, allergy-friendly urban spaces.

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