The Allergy Trigger Atlas: Spatial and Biological drivers of plant sensitization in China

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Research

Abstract

Background: The rising prevalence of allergic diseases in China, driven by extensive biodiversity and widespread allergenic plants, has become a significant public health concern. This study investigates the distribution patterns, phylogenetic diversity, and seasonal dynamics of allergenic plants across China to assess regional and temporal allergy risks.

Methods: Using species distribution data from the *Flora of China*, National Specimen and Infrastructure (NSII), and GIS-based spatial analysis. Phylogenetic analysis under the APG IV framework revealed that allergenic plants are polyphyletic, distributed across multiple evolutionary lineages.

Results: The findings reveal that (1) 1,668 allergenic plant species were identified, Southwest China faces the highest allergy risk, with Southern cities generally surpassing Northern China in allergy risk due to high species richness and climatic conditions favoring pollen dispersal; (2) Spring poses the highest allergy risk, seasonal analysis shows spring (March-May) as the peak period for pollen-related allergies, driven by woody plants followed by summer and autumn; (3) The distribution of allergic plant species in Chinese cities is generally scattered or random, contributing to intricate and sporadic allergic scenarios; (4) Certain evolutionary branches have high number of allergenic plant species, but the phylogeny signal of all the 38 genera is weak.

Conclusions: This study provides crucial insights into the geographical and seasonal dynamics of allergic plants in China, facilitating a more informed approach to allergy management. It finds consistency in seasonal distribution conclusions. Climate affects allergic plant distribution. Suggestions are given for urban greening and travel.

Keywords: Allergenic plants; China; phylogenetic diversity; sensitization pattern; seasonal distribution

摘要

*背景：*在中国，由于丰富的生物多样性和广泛分布的致敏植物，过敏性疾病发病率不断上升，已成为重大公共卫生问题。本研究通过探究中国致敏植物的分布格局、系统发育多样性及季节动态，评估区域性与季节性过敏风险。

*材料与方法：*基于《中国植物志》、国家标本资源共享平台（NSII）的物种分布数据，结合 GIS 空间分析技术展开研究。根据 APG IV 分类系统进行的系统发育分析表明，致敏植物具有多系起源特征，广泛分布于多个进化支系中。

*结果：*研究发现（1）共鉴定出 1,668 种致敏植物，中国西南地区因物种丰富度高且气候条件利于花粉传播，过敏风险居全国之首，南方城市总体风险高于北方；（2）春季（3-5 月）木本植物花粉释放导致过敏风险达到峰值，夏秋季次之；（3）中国城市中致敏植物多呈分散或随机分布，形成复杂零星的致敏格局；（4）特定进化支系含致敏植物种类较多，但 38 个属的系统发育信号均较弱。

*结论：*本研究揭示了致敏植物在中国的地理与季节分布规律，为过敏防控提供了科学依据。研究验证了季节分布结论的一致性，证实气候对致敏植物分布的影响，并为城市绿化建设和民众出行提出了建议。

*关键词：*致敏植物；中国；系统发育多样性；致敏模式；季节分布

Background

Allergic reactions induced by plants, particularly those related to pollen allergy, constitute prevalent challenges in the daily lives of individuals. The 2022 Epidemiological Survey Report and Status Analysis of Allergic Diseases in China underscores the surge in allergic disease prevalence in the country. Despite a relatively low incidence rate among patients with allergic diseases, the shortage of specialists has contributed to a significant economic burden (Zhao & Liu 2022). Globally, allergic rhinitis has a prevalence of 11%, with China experiencing an average incidence rate of 10-15%, with 30% attributed to allergic pollen. Currently, over ten million individuals suffer from allergic pollinosis, with an incidence rate ranging from 0.5% to 1%, and a 5% high incidence rate (Li *et al*. 2020, Xiao *et al*. 2011). China, rich in biodiversity, faces a mounting problem of plant allergies with a substantial impact on people's lives.

Given China's diverse geographical and climatic conditions, coupled with a wide array of plant species, the challenge of plant allergies becomes notably intricate. A comprehensive examination of Wang Yonghua's research on allergic plants identifies 38 genera worldwide causing human allergies. Further analysis based on these 38 genera, utilizing data from the Flora of China, reveals 1996 plants capable of inducing allergies in the country (Table 1). The diverse distribution and flowering seasons of these plants contribute to varied allergens, marked by significant regional and seasonal disparities (Wang 2005). The long-term selection of urban greening tree species, influenced by specific climatic and environmental factors, further amplifies the impact, as allergy-prone plants like poplar, willow, and *Artemisia annua* are extensively planted. Consequently, plant allergies exert a broad influence on the population (Shi *et al* 2019, Wu *et al*. 2015, Ma *et al*.2013, Liu *et al*. 2011, Zhou *et al*. 2008). In summary, China's rich plant diversity has led to a surge in plant allergy cases, transforming it into a pervasive concern. Considering the daily life risks of plant allergies in China, this study investigates the distribution pattern and phylogenetic diversity of allergic plants. It delves into the current situation and causes of plant allergies, scrutinizing allergic risks concerning different regions and seasons. The findings aim to offer a reference for allergic populations considering travel or residence choices.

Allergy risk depends on the diversity, quantity, pathogenicity, and pollination capacity of allergenic plants, with higher exposure and stronger reactions increasing susceptibility in sensitive individuals. 1. Allergy Risk from the Perspective of Species Diversity. The abundance of allergic plant species directly correlates with the heightened risk faced by individuals prone to allergies. Regions boasting a rich diversity of allergic plants pose a greater likelihood of allergic reactions among the "potential plant allergy population." This group may remain non-allergic in their original habitat, but exposure to a broader spectrum of allergic plants in tourist destinations can trigger allergic reactions. 2. Allergy Risk from the Perspective of Species Quantity. The quantity of allergic plant species also plays a pivotal role in determining the allergic risk for individuals. While two regions may share similar types of allergic plants, the one with a higher number of such plants presents a graver risk. A region with an extensive array of allergic plants increases the potential for contact between plants and individuals, elevating the overall risk of allergies. 3. Allergy Risk from Pathogenicity of Allergic Plants (Allergic Clinical Reaction). The clinical reactions induced by different types of allergic plants vary in pathogenicity. Some highly pathogenic plants may lead to more severe adverse reactions, extended recovery cycles, or more intolerable physiological responses. Consequently, plants with stronger clinical responses pose higher risks to individuals with allergies. 4. Pollination Capacity of Allergic Plants. Considering the sensitizing approaches of allergic plants, those requiring physical contact may not present high allergic risks. Therefore, emphasis is often placed on plants inducing allergies through airborne pollen transmission. Plants with substantial pollination capacities can disseminate large quantities of tree or flower pollen, significantly increasing the likelihood of individuals inhaling these particles, consequently heightening the risk of allergies.

In this comprehensive analysis, we aim to provide a nuanced understanding of the multifaceted factors contributing to plant allergies in China, offering valuable insights for individuals susceptible to allergies in their daily lives.

Materials and Methods

Study area

China, positioned in East Asia along the west coast of the Pacific, boasts a population exceeding 1.4 billion and holds a pivotal global demographic standing. Encompassing a vast territory of approximately 9.6 million square kilometers, China spans nearly 50 degrees of north-south latitude, predominantly residing in the temperate zone with a small portion in the tropical zone, featuring diverse climatic characteristics. Eight major research areas have been identified based on regional climatic distinctions: North China, the southeast coast, the middle and lower reaches of the Yangtze River, the northeast, the northwest, the southwest and Tibet, and the southern coast. In terms of living habits, the Yangtze River traditionally divides China into the north and south. Each of these eight regions exhibits distinct plant ecological conditions, contributing to varying patterns of allergic plant species distribution. For instance, Northeast and North China are primarily characterized by poplar and elm; the southeast coastal areas feature pine and *Artemisia* as dominant plants, while the southwest region is marked by *Morus* and *Campanula* (Cheng *et al*. 2015, Yang *et al*.2015). The regional diversity in the distribution of allergic plants results in a complex and varied landscape of plant allergy issues faced by the Chinese populace.

Data source

Species Diversity Data: This study utilizes species distribution data of allergic plants based on 38 genera compiled by Wang (Wang 2005). Extensive research involved browsing the Flora of China and examining flora across all levels of administrative regions, including 34 provincial administrative regions and 2358 municipal and county-level administrative regions. After screening, 1668 allergic plants were identified nationwide, and their locations were documented in tabular form to establish initial data on the distribution of allergic plants in China.

Plant Sample Distribution Data: The distribution records of Chinese allergic plant samples are drawn from NSII (National Specific Information Infrastructure). Utilizing data tables, GIS software is employed to convert and map the format, incorporating sample distribution records, standard collection information, and other relevant data.

Data Collation: With over 8.9 million pieces of data on allergic plant distribution, processing involves using C language standard library functions in Dev C++software. Techniques include employing the fopen() function for text processing, hash mapping functions in the map library for check and retrieval operations, and the sort() function in the algorithm library for reordering and reorganizing content. Multiple tables, such as flowering dates of allergic plants and types of allergic plants in different regions, are merged and formatted.

Data analysis

Distribution Map for Data Visualization. To enhance data comprehension, this study visualizes the distribution data of allergic plant species. ArcGIS software is employed to process data layers, incorporating GIS data of provincial and municipal/county administrative boundaries downloaded from China's national basic geographic information data website. The map adjusts color segmentation boundaries and colors based on specific data conditions.

Evolutionary Tree Construction. To explore the phylogenetic relationship of allergic plant species, an evolutionary tree is constructed using R language. The data of 1668 selected allergic plants are read through R language, and the "phylomaker" function in the "devtools" library of R language species is utilized to draw the tree diagram, exploring the evolutionary relationships among these plants. This information aims to provide a reference basis for the residence or travel decisions of allergic individuals in China. A phylogenetic tree was constructed based on a curated list of 38 allergenic plant genera. The tree was generated using the R package V.PhyloMaker2 (Jin and Qian, 2022), which enables large-scale tree construction using the GBOTB.extended mega-tree and the Taxonomic Name Resolution Service (TNRS). The final evolutionary tree was constructed under Scenario 3, where unmatched taxa are inserted at the genus level. Additional packages including openxlsx (for data import) and ape (for tree export and visualization) were used in the workflow. All computations were performed in R version 4.4.2.

Results

Genus Distribution of Allergic Plants

From the perspective of the number of allergic plant species, Salix has the highest number, followed by Ilex and Artemisia. However, the common belief is that poplar is the most likely to cause allergies. This suggests that willows contribute to more diverse allergic problems due to the presence of different species, whereas poplars are perceived as more stable with a relatively singular impact. Regions where poplar allergies are prevalent, such as in Land A, are likely to have similar situations in Land B.

Table 1. 38 genera of allergenic plants and the number of species in China

Family	Genus	Genus in Chinese	Species number
Salicaceae	*Salix*	柳属	383
Aquifoliaceae	*Ilex*	冬青属	258
Asteraceae	*Artemisia*	蒿属	245
Salicaceae	*Populus*	杨属	155
Aceraceae	*Acer*	槭属	138
Elaeagnaceae	*Elaeagnus*	胡颓子属	82
Fagaceae	*Quercus*	栎属	48
Betulaceae	*Betula*	桦木属	41
Oleaceae	*Ligustrum*	女贞属	40
Cupressaceae	*Juniperus*	刺柏属	32
Ulmaceae	*Ulmus*	榆属	29
Plantaginaceae	*Plantago*	车前属	27
Oleaceae	*Fraxinus*	梣属	24
Poaceae	*Achnatherum*	芨芨草属	19
Tamaricaceae	*Tamarix*	柽柳属	19
Chenopodiaceae	*Chenopodium*	藜属	17
Amaranthaceae	*Amaranthus*	苋属	16
Moraceae	*Morus*	桑属	13
Poaceae	*Sorghum*	高粱属	13
Chenopodiaceae	*Kochia*	地肤属	10
Juglandaceae	*Pterocarya*	枫杨属	7
Simaroubaceae	*Ailanthus*	臭椿属	7
Juglandaceae	*Carya*	山核桃属	6
Fagaceae	*Castanea*	栗属	5
Moraceae	*Broussonetia*	构属	5
Arecaceae	*Trachycarpus*	棕榈属	4
Juglandaceae	*Juglans*	胡桃属	4
Cannabaceae	*Humulus*	葎草属	3
Casuarinaceae	*Casuarina*	木麻黄属	3
Platanaceae	*Platanus*	悬铃木属	3
Styracaceae	*Alniphyllum*	赤杨叶属	3
Asteraceae	*Ambrosia*	豚草属	2
Cupressaceae	*Platycladus*	侧柏属	2
Meliaceae	*Melia*	楝属	2
Myrtaceae	*Melaleuca*	白千层属	2
Cannabaceae	*Cannabis*	大麻属	1
Euphorbiaceae	*Ricinus*	蓖麻属	1
Cupressaceae	*Sabina*	圆柏属	0
Count in Total		38 genera	1669

Species abundance distribution and allergy risks assessment

The distribution of species richness of allergic plants in China exhibits a gradual decline from the southwest region outward. Southwest China, particularly Sichuan and Yunnan provinces, has the highest species richness, indicating more complex botanical sources of allergic problems and higher allergy risks. Conversely, the southeast coastal areas of Northeast China and the southern coastal areas have the lowest species richness, suggesting a lower risk of allergies with a prevalence of more singular types of allergic plants. At the city and county level, areas with the most abundant species of allergic plants are concentrated in the western region of Sichuan Province, the northern region of Yunnan Province, and Chongqing. These areas face the highest allergy risks, followed by the provinces in the northwest, while the Qinghai-Tibet Plateau generally exhibits lower risks. The results are attributed to altitude and climate type differences in these areas. People's individual differences and sensitization to different plants contribute to three categories: non-plant allergy people, plant allergy people, and "potential allergy people." The latter category, despite not experiencing plant allergies, may have an allergic risk to certain allergenic plant species they have not encountered. Hence, those traveling or living in areas with high abundance of allergic plant species should take precautionary measures (Figure 1)

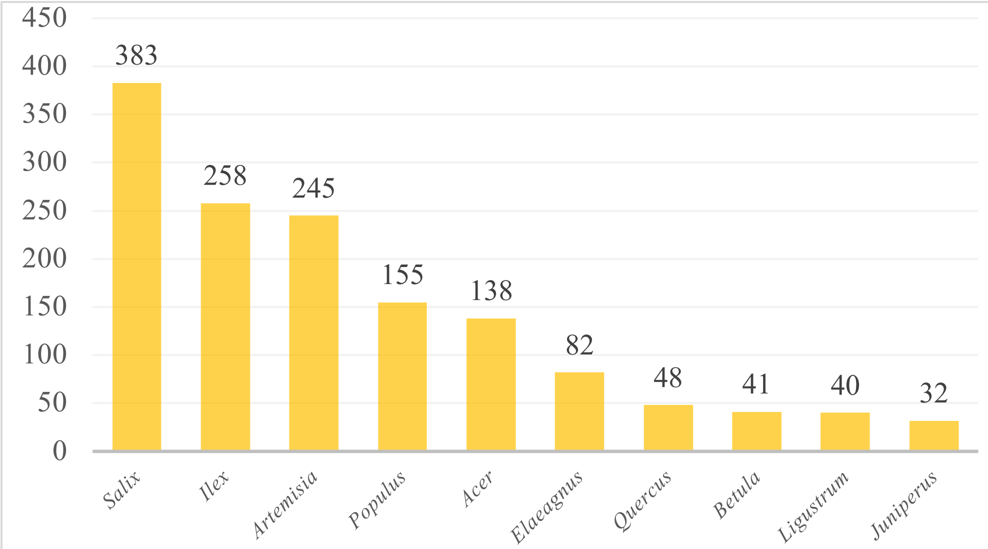

Figure 1. The number of species corresponding to the ten genera of pollen allergy

Seasonal distribution of allergic plants and allergy risks assessment

Out of 1669 pollen-allergic plant species, 1086 have flowering records in China, with the seasonal distribution primarily concentrated in spring. During April and May, about 500 species of allergic plants release pollen, making spring the season with the highest risk of pollen allergies. The intersection of summer and autumn (August and September) also witnesses a significant number of species (around 300) spreading pollen, ranking second in risk. Contrary to common belief, while spring has the highest risk, the risk during summer and autumn (June to October) is not significantly lower. Winter has the lowest risk of allergy (Figure 2)

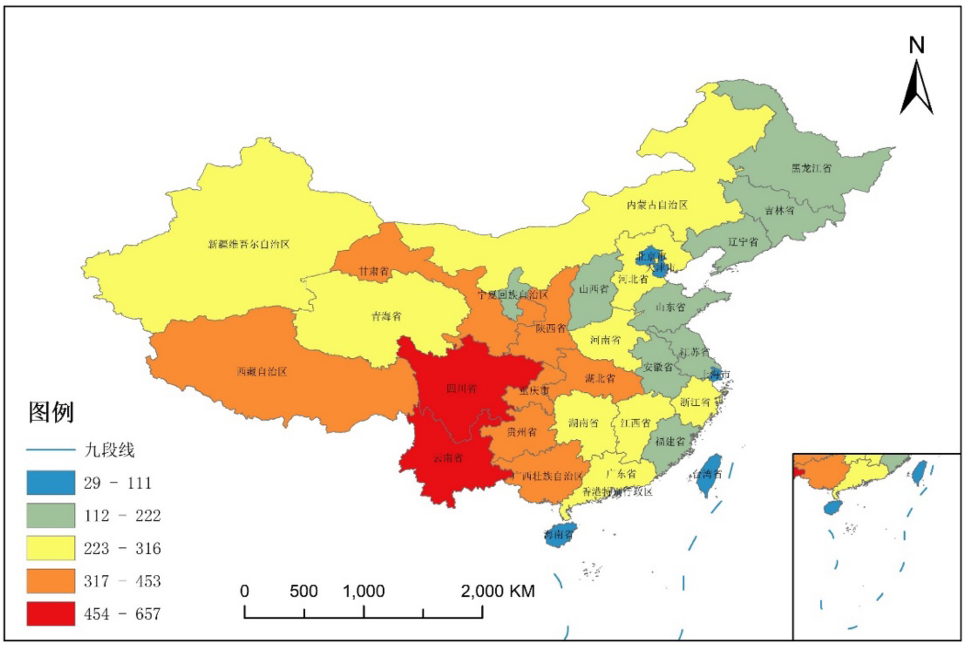

Figure 2. Distribution map of species richness (provincial division)

The distribution map based on GIS analysis indicates that in winter (December to February), few allergic plants pollinate, especially in the north. The south may still face allergy risks from *Elaeagnus*. From March to May, the number of pollinating allergic plants increases, with the risk being higher in the south than in the north during spring. From June to October, the north experiences a higher risk of allergy than the south. The southwest region, rich in allergic plant species, mainly pollinates in spring, resulting in lower allergy risks in summer and autumn (Figure 3)

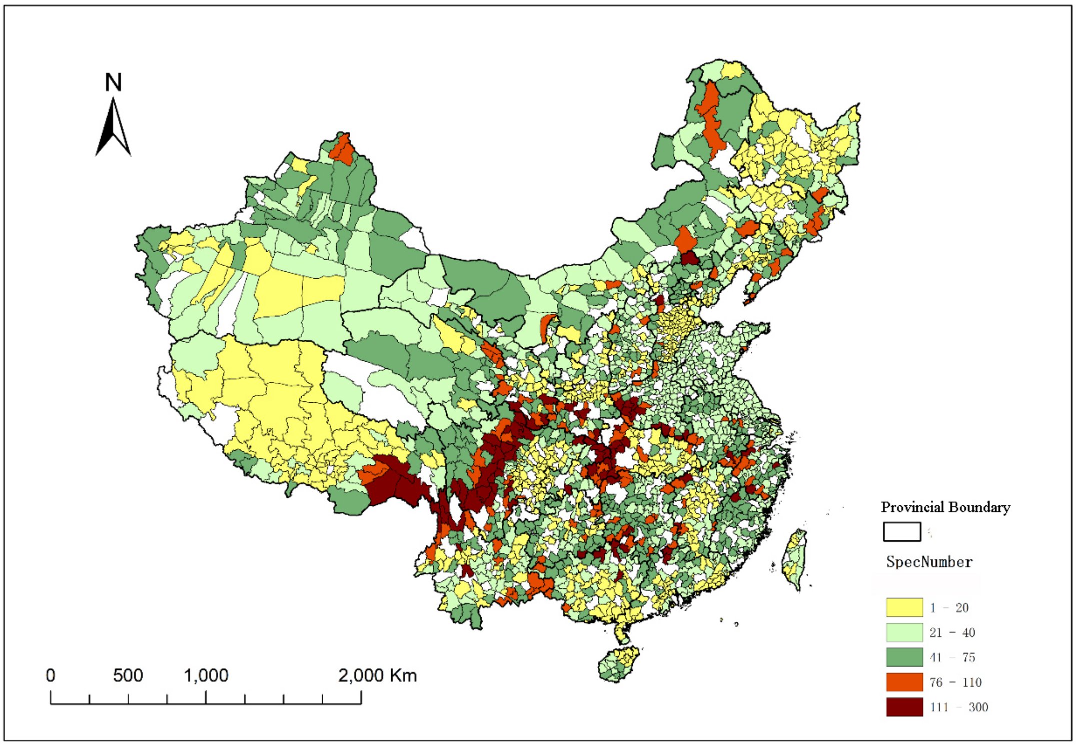

Figure 3. Distribution map of species richness (city and county level division)

Summary of Allergic Risk for Various Kinds of Allergic Plants

Considering both the depth and breadth of allergy risk (pollination volume and pathogenicity), the analysis includes existing research on the pollination capacity and pathogenicity of part of allergic plants. To deepen our understanding of the allergenic risk posed by allergic plants, we have employed the construction of a genetic evolutionary tree. This method, in conjunction with prior research findings and an exploration of the genetic correlation among various allergic plant species, enables a comprehensive analysis and summarization of the current allergenic risk associated with these plants. To enhance our understanding of the allergenic risk posed by allergic plants, we constructed a phylogenetic tree using 38 allergenic genera recorded across China. The resulting tree shows clear clustering among dominant genera such as Salix, Artemisia, and Ilex, which also contribute the highest number of allergenic species. This phylogenetic structure provides a framework for interpreting the evolutionary patterns behind allergen distribution and supports the identification of lineage-level associations among risk-prone taxa. In daily life, individuals are primarily exposed to urban greening plants. Drawing from a synthesis of existing research results, it is evident that among the urban greening plants in China: Torch tree, white wax, and clove emerge as the most pathogenic species from a pathogenicity perspective. Juniper and *Platycladus orientalis* are the primary species exhibiting strong pathogenicity. Plants with weaker pathogenicity include Ginkgo biloba, *Pinus tabulaeformis*, *Pinus bungeana*, and Elm. In terms of pollination capacity, plants with substantial pollination include *Pinus bungeana*, Juniper, *Platycladus orientalis*, *Betula platyphylla*, Magnolia grandiflora, white wax, and Salicaceae plants. Conversely, ginkgo and elm exhibit lower pollination capacity (Yi & Hong 2022, Newman *et al*.2017, The Angiosperm Phylogeny Group 2009). Therefore, we intend to analyze the allergy risk associated with various allergic plants based on these premises.

From the perspective of evolutionary relationships under the APG IV classification system, allergenic plants do not exhibit a clear monophyletic clustering trend on the phylogenetic tree. Instead, they are widely distributed across multiple major branches. For example, Salicaceae (genus *Salix* and *Populus*) belongs to Malpighiales, Ilex to Aquifoliales, *Artemisia* to Asterales, and Acer to Sapindales, while Elaeagnus, Ulmus, and others are part of Rosales. These groups are not closely related in evolution, suggesting that allergenicity may not have originated from a single ancestral trait but rather emerged or persisted independently as adaptive features in different lineages. Additionally, gymnosperms such as those in Pinales (e.g., *Juniperus*, *Sabina*) also include many allergenic species, indicating that allergenicity may be a widespread ecological adaptation strategy among seed plants.

Notably, certain families or genera contain significantly more allergenic species than others, such as Salix (383 species), Ilex (258 species), Artemisia (245 species), Populus (155 species), and Acer (138 species), which belong to Salicaceae, Aquifoliaceae, Asteraceae, and Sapindaceae, respectively. These groups often have broad geographical distributions and strong ecological adaptability, possibly due to their reproductive strategies (e.g., wind pollination) or the accumulation of secondary metabolites (e.g., volatile organic compounds, pollen proteins), making them more likely to trigger allergic reactions. Furthermore, orders such as Rosales and Asterales also encompass a large number of allergenic plants, which may be related to their ecological diversity and extensive speciation. Overall, the distribution of allergenicity in the plant kingdom demonstrates polyphyletic origins and broad-spectrum characteristics, reflecting convergent evolution or the retention of conserved traits across different evolutionary pathways.

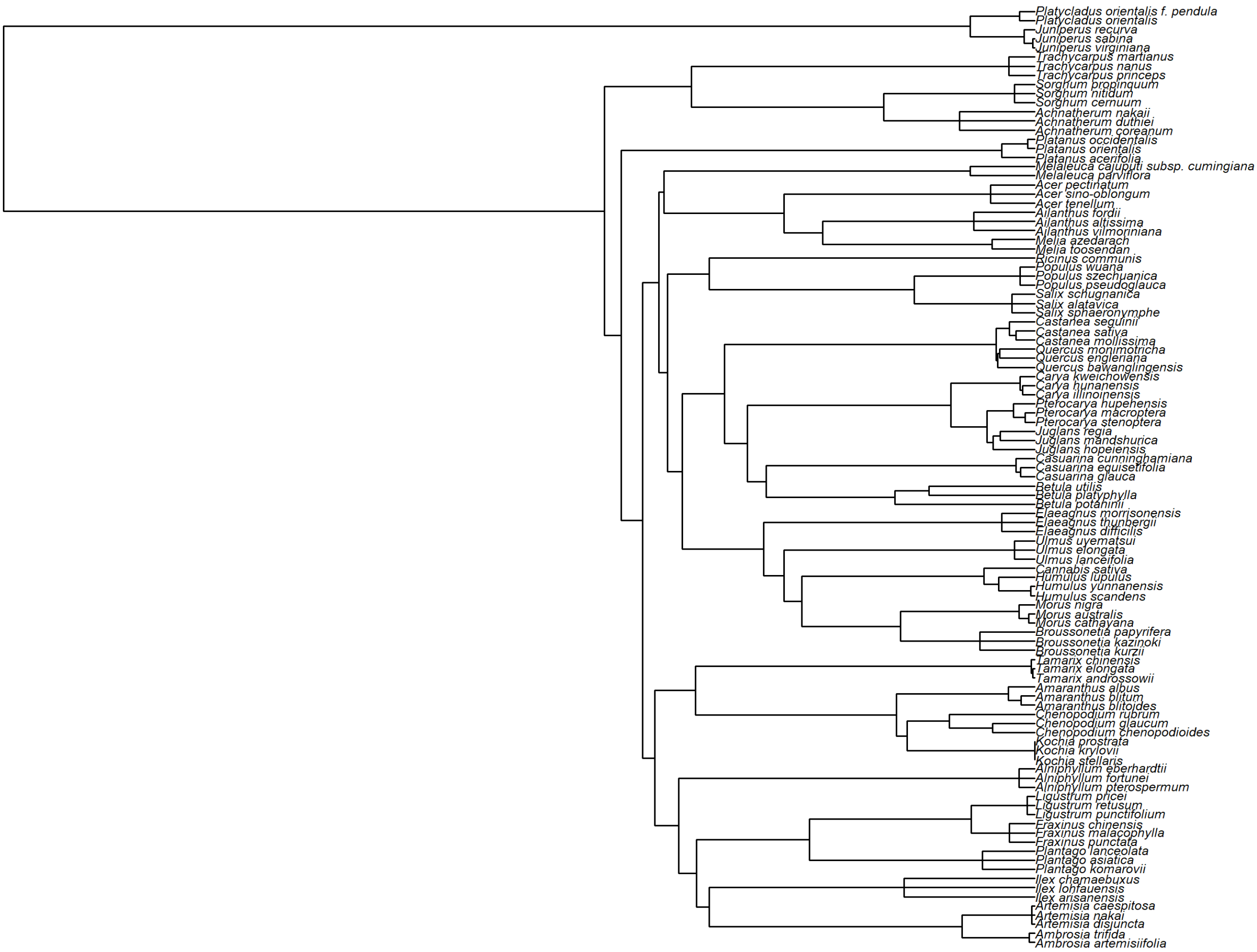

Figure 4. Phylogenetic Tree of 38 Allergenic Plant Genera

From the perspective of evolutionary relationships under the APG IV classification system, allergenic plants do not exhibit a clear monophyletic clustering trend on the phylogenetic tree. Instead, they are widely distributed across multiple major branches. For example, Salicaceae (genus Salix and Populus) belongs to Malpighiales, Ilex to Aquifoliales, Artemisia to Asterales, and Acer to Sapindales, while Elaeagnus, Ulmus, and others are part of Rosales. These groups are not closely related in evolution, suggesting that allergenicity may not have originated from a single ancestral trait but rather emerged or persisted independently as adaptive features in different lineages. Additionally, gymnosperms such as those in Pinales (e.g., Juniperus, Sabina) also include many allergenic species, indicating that allergenicity may be a widespread ecological adaptation strategy among seed plants.

Summary of highly pathogenic allergic plants

Lacqueraceae: According to clinical case data, the torch tree produces sensitized milk, leading individuals with sensitive skin to experience a strong allergic reaction upon contact. Dr. Gao Xianming from the Institute of Botany explains that the primary cause of torch tree sensitization is the axillary inflorescence of the *Toxicodendron* genus, resulting in highly irritating milk for human skin (Kraft *et al*. 2017). Referring to the genetic evolutionary tree, we observe the presence of mango, cashew, and other related plants in China. However, considering the infrequency of people coming into contact with unfamiliar plants, the author contends that this plant type is highly pathogenic, but due to the low likelihood of human contact, the overall risk remains low.

***Artemisia* in Compositae:** *Artemisia* in Compositae: Research indicates that the average positive rate of Artemisia pollen in China is 28.6%, signifying a high level of prevalence. Artemisia pollinosis typically occurs from June to October, reaching its peak in August and September (summer) (Wang 2018, Zhang *et al*.2021, Li *et al*. 2017, Heinzerling *et al*.2013, Ma *et al*.2021). This underscores the elevated allergy risk associated with Artemisia plants. Given the widespread cultivation of Artemisia, its impact extends across a broad geographical area. Urban residents in northern China are advised to exercise heightened protection during the flowering period of Artemisia plants, especially in the summer months.

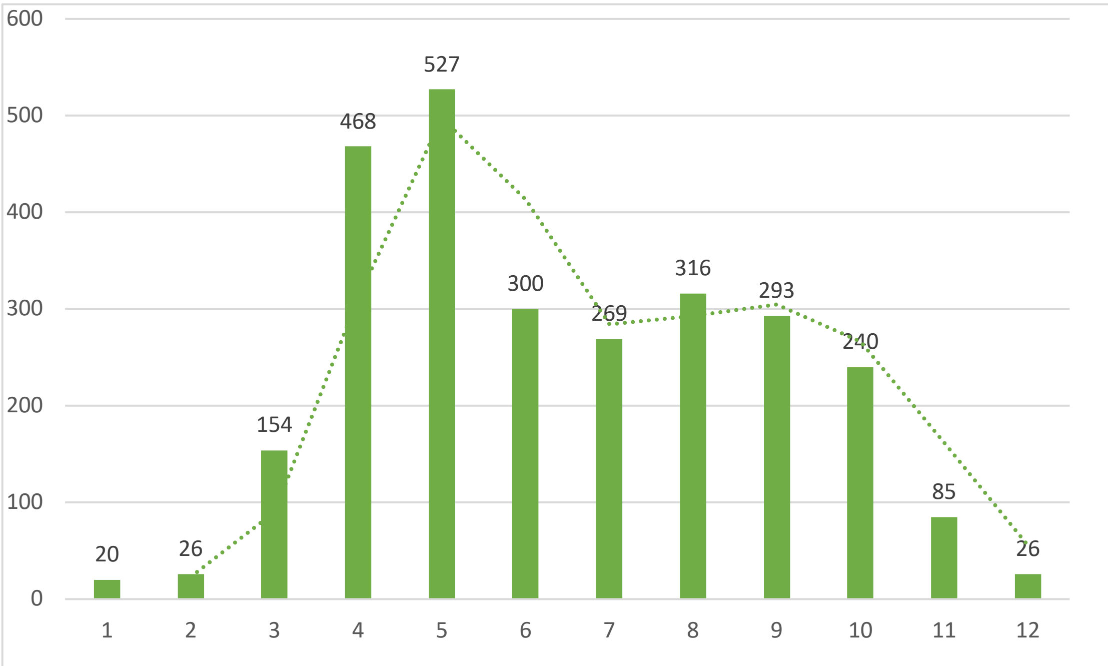

Figure 5. Number of species in each month during the pollination period of allergic plants

Cupressaceae: During the spring pollination season, the concentration of juniper pollen suspended in the atmosphere in Beijing can reach 294 g/(m^3 · d) (Zhang 2013). Clinical studies conducted in various countries reveal that the positive rate of skin prick tests for cypress pollen in patients with pollinosis can be as high as 36.25%. Furthermore, an analysis of 200,000 allergen-specific IgE (sIgE) test results at Beijing Union Medical College Hospital indicated a remarkably high positive detection rate of sIgE in juniper pollen, reaching 46.3% (1876/4053) (Tang *et al*. 2015). Based on the analysis of the sensitization causes of cypress plants, the Universal Protein database includes ten types of pollen allergen proteins from various genera and categories within the cypress family, all having a molecular weight of about 40 kD. These proteins exhibit strong allergenicity and sensitization (Yao & Zhang, 2009, Zhong 2009). It can be inferred that Cypressaceae plants generally possess high pathogenicity and present a substantial risk of sensitization.

***Fraxinus*:** According to the experiment conducted by Wang *et al*., the incidence of adverse events caused by white wax pollen was 0.583% (6/1029). These events were primarily manifested as symptoms such as a runny nose, sneezing, itchy nose, blocked nose, itchy eyes, and local skin reactions caused by pricking, among others. Notably, no serious adverse events were reported.

Summary of allergic plants with large pollination capacity.

To sum up, these allergic plants have a large pollination capacity and have a wide impact on the population; however, the sensitization reaction is not strong, and the incidence is low. To enhance our understanding of the allergenic risk posed by allergic plants, we have employed the construction of a genetic evolutionary tree. This approach, combined with previous research findings and an examination of the genetic correlation among various allergic plant species, facilitates the analysis and synthesis of the current allergenic risk associated with these plants. In everyday life, individuals are primarily exposed to urban greening plants. Drawing from existing research, we have identified key pathogenic and highly pathogenic species among urban greening plants in China. Notably, torch tree, white wax, and clove exhibit the highest pathogenicity, while Juniper and *Platycladus orientalis* are characterized by strong pathogenicity. Additionally, Ginkgo biloba, *Pinus tabulaeformis*, *Pinus bungeana*, and Elm exhibit weaker pathogenicity. Pollination capacity varies, with *Pinus bungeana*, Juniper, *Platycladus orientalis*, *Betula platyphylla*, Magnolia grandiflora, white wax, and Salicaceae plants showing high pollination capacity, whereas Ginkgo and elm exhibit lower pollination capacity. Consequently, we base our analysis of allergy risk on these premises. Seasonal allergy risk analysis based on the pathogenicity and pollination: the pathogenicity intensity and pollination capacity of allergic plants with their distribution data, the analysis concludes that the highest risk of sensitization is in spring (March to May), followed by autumn (August to October). Summer (June to July) has the lowest risk, and winter has almost no strong sensitization risk. This conclusion aligns with the previous conclusion based on distribution patterns, indicating that spring poses the highest overall allergy risk, followed by autumn and summer, with winter having the lowest risk.

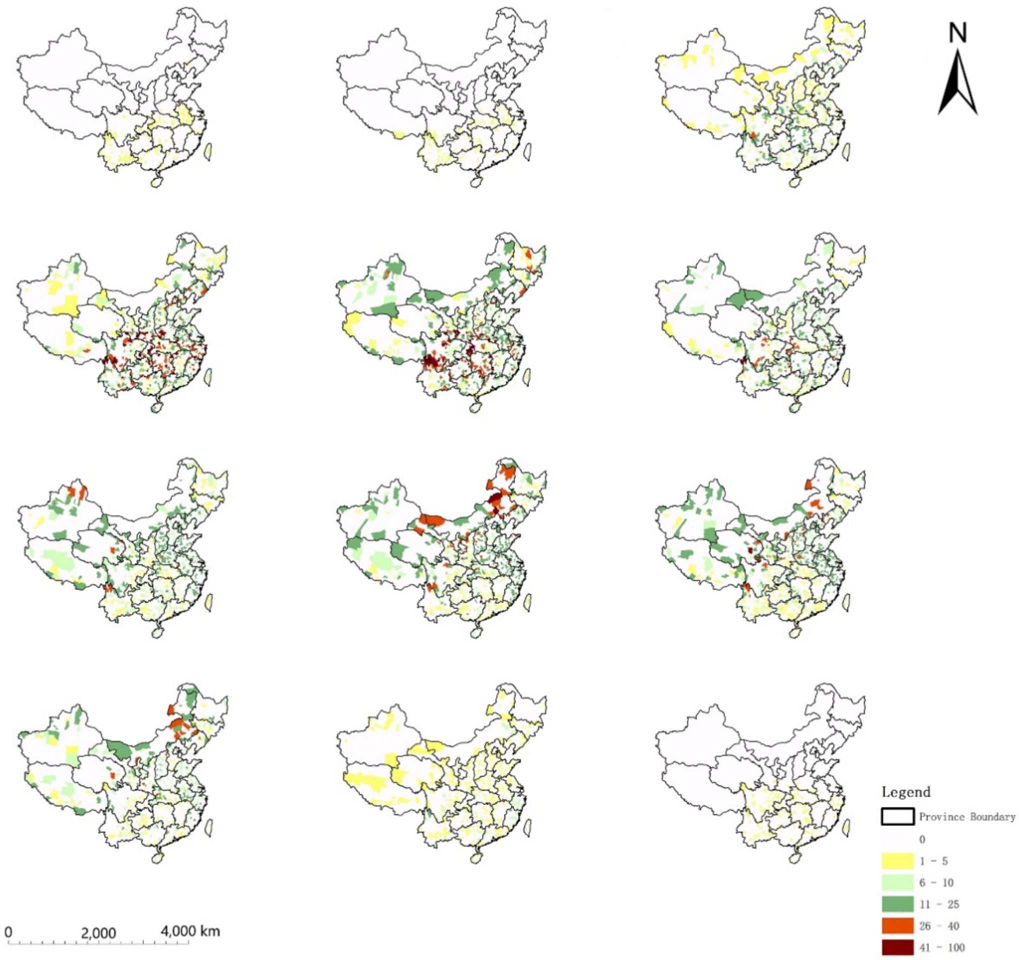

Figure 6. Abundance distribution of allergic plants at florescence in each month

Discussion

The Value of Integrating Traditional Knowledge and Modern Science in Ethnobotany. In the field of ethnobotany, allergies, as long-standing health issues, are closely linked to traditional plant use. For example, ethnic minorities in southwestern China have developed practical knowledge about local allergenic plants through long-term experience, such as the Yi people's avoidance of sensitizing Anacardiaceae plants and the Dai people's seasonal protection against Artemisia during flowering periods. By quantifying data (e.g., phylogenetic tree construction, NRI/NTI index calculations), this study translates traditional experiences into verifiable scientific evidence for the first time. It confirms that high-risk plants in the southwest (e.g., Salix, Morus) closely overlap with local ethnic groups' traditional "toxic plant" lists and reveals a positive correlation between the allergenicity of torch trees (Anacardiaceae) and their genetic divergence time (Fig. 4). This integration of traditional knowledge with molecular systematics not only provides an "experience-to-data" research paradigm for ethnobotany but also validates the practical value of traditional ecological knowledge (TEK) in modern public health through interdisciplinary methods.

The Phenology and Geographical Indicative Significance of Allergenic Plant Distribution Patterns for Regional Populations. This study clinically validates the distribution characteristics of 1,668 allergenic plant species in China, revealing significant phenology regularities and geographical regularities. The study's revelation of seasonal patterns in allergenic plants (e.g., woody plants dominating spring and herbaceous plants prevailing in autumn) implicitly correlates with the farming calendars and herbal collection timings of some ethnic groups. For instance, the Mongolian people's protective measures against Betula pollen during spring nomadic movements align with this study's finding of high pollination capacity in northern Betula species in spring. By integrating such traditional knowledge, modern communities can optimize allergy prevention strategies: in ethnic minority settlements in the southwest, low-sensitization greening tree species (e.g., replacing high-risk Salix with low-sensitization Ligustrum) can be promoted alongside traditional "plant taboo" cultures; in northern agro-pastoral zones, grazing routes can be adjusted to reduce contact with Artemisia during its flowering period (June-October). This cycle of "traditional cognition-scientific validation-applied intervention" not only strengthens ethnobotany's role in disease prevention but also fosters complementarity between indigenous knowledge systems and modern healthcare, offering new pathways to balance cultural heritage and public health.

For the geographical aspect, in Southwest China, where allergenic plant diversity is particularly high, species such as *Salix* and *Artemisia* are also part of long-standing traditional plant use among local ethnic communities. The spatial and seasonal patterns revealed in this study offer a practical reference for managing such plants—allowing cultural practices to continue while reducing potential health risks. Bringing allergy awareness into local plant use can help balance tradition with wellbeing. Meanwhile, the southwestern region (e.g., Sichuan and Yunnan), with the highest species richness (dominated by genera such as *Salix* and *Artemisia*), emerges as the core area of allergy risk. Southern cities generally face higher risks than northern ones, with a notable seasonal peak in spring (April-May) when over 500 species release pollen. These findings provide critical references for populations in different regions, especially highly sensitive allergic groups. Residents in southwestern or southern cities should prioritize precautions against pollen exposure from woody plants (e.g., *Populus*, *Salix*) in spring, while northern residents should be vigilant about the allergenicity of herbaceous plants like Artemisia in late summer and early autumn (August-September). GIS-based visual distribution maps (e.g., Figs. 2-3) help individuals identify potential allergy risks in their place of residence or travel destinations—plateau areas such as Tibet and Qinghai have significantly lower risks due to low species density compared to eastern coastal regions.

The study acknowledges the individual differences in populations regarding allergic reactions to plants. The analysis aims to provide a universal conclusion for the entire population, but individual experiences and sensitivities may vary. "Potentially allergic populations" who have not encountered certain allergenic plants need to pay attention to allergenic risks when traveling to unfamiliar areas. This analysis serves as a reference for those unfamiliar with the distribution of allergic plants, emphasizing the importance of personal life experiences and allergy history.

Relationship between species richness and allergenic risk. The high species richness of allergenic plants in Southwest China, primarily in Sichuan and Yunnan, is fundamentally linked to the region's warm, humid climate and complex topography. These climatic conditions—characterized by abundant rainfall and year-round mild temperatures—create optimal environments for plant diversification, allowing 383 species of *Salix* (willow) and 245 species of *Artemisia* (mugwort) to thrive (Table 1). The causal chain is threefold: (1) prolonged growing seasons extend pollen release periods, with spring alone witnessing 527 allergenic plant species in bloom (Fig. 4); (2) high humidity enhances pollen adhesion and dispersal, increasing human exposure; and (3) mountainous microclimates foster ecological niches for rare allergic species, elevating the diversity of allergens. And also a longer growing season typically leads to a longer duration of pollen release and a higher cumulative concentration of pollen in the air. Climatic factors such as temperature and humidity play a crucial role in shaping both pollen abundance and allergenic potential. Previous research has shown that rising temperatures and increased humidity are associated with greater pollen production and enhanced allergenic protein expression in plants (Choi *et al.*, 2024). This biodiversity directly amplifies allergic risk, as demonstrated by the 46.3% positive IgE detection rate for *Juniperus* pollen in clinical tests (Tang et al. 2015), where species-rich regions exhibit higher cross-sensitization rates due to shared allergenic proteins in phylogenetically clustered taxa (e.g., Cupressaceae). While species richness alone does not necessarily determine the level of allergy risk, its interaction with these climatic conditions may create a more complex and persistent sensitization environment.

Analysis of the Relationship Between Evolution and Allergy: Observing the genetic evolution tree of allergic plants, the study notes that species with stronger sensitization or greater pollination capacity generally have a late differentiation time. Plants like *Platycladus*, *Juniperus*, *Populus*, and *Salix* exhibit this correlation, suggesting that allergenicity may be linked to the phylogeny degree of plants. The study finds consistency in the conclusions drawn from both phylogenetic diversity analysis and seasonal distribution analysis.

Seasonal Phenology and Human Exposure Dynamics. The seasonal pattern of allergenic risk—spring > autumn > summer > winter—reflects the synchronized flowering of plant functional groups and human activity rhythms. In spring, 500+ woody species (e.g., *Populus*, *Salix*) dominate pollen release, driven by temperature cues for reproduction (Fig. 4). This coincides with increased outdoor activities, creating a "double exposure" effect: higher airborne pollen concentrations (e.g., 294 μg/m^3·d for *Juniperus* in Beijing; Zhang 2013) and prolonged human-plant contact. Autumn's secondary peak, led by 300+ herbaceous species (*Artemisia*), arises from adaptive strategies to avoid spring competition, but its causal link to allergy is modulated by atmospheric conditions—cooler, drier air in northern China enhances pollen dispersal efficiency, explaining why late summer-autumn risks surpass the south (Fig. 2). Winter's low risk is directly tied to dormancy of most angiosperms, though evergreen *Elaeagnus* in the south remains a minor exception. Woody plants, such as willow, juniper, *Platycladus orientalis*, poplar, and white wax, contribute to the highest allergy risk in spring. Herbaceous plants, particularly Artemisia species, dominate the allergy risk in autumn. Summer, as a transitional season, witnesses fewer allergic plant species pollinating, and winter carries almost no risk. This consistency reinforces the conclusion that spring poses the highest overall allergy risk, followed by autumn and summer, with winter having the lowest risk.

Suggestions for Planting Urban Greening Plants and traveling: The study suggests that relevant departments consider multiple factors, including pollination capacity, pathogenicity, and pathogenicity, when selecting urban greening plants. Opting for species with low pathogenicity, low pollination capacity, and no severe clinical reactions is recommended. Local data and analysis should inform the selection of plant species. The study can provide a solid basis for human intervention in plant selection introduces bidirectional causalities in urban environments. While cities like Beijing aim to enhance green coverage, the overuse of high-pollinating species (*Pinus bungeana*, *Fraxinus*) creates artificial allergenic hotspots. For example, *Fraxinus* (ash trees), planted for shade and rapid growth, release copious pollen despite low individual pathogenicity (0.583% adverse event rate; Wang et al.), illustrating how sheer pollen volume—rather than species richness—can elevate risk. Conversely, cities using low-pollination species (*Ginkgo biloba*, *Ulmus*) show reduced sensitization rates, even with moderate species diversity. This highlights a critical causal shift: in urban contexts, management decisions (e.g., monoculture planting) may outweigh natural biodiversity in determining allergy risk. Additionally, phylogenetic clustering of planted species (e.g., Cupressaceae in northern cities) increases allergenic protein similarity, amplifying cross-reactivity among susceptible populations. Travel plans can benefit from the conclusions of the study. Using the allergy risk distribution map for each season, travelers can understand the allergy problems in the destination and take adequate precautions. The analysis provides a preliminary understanding of the types of allergic plants at the destination, aiding in preparations to prevent severe allergic reactions. To improve accuracy, future research can explore satellite imaging to capture the distribution of specific allergic plants. Additionally, real-time statistical data of urban pollen concentrations can be analyzed to closely examine the impact of allergic plants. This dual approach aims to enhance the precision of research findings.

Conclusion

This study provides crucial insights into the perspective of distribution patterns, seasonal distribution, phylogenetic diversity, individual differences, climate impact, evolution, and provides practical suggestions for urban planning and travel. The study concludes that Southwest China faces the highest allergy risk, Southern cities generally have higher risks than Northern China, and the allergy risk is highest in spring, followed by summer and autumn, with almost no risk in winter. The distribution of allergic plant species in Chinese cities is generally dispersed or random, presenting complex and varied allergic situations.

Certain provinces face lower allergy risk, while others face relatively higher risk. Offering actionable strategies for urban greening and public health. Suggestions are given for urban greening and travel.

Declarations

List of abbreviations: NSII-National Specimen and Infrastructure (NSII); APG IV- Angiosperm Phylogeny Group classification for the orders and families of flowering plants.

Ethics approval and consent to participate: The development of the study followed the ethical and legal guidelines for the development of research on traditional knowledge. The project was approved by the Ethics Committee for Research with Human Beings of the Federal University of Santa Catarina (CEPSH) under the number: 82427718.0.0000.0121 de 18/06/2018. The participation of healers was subject to the acceptance of the Free and Informed Consent Form. The project was registered with SISGEN under the number A011D4A.

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