A Study on Urban Vegetation and Pollen Allergy in Beijing

Jiayi Liu *

International Department, Beijing No. 35 High School, Beijing, China

* Corresponding Author Email: floraljy@163.com

Abstract. Beijing, as an ecological city with a forest coverage rate reaching 44.95%, significantly benefits from its abundant vegetation resources which improve the urban environmental quality. However, the dense distribution of numerous anemophilous (wind-pollinating) plants makes it a high-incidence area for seasonal pollen allergies in Northern China. Pollen allergy can trigger severe immune responses, with some patients even experiencing health-threatening complications. Although the literature on pollen allergy in Beijing is relatively rich, existing findings are dispersed across the fields of botany, environmental science, and medicine, lacking systematic integration. Comprehensive research is particularly insufficient regarding the spatiotemporal distribution patterns of allergenic plants, the dynamics of pollen dispersal, and the analysis of their association with allergy symptoms. This paper systematically analyzes the types, sensitization mechanisms, and control measures of major allergenic plants in the Beijing area. It clarifies the differences in sensitization risks between native and introduced species, reviews the research progress on allergy mechanisms and pollen dispersal dynamics, and proposes recommendations for constructing a pollen allergy prevention and control system. This study provides an important reference for a deeper understanding of the pollen allergy issue in Beijing and lays a scientific foundation for the formulation of subsequent control strategies.

Keywords: Pollen allergy; Beijing vegetation; Allergenic plants; Immune mechanism; Prevention and control strategies.

1. Introduction

Pollen is one of the major outdoor allergens that has posed a large and growing concern in public health worldwide. According to the World Health Organization, over the next 20 years, about 35% of the world's population will suffer from pollen allergy diseases, and diseases associated with allergic rhinitis and asthma will impose a huge burden on human health and social productivity. Epidemiological data have demonstrated the adult disease prevalence of pollen allergies in developed countries to be 20%–30% and childhood disease prevalence to be up to 40%. In the northern region of China, due to specific types of vegetation landscape characteristics and climatic conditions, the issue of pollen allergy has become a more prominent concern. Between 25% and 33% of respiratory allergic diseases in the region of Beijing are directly attributable to pollen. Climate warming increases spatial-temporal expansion of pollen pollution. For example, the pollen season has been extended by 20 days and the concentration has increased by 21% since 1990 in North America. In Beijing, the period of heightened spring pollen takes an advance because of increasing temperatures, and the risk of sensitization from tree pollen (like Sabina chinensis and Populus) is much larger precursively than that from weed pollen in later seasons. summer and fall.

Pollen allergy research was initiated in the mid-19th century into the pathogenic mechanisms. In 1819, John Bostock, a British physician, described for the first time the disease termed "hay fever." It was in 1873 that Blackley experimentally proved its occurrence due to pollen contact and formally established the term "pollinosis." The modern immunological study established that the Type I hypersensitivity reaction mediated by IgE is the basic mechanism of development in pollen allergy: proteins of pollen bind with immunoglobulins and thus histamine is released. The symptoms include edema of the mucosal membrane, rhinitis, and asthma, etc. Over 150 allergenic pollen proteins have been identified across the world, with anemophilous plants being their primary sources due to the massive production of pollen grains as the male reproductive agents. Local studies have shown that in Europe and America, sensitization is highest to timothy grass and other grass pollens and concentration has correlation with emergency visits due to asthma. Prevalence of pollinosis in Japan is attributed to the expansion of Japanese cedar (Cryptomeria japonica) plantations and it stands at 42.5%. The leading allergens in Northern China are Sabina chinensis and Artemisia species, and in the South are dust mites and mold spores. It is only under such circumstances that the symptoms are relatively held back by desensitization and antihistamines therapy, according to the Peking Union Medical College Hospital research. When sensitized pollen concentrations reach the threshold, the efficacy of treatment is considered to be virtually non-existent. Therefore, source allergenic plant control, i.e., high-risk tree species replacement, along with accurate pollen forecast systems, e.g. pollen distribution maps, has become the major research and control direction.

This paper systematically reviews research on pollen allergies in Beijing from the characteristics of vegetation cover, mechanisms of sensitization to pollen, dynamics of dispersal, and strategies for control. It is toward revealing the distribution patterns of allergenic flora and their relationship with allergy symptoms as a basis for accuracy in preventing and managing an allergic reaction to pollen. This, in turn, would provide reference material for drawing up a plan that involves both urban ecological planning and public health policies.

2. Beijing's Vegetation and Allergies

At 44.95% forest coverage, Beijing is an ecological city with rich vegetation resources. Its urban forests play important roles in heat island mitigation, noise reduction, air purification, rainwater interception, and the maintenance of biodiversity. Data indicate 2714 species of vascular plants in Beijing, of 178 families and 1024 genera, within the city proper. The percentage of forest coverage in the area increased from 12.83% in 1980 to 44.95% in 2024. There are 21 arboreal tree species (including varieties/cultivars) in the region, with 13 families and 17 genera. Of these, 5 are evergreen coniferous trees (in 2 families and 4 genera) and 16 are deciduous broad-leaved trees (11 families and 13 genera) [1]. On the other hand, the plentiful greenery comprises many allergic plants. These plants, pollinated by wind, release lots of pollen supplied in spring and fall, making Beijing an area with high incidence of seasonal pollen allergies in Northern China [2].

Allergenic flora is represented by 68 species from 25 families and 41 genera, among which 36 are tree species, 5 shrub species, and 27 herbaceous species. Major allergenic species are, therefore, Artemisia (Asteraceae), Humulus (Moraceae), and grasses (Gramineae) [3]. The small percentage of highly allergenic pollen comes from roadside green spaces and urban derelict lands. In terms of species origin, out of 68 allergenic plant species, 36 are native (53%) and 32 introduced (47%), with the main type being North Temperate (in 42% of the 41 genera) [4]. Other research found peak flowering periods of allergenic plants to be in spring (March to April) and autumn (July to September), very well defined seasonally. Pollen from Cupressaceae comes into a sharp rise in spring, starting in March (average temperature 6–13°C). Check the data of the monitoring. In March, the concentration of Cupressus pollen reached 12,918 grains/m^3, accounting for 57.1% of the total count for that month. It is in mid-April when we see the flowering peak of arboreal allergenic Oleaceae, Pinaceae, Cupressaceae, and Moraceae. Among these, the concentration of Platanus pollen was the highest at 8,640 grains/m^3, which is 32.6% of the total count for that month. The autumn pollen peak falls in August–September. This is mostly composed of herbaceous plant groups which include Artemisia, Humulus, Ambrosia, Polygonaceae, and Amaranthaceae. The concentration is for Artemisia pollen, with 2,780 grains/m^3 in August (36.7%) and 4,052 grains/m^3 in September (50.5%) [5]. These high-concentration pollen grains' seasonal distribution is the main cause of the heightened incidence of pollen allergy in Beijing.

Table 1. Major Plants in Beijing.

Numbering	Tree Species	Scientific Name	Frequentness/%
1	Sophora japonica	Sophora japonica	34.51
2	Populus tomentosa	Populus tomentosa	12.68
3	Fraxinus microphylla	Fraxinus pennsylvanica x Fraxinus velutina	11.97
4	Ginkgo biloba	Ginkgo biloba	7.75
5	Ailanthus altissima	Ailanthus altissima	6.34
6	Fraxinus chinensis	Fraxinus pennsylvanica	5.63
7	Platanus occidentalis	Platanus occidentalis	4.93
8	Koelreuteria Paniculata	Koelreuteria paniculata	4.93
9	Chinese pine	Pinus tabulaeformis	1.41
10	Juniper	Sabina chinensis	1.40
11	Populus canadensis	Populus canadensis	1.41
12	Early willow	Salix matsudana	1.41
13	Cedar	Cedrus deodara	0.70
14	Pinus bungeana	Pinus bungeana	0.70
15	Platycladus orientalis	Platycladus orientalis	0.70
16	Magnolia	Magnolia denudata	0.70
17	Elm	Ulmus pumila	0.70
18	Robinia pseudoacacia	Robinia pseudoacacia	0.70
19	Ailanthus altissima	Ailanthus altissima ‘Qiantou'	0.70
20	Paulownia tomentosa	Paulownia tomentosa	0.70
21	Golden Tree	Catalpa speciosa	*N/A*

3. Relationship between Plants and Allergies

Pollen allergy can induce a variety of clinical symptoms, including seasonal allergic rhinitis, allergic asthma, allergic conjunctivitis, and skin inflammation. Common symptoms involve the respiratory system, such as nasal congestion, nasal itching, frequent sneezing, clear watery nasal discharge, and pharyngeal discomfort. Severe cases can trigger asthma or even become life-threatening. This section systematically analyzes the association mechanisms between plants and pollen allergy from three aspects: the immune mechanism of pollen allergy, pollen structural characteristics, and environmental influencing factors.

3.1. Core Mechanism of Allergy

Pollen allergens elicit a type-I hypersensitivity reaction in pollen-sensitive atopic individuals. This is mediated by the immunoglobin-E or IgE antibodies detected in the serum of allergic individuals. Other antibody classes such as IgG are also generally detected. On subsequent allergen encounters, the antibodies bind to the antigens leading to the release of potent mediators from mast cells and basophils. The high affinity IgE receptor on mast cells and basophils is occupied, and these get cross-linked following the first exposure to pollen allergens in sensitive individuals. The process of sensitization is two-fold: first, allergens gain access to the hydrophilic milieu of the body and express a myriad of allergenic proteins and other bioactive molecules which set up an inflammatory environment polarized by Th2 cells; second, specific B cell line stimulation by IL-4 and IL-13 resulted in IgE synthesis. IgE, or the immunoglobulin responsible for allergic reactions, binds to high-affinity receptors (FcεRI) on the surface of mast cells and basophils. Thereby it places the body in a sensitized state already challenged by antigens. Effector cells then further react to the antigen challenge of the mast cells and basophils that are bound to surface IgE specific for that allergen, leading to the release of vasodilators, increased vascular permeability agents, and smooth muscle activators. Constriction of the bronchia then later results in bronchial and other upper respiratory constrictions; hence, the symptoms of allergies such as nasal swelling, running, and repeated sneezing may proceed, in acute cases to systemic anaphylactic reactions or asthma [6].

T cells are very important in allergic reactions. There are two types of CD4+ T helper cells. Th1 and Th2. The former secrets IL-2, IFN-γ, and TNF-α and carries out cell-mediated immunity; IL-4, IL-5, etc are secreted by the latter and is closely related to immediate hypersensitivity reactions [7]. Pollen allergens selectively activate Th2 cells. Thus, there is an imbalance in the Th2/Th1 ratio. Leading to too much IgE for the allergic cascade to occur subsequently [8].

3.2. Structure and Dispersal Characteristics of Pollen

3.2.1 Pollen Structure

Pollen is the male gametophyte of seed plants, highly variable in its morphology but commonly consists of the following typical components: (1) Sporoderm, comprising the exine and intine. The exine is the outer layer, while the intine is the inner one. The exine layer is made up of sporopollenin, exhibiting very high chemical stability against acids and bases. The intine layer, comprising cellulose and pectin, contacts the stigma and takes up water. (2) Aperture: The number and arrangement of apertures in different species (e.g., monoporate, tricolpate, tricolporate) are the routes for the entry of the pollen tube and hence directly related to the mode of dispersal as well as the reproductive success. Anemophilous pollen is designed for wind dispersal and hence usually small (15–50 μm) and light (e.g., Pinus). Some species (e.g., Picea) have saccate (air sacs) to further increase the volume for buoyancy and, thus, the time of suspension in the air, hence increasing the effectiveness of dispersal [2].

3.2.2 Environmental Factors Affecting Pollen Dispersal

Pollen dispersal is regulated by multiple environmental factors, significantly impacting its concentration and allergenic risk:

Temperature: Anther dehydration and anther wall involution are processes retarded at lower temperatures and, therefore, release of the pollen also. It means that as long as the condition is wet and the morning temperature especially does not climb above spring-summery daily variation, there is normally no explosive pollen dispersal. Prolonged suspension time results since high temperatures cause thermal turbulence close to the surface, carrying pollens to heights of hundreds of meters. Research shows that the pollen vertical transportation height can go up from 10 m to 30 m when the surface temperature is 8°C higher than the air temperature and the horizontal dispersal area also increases by 3-5 times. Turbulence is suppressed under nocturnal temperature inversions, and the pollen remains lifted near the ground, which creates a kind of "pollen fog" [5].

Humidity: Low humidity (RH<40%) reduces the adhesion force on the pollen surface, promoting detachment from the anther, but may cause the exine lipid layer to become brittle, damaging the aperture. High humidity (RH 60%–70%) causes pollen to absorb water and swell, increasing the settling velocity by about 1.5 times, showing a weak negative correlation with pollen concentration [2].

Wind Speed and Wind Field: At a wind speed of 0.5–5 m/s, the linear positive correlation between wind speed and pollen dispersal flux is realized. At this maximum threshold of wind speed, which is 8 m/s, the rate of collision and fragmentation of pollen increases. The proportion of intact pollen will drop to below 30%. Under the influence of the vortex shedding around building structures, the pollen is lifted up again, and the pollen concentrations in towns are 2–3 times higher than in open terrain. When the gusty wind coincides with the plants' vibrating time, the pollen grains' amount discharged at once can be increased to 70% [5].

Light: Light promotes the drying and dehiscence of pollen sacs and pollen maturation. Strong light intensity (>5000 lx) combined with dry climate can significantly increase pollen release, especially during clear spring weather, easily leading to high-concentration pollen dispersal [2].

3.3. Seasonal Characteristics of Allergies and Allergens

The incidence of pollen allergy is highly correlated with pollen concentration and its seasonal distribution. Hospital data from the Beijing area show that the peak visit month for the Allergy Department is August (13.5% of the annual total), for the Otolaryngology Department is June (16.5%), and for the Respiratory Department is December (15.7%). Overall, there are two peaks: spring (March–April) and autumn (August–September) [9]. This trend aligns with the flowering period distribution of allergenic plants in Beijing's urban area: spring is dominated by tree pollen (e.g., Cupressus, Platanus), while autumn is dominated by herbaceous pollen (e.g., Artemisia, Humulus). The bimodal seasonal characteristic of pollen concentration is highly consistent with the changes in the number of visits for allergic rhinitis, asthma, and other related diseases, indicating that pollen exposure is the main driver of seasonal fluctuations in allergies in Beijing. Further analysis reveals a strong correlation between the high concentration of Artemisia pollen in autumn (accounting for 50.5% in September) and the peak visits to allergy departments, highlighting the critical role of herbaceous plants in autumn allergy prevention and control [5].

4. Prevention and Treatment of Pollen Allergy

4.1. Prevention Measures

Prevention of pollen allergy requires addressing both source control and individual protection, combined with ecological planning, monitoring and early warning, and public behavior intervention to form a multi-layered control system.

Design and Plant Selection: In the planning of urban greening, low-allergenic plants should be used, and the use of highly allergenic species should be minimal. Such highly allergenic species include for example Juniperus and Thuja and also Prunus persica (Mountain Peach) and Prunus persica var. duplex (Flowering Peach) and further Pinus bungeana (Lacebark Pine) and Pinus tabuliformis (Chinese Pine) and any type of Cedar and Populus tomentosa (Chinese White Poplar) as well as herbaceous plants from the Polygonaceae, and Amaranthaceae, Gramineae, Humulus, species from Artemisia, and Ambrosia species (Asteraceae) [3]. Either less pollenic species or entomophile-pollinated, for example Ligustrum or Malus, can be considered from the alternatives suggested. Do not plant allergenic species in upwind places regarding the city's center or the most populous parts of the city. Rather than these, give priority to plant highly allergenic species in such parts as sparsely populated suburban parks or isolation belts.

Plant Management: In the case of existing highly allergic plants, good daily management can help reduce the release of pollen. Measures are as follows: (i) Pruning the branches of flowers to reduce pollen production, and this should be done very frequently; (ii) Spraying water mist to suppress the dispersion of pollen; (iii) Growth regulators or pollen inhibitors such as ethephon should be injected to induce the flowering cycle. The injection application should be noted with monitoring the flowering period for proper and effective intervention [10].

The Pollen Monitoring and Forecasting System: Constructing a pollen forecasting system would be considered the primary way to avoid pollen allergies. Long-term concentrations monitored at multiple sites in Beijing, on meteorological parameters (temperature, wind speed, humidity, and more), and the pollen count will be replaced by phenological information like Leaf Area Index (LAI) derived from satellite remote sensing data. Algorithms such as Orthogonal Screening Regression and NARX neural networks will be utilized to develop high- to medium-term term pollen concentration forecast models [11]. In turn, this model output information will be converted into attractive forecast products in both text and graphical formats via digital media, depicting real-time pollen concentration levels, allergenic risk levels, and recommendations for protection to the general public. For instance, Beijing can adopt the Pollen Map model of Europe and America, and then add a mobile app push in place, to help the allergic to plan when and how to protect.

Individual Protection Measures: The public can reduce pollen exposure through the following methods: (1) Avoid pollen and thunderstorms (where the former can induce rupture of pollen grains and the release of sub-micron allergenic particles increasing the individual risk of allergies) [12] and stay indoors at home during the hours of greatest pollen presence, typically between 5 and 10 in the morning in the spring and early evening in the fall; (2) Wear a mask, glasses, and overalls to cover all skin surfaces when outside; (3) Wash the nasal cavity, face, and eyes with isotonic saline or clean water after returning home to eliminate any remaining pollen; (4) Keep the indoor pollen count lower than the outdoor by keeping doors and windows closed-F use fresh air systems or air purifiers and then clean the home, too. Indoor use of pollen is also suggested by the preventive use of antihistamines by sensitive persons if they contact a physician prior to the pollen season.

4.2. Treatment Methods

The treatment of pollen allergy primarily involves pharmacological intervention and immunotherapy, aimed at alleviating symptoms and reducing long-term allergy risks.

Pharmacological Treatment: Acute symptoms such as nasal congestion, rhinorrhea, and sneezing can be relieved by the fast action of H1 antihistamines such as cetirizine or loratadine; Late-phase reactions, in this case, allergic asthma, can be treated with leukotrienes Montelukast.; Glucocorticosteroids such as budesonide have a wide range of anti-inflammatory effects and can reduce nasal mucosal as well as respiratory symptoms; Oral 5-Lipoxygenase inhibitors such as zileuton can be taken prophylactically to help a patient to stay without any symptoms during the pollen season. In supplementary therapy for allergic reactions to pollen, the disease can be controlled only by the administration of Minkang tablets or traditional Chinese medicine specific to the TCM syndrome under the guidance of the diagnosis "Bi Qiu" and "Yin Zhen". This is applicable only for mild-to-moderate patients and not for a large population [13].

Allergen-Specific Immunotherapy (AIT): AIT uses incremental doses of pollen allergens administered either sublingually or via subcutaneous injection to increase the patient’s tolerance for the long-term suppression or elimination of symptoms. This therapy normally lasts between 3 to 5 years during which the possibility of the allergic disease transformation, for instance, allergic rhinitis to asthma is completely preventable [14]. The clinical study has provided that the efficiency of AIT is 70%–80% for main allergic pollens such as Artemisia and Cupressus. AIT should be taken in professional medical institutions.

5. Conclusion

Beijing is an ecological city with high vegetal coverage and, thus, greatly benefits from its urban forests in improving environmental quality. However, on the other side, the presence of anemophilous pollen grains from many plants increases the public health risk regarding allergic reactions. In this research, through a systematic analysis, the spatiotemporal distribution pattern of allergenic flora in Beijing is gradually clarified. That is, the peak periods at which the pollen release is concentrated are spring (March to April, where the main types are tree pollens like Cupressus and Platanus) and autumn (August to September, where the main types are herbaceous pollens like Artemisia). Environmental dynamic analysis shows that the surface radiation temperature difference enhances thermal turbulence and therefore accelerates the range of dispersal of pollen. A resonance in wind gusts with plant vibration frequencies could increase the release of pollen by 70%. The vortex effect of urban building groups will further increase the secondary suspension of pollen. The urban area will have 2–3 times more pollen concentration than the open area. Information on allergy mechanisms reveals that pollen allergy is fundamentally based on the IgE-mediated Type I hypersensitivity reaction, imbalanced in Th2/Th1, from where provocative factors flow to cause such symptoms as rhinitis and asthma.

To combat pollen allergies, this paper suggests building a multi-level system for prevention and control: (1) Improve green design with a priority for low-allergy plants and adjust the planting layout for highly allergic species; (2) Management of the existing plants through pruning, spraying, and intervention of inhibitors that control the release of pollen; (3) A pollen forecasting system, integrating meteorological data, vegetation phenology, and machine learning algorithms for 72 hours accurate forecasting; and (4) The graded protection guidelines that encourage the public to use medical masks, nasal physical barriers, and purification devices. Effective medications to relieve symptoms and decrease long-term risks include antihistamines, glucocorticosteroids, and AIT. Early symptom onsets with the beginning of the pollen seasons due to climate warming and the potential allergenic risk of invasive species, such as ragweed (Ambrosia), should be monitored in the long run.

This study reveals the driving mechanisms and control pathways for pollen allergy in Beijing, integrating evidence from ecology, meteorology, and medicine. It provides a scientific basis for balancing ecological construction and public health security in megacities. The study future quantifies pollen exposure thresholds for sensitive populations, to optimize precise control strategies and to explore the long-term impact of invasive species on allergy risks under climate change scenarios where this research will be able to support the sustainable development of Beijing as an ecological city.

References

[1] Hu L L, Ma J L, Zhao J M, et al. Composition and distribution characteristics of vascular plants in Beijing. Chinese Journal of Ecology, 2023, 42(12): 2903-2910. DOI:10.13292/j.1000-4890.202312.026.

[2] Yang Y. Study on the dispersal patterns and influencing factors of tree pollen in Beijing urban area. Beijing Forestry University, 2007.

[3] Xiao L, Wang C Y, Song T Y, et al. Research progress on pollen exposure characteristics and sensitization risk assessment in urban green spaces. Chinese Urban Forestry, 2022, 20(06): 159-167.

[4] Zhu Y N. Distribution characteristics and prevention of pollen allergenic plants in communities of Changping District, Beijing. Chinese Academy of Forestry, 2022. DOI:10.27625/d.cnki.gzlky.2022.000311.

[5] Wang X Y, Ning H Y, Chu S M, et al. Analysis of sensitization characteristics of tree pollen allergens in Beijing area. Journal of Clinical Otorhinolaryngology Head and Neck Surgery, 2017, 31(23): 5. DOI:10.13201/j.issn.1001-1781.2017.23.010.

[6] Gilles-Stein S, Beck I. Initiating pollen sensitization – complex source, complex mechanisms. Clinical and Translational Allergy, 2020, 10(1): 36.

[7] Xie Z J, Guan K, Yin J. Advances in the clinical and mechanism research of pollen induced seasonal allergic asthma. American Journal of Clinical and Experimental Immunology, 2019, 8(1): 1-8.

[8] Yang Q L, Ouyang T, Yan H, et al. Research progress on pollen allergy. Chinese Agricultural Science Bulletin, 2015, 31(24): 5. DOI:CNKI:SUN:ZNTB.0.2015-24-028.

[9] Wang X Y, Tian Z M, Ning H Y, et al. Analysis of the relationship between airborne pollen distribution and allergic disease visits in Beijing urban area. Journal of Clinical Otorhinolaryngology Head and Neck Surgery, 2017, 31(10): 5. DOI:CNKI:SUN:LCEH.0.2017-10-006.

[10] Cariñanos P, Marinangeli F. Urban green spaces and pollen allergy: opportunities and challenges for management. Landscape and Urban Planning, 2021, 208: 104039.

[11] Wang Q Z. Research on automatic pollen detection algorithm based on deep learning. [Reference incomplete].

[12] Zhang D S, Hai Y L, Feng T, et al. Application research on 1-4 day pollen concentration forecast in Beijing area. Meteorology, 2010, (5): 128-132. DOI:10.7519/j.issn.1000-0526.2010.5.020.

[13] Bousquet J, Bachert C, Bernstein D, et al. Advances in pharmacotherapy for allergic rhinitis: a focus on second-generation antihistamines and intranasal corticosteroids. Allergy, 2021, 76(6): 1667-1681.

[14] Wang L, Zhu L Z, Shen X D, et al. Research status and coping measures of pollen allergy. Modern Horticulture, 2025, 48(1): 31-36. DOI:10.3969/j.issn.1006-4958.2025.01.010.