IDENTIFYING ALLERGENIC POLLEN PRODUCING PLANTS IN THE FLORA OF IĞDIR UNIVERSITY CAMPUS, TÜRKİYE

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Abstract. This study aims to identify plant taxa with the potential to produce allergenic pollen within the boundaries of Iğdır University's Şehit Bülent Yurtseven Campus, located in the easternmost part of Türkiye, and to evaluate these taxa from various perspectives. Pollen allergies are a significant public health issue that negatively impacts individuals' quality of life, particularly during spring and summer months. Accordingly, as a result of field observations and literature reviews conducted in the campus area, plant species with allergenic potential were identified and their seasonal distribution, density and relationship with environmental factors were analyzed. As a result of the research, a total of 92 plant taxa that may cause allergic reactions were identified within the borders of the campus. These plants were classified at the family level and evaluated in terms of life forms, flowering periods and allergen rates. According to the findings, 35 plants have low, 24 plants have medium and 33 plants have high allergenic potential. Additionally, recommendations have been developed for the use of these species in landscape design. The study aims to contribute to a healthier and more livable campus ecosystem by adopting an interdisciplinary approach between botany and health sciences.
Keywords: *allergen pollen, Iğdır, public health, landscape planning, ornamental plants*

Introduction

Open and green urban spaces are planned considering their economic, ecological and social functions for the purpose of reduce the negative effects of rapid urbanization, which is one of the main environmental problems faced today, and to create livable and sustainable cities (Çetinkaya and Uzun, 2014; Gülçin, 2020). Urban green spaces are essential components of urban environments that offer recreational opportunities, life-enhancing benefits and ecological protection to urban residents (Vieira et al., 2018; Ugolini et al., 2020). These areas not only contribute to re-establishing the interaction between humans and nature, but also play an important role in improving the quality of life of urban dwellers through the environmental, social and economic benefits they offer (Ahern, 1995; Bayramoğlu and Yurdakul, 2019; Ekren, 2020; Eren et al., 2020). In recent decades, awareness of the importance of nature and natural environments for human health has increased, particularly mental health and psychological well-being. For example, green spaces in urban environments strengthen the connection with nature while also reducing potential harm by providing ecosystem services such as increasing resilience to climate change, protecting biodiversity, and reducing urban heat through climate regulation. They also benefit mental health by providing recreational opportunities (Lee and Maheswaran, 2011; Wolch et al., 2014; Markevych et al., 2017; Kabisch, 2019; Marselle, 2019; Beute et al., 2023).

Despite the multifaceted benefits they provide to the urban ecosystem, it is seen that the plant species preferred in the design of urban open and green spaces are mostly selected only by considering their form, color and aesthetic features (Bayramoğlu and Şatıroğlu, 2018; Sarı and Karaşah, 2018). However, the main purpose of the plant design

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process should be to create spaces that have both esthetic and functional qualities for users. In this context, the selection of plant taxa to be used in urban open and green spaces should take into account not only their morphological and physiological characteristics, but also their aromatic qualities, toxicity, and potential to spread pollen that may lead to allergic reactions in humans. Such multifaceted evaluations will contribute to making vegetative design practices more sustainable and effective in terms of both environmental and user health (Çorbacı and Ekren, 2021; Hatipoğlu and Ekren, 2022).

Plants produce a large amount of pollen during pollination periods under the influence of environmental conditions and spread this pollen into the atmosphere. Climatic changes due to global warming may lead to shifts and changes in the vegetation periods of plants and consequently pollen production periods. In aerobiological studies conducted in different years, it has been determined that the total amount of pollen in the atmosphere increases over time (Kobzar, 1999; Gioulekas et al., 2004a,b).

Although pollen plays an important role in the reproductive processes of plants, it can have adverse effects on human health as a result of its dispersion in the atmosphere. Especially allergenic pollen can cause respiratory diseases, seasonal allergic rhinitis and asthma attacks in susceptible individuals. In recent years, increasing urbanization, climate changes and the transformation of biodiversity have further complicated the atmospheric dispersion and allergenic effects of pollen. In this context, determining the flora structure in certain regions and the plant species with allergenic potential in this flora is of great importance in terms of protecting public health and minimizing environmental risks.

The main objective of this study is to identify plants that produce allergenic pollen, which may have adverse effects on human health, among the plant species found in the flora of Iğdır University's Şehit Bülent Yurtseven Campus. In this direction, plant taxa growing naturally within the borders of the campus or planted for landscaping purposes were examined and their pollen spreading properties and potential allergenic effects were determined. The data obtained aims to contribute to the identification of plants that may pose a risk to human health in the campus ecosystem and to make healthier and more conscious plant design decisions in future landscape arrangements. In addition, this study aims to prepare a scientific basis for the creation of sustainable and healthy urban living spaces by drawing attention to the need to adopt a health of the public sensitive approach in urban green space planning.

Materials and methods

The main material of this study consisted of perennial plant species that were planted as part of the Landscape Project and used in the landscape design of Iğdır University Şehit Bülent Yurtseven Campus. The research was conducted at the campus located in Iğdır Province, near Mount Ararat, in the easternmost part of Türkiye, bordering Iran, Nakhchivan, and Armenia. The study was carried out in 2025 and included systematic weekly field observations covering the entire campus area. During these observations, perennial plants located in sports fields, medians, entrance arrangements, recreation areas, and seating/resting zones were examined in situ, and routine maintenance practices were performed. This comprehensive assessment enabled a detailed examination of the plant material within the campus landscape from all perspectives.

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Study area and climate conditions

The first higher education institution in Iğdır was Iğdır Vocational School affiliated to Kars Kafkas University and was established in 1995. In 2006, Iğdır Faculty of Agriculture was established affiliated to Kafkas University, and then in 2008, an independent university was established under the name of Iğdır University and other units were connected to it. In 2014, Iğdır University Şehit Bülent Yurtseven Campus started to serve. Many buildings have been established within the campus and the landscaping project of these areas has been completed and put into service. The landscape project, which started in 2016 at Iğdır University Şehit Bülent Yurtseven Campus, was completed in 2020 (*Figure 1*).

Figure 1. *Landscape view of the research area*

The average maximum temperature in Igdir between 1941 and 2024 is 29.6°C in June, 33.4°C in July, 33.2°C in August and 29.0°C in September. The average monthly total precipitation is 31.3 mm in June, 14.1 mm in July, 9.5 mm in August and 11.4 mm in September (Anonymous, 2025). In the studies conducted in Iğdır, it was determined that the amount of precipitation is low and it is the province with the lowest rainfall in Türkiye. In the evaluations made, it shows arid and semi-arid characteristics according to different methods. This situation makes irrigation important in landscape studies and agricultural activities (Karaoğlu, 2011).

Method

This study was carried out in three main stages. In the first stage, plant taxa in the study area were identified in situ based on taxonomic studies conducted by Davis (1965-1988), and Akkemik (2014a,b). The identification of the plants at the species level was carried out by taking into account the distinctive morphological features presented in the literature and certification information, if any; photographs of the identified individuals were taken and recorded. Thus, the accuracy of the taxa was verified by both literature data and on-site observations. In the second stage of the study, the plants identified in the area were classified according to their life forms; accordingly, the individuals were examined under 4 headings: tree, treelet, shrub and Climber. The pollen production

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potential of species belonging to each life form was evaluated in the context of allergenicity levels of pollen. When determining the allergenic potential, the existing literature on the effects of pollen on human health was reviewed; in particular, studies by Peternel et al. (2004), Acar (2013), and Cariñanos et al. (2014, 2016) were utilized. As a result of these assessments, species were divided into three categories: low (1), moderate (2), and high (3) allergenic potential. The flowering period of plants was also evaluated as a separate variable. The reason for this is that this period corresponds to the time when pollen production and dispersal into the environment are most intense. The flowering periods of each species were determined by month.

In the final stage of the study, comprehensive statistical and visual analyses were applied to examine the relationships between the flowering periods of plant species and their allergenic properties, and to evaluate the multidimensional structural similarities between species. To assess structural similarities between species, a similarity matrix was first created in the R environment (R Core Team, 2016), making it possible to identify different patterns by grouping taxa with similar flowering periods and allergenic properties. Based on these patterns, species were classified into different clusters using hierarchical cluster analysis with the Ward method and the Euclidean distance index, and the relationships between taxa were visualized with a dendrogram. Subsequently, Principal Component Analysis (PCA) was performed using PAST software (Hammer et al., 2001; Taşkın et al., 2025) to evaluate multivariate relationships and identify the components contributing most to data variance, thereby visualizing the spatial distributions of species in terms of their flowering and allergenic profiles. Network analysis was also performed to examine the interspecies relationships between taxa sharing similar characteristics in greater detail. Additionally, the monthly distribution of allergenic potential was visualized using heat maps created with Python's Seaborn library (Waskom, 2021; Taşkın et al., 2025), highlighting the periods with the highest allergenic intensity. Finally, the distribution of plant taxa according to their life forms, species, and families was systematically presented using SankeyMATIC (SankeyMATIC, 2025; Taşkın et al., 2025), providing a clear and comprehensive representation of the structural composition of the dataset.

Results and discussions

Information on the plant taxa identified to emit allergenic pollen in the study area and the families, life forms, flowering periods and allergenicity rates of these taxa are presented in *Table 1*.

A total of 92 taxa were identified as exhibiting allergenic properties within the study area. When analyzed according to their growth forms, 14 were coniferous trees and treelets, 4 were coniferous shrubs, 45 were broad-leaved trees and treelets, 25 were broad-leaved shrubs, and 4 were climbing plants. In addition, among these 92 allergenic taxa, 35 were found to be of natural origin, while 57 were of exotic origin (*Figure 2*).

When the plant taxa identified in the study area were evaluated according to their families, it was determined that the families with the highest number of taxa were Rosaceae (15 taxa), Cupressaceae (9 taxa), Pinaceae (9 taxa), and Oleaceae (8 taxa). In this regard, the Rosaceae family stands out in terms of the number of taxa it contains and its allergenic properties, and it is the family with the most allergenic potential in the study area (*Figure 3*).

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Table 1. *Plant taxa with allergic pollen detected in the study area and their characteristics*

Family	Scientific name	Plant type	Life form	Flowering period (months)	Allergen rate
Adoxaceae	*Viburnum opulus L.*	Shrub	Natural	5-7	2
	Viburnum tinus L.	Shrub	Natural	2-4	2
	Viburnum tinus L. var. lucidum	Shrub	Exotic	5-6	2
Berberidaceae	*Berberis thunbergii DC. 'Atropurpurea'*	Shrub	Exotic	4-5	3
	Berberis thunbergii 'Atropurpurea Nana'	Shrub	Exotic	4-5	3
Betulaceae	*Betula alba L.*	Tree	Natural	3-4	3
	Betula pendula Roth.	Tree	Natural	3-4	3
Bignoniaceae	*Campsis radicans L.*	Climber	Exotic	6-9	1
	Catalpa bignonioides Walt.	Tree	Exotic	5-7	1
	Catalpa bignonioides Walt. 'Nana'	Tree	Exotic	5-7	1
Cannabaceae	*Celtis australis L.*	Tree	Exotic	3-5	2
Caprifoliaceae	*Symphoricarpos albus (L.) S.F. Blake*	Shrub	Exotic	4-5	2
Cupressaceae	*Cupressus sempervirens L.*	Tree	Natural	4-5	3
	Cupressus arizonica Greene 'Glauca'	Tree	Exotic	8-9	3
	Cuprocyparis leylandii (A.B. Jacks. & Dallim.) Farjon	Tree	Exotic	3-4	3
	Juniperus horizontalis Moench	Shrub	Exotic	4-5	3
	Juniperus sabina L.	Shrub	Natural	4-5	3
	Junıperus × media Van Melle 'Mint Julep'	Shrub	Exotic	4-5	3
	Platycladus orientalis (L.) Franco	Tree	Natural	4-5	3
	Thuja orientalis L. 'Compacta Nana'	Shrub	Exotic	4-5	3
	Thuja occidentalis 'Smaragd'	Tree	Exotic	4-5	3
Elaeagnaceae	*Elaeagnus angustifolia L.*	Tree	Natural	4-6	3
Fabaceae	*Cercis siliquastrum L.*	Tree	Natural	3-4	1
	Gleditsia triacanthos L.	Tree	Exotic	5-7	2
	Robinia hispida L.	Tree	Exotic	4-6	2
	Robinia pseudoacacia L.	Tree	Exotic	4-6	2
	Wisteria sinensis (Sims) Sweet.	Climber	Exotic	4-7	2
Ginkgoaceae	*Ginkgo biloba L.*	Tree	Exotic	4-5	2
Juglandaceae	*Juglans regia L.*	Tree	Natural	4-5	3
Lamiaceae	*Lavandula angustifolia Mill.*	Shrub	Natural	6-8	1
	Rosmarinus officinalis L.	Shrub	Natural	5-6	1
Lythraceae	*Lagerstroemia indica L.*	Tree	Exotic	7-9	1
Malvaceae	*Hibiscus syriacus L.*	Shrub	Exotic	6-9	1
	Tilia tomentosa Moench.	Tree	Natural	6-7	2
	Tilia platyphyllos Scop	Tree	Natural	6-7	2
Meliaceae	*Melia azedarach L.*	Tree	Exotic	4-5	1
Moraceae	*Morus alba L.*	Tree	Natural	4-5	3
Oleaceae	*Fraxinus angustifolia Vahl*	Tree	Natural	4-5	3
	Fraxinus excelsior L.	Tree	Natural	4-5	3
	Fraxinus ornus L. subsp. ornus	Tree	Natural	4-5	3
	Forsythia intermedia Zabel.	Shrub	Exotic	3-4	3
	Ligustrum japonicum Thunb.	Treelet	Exotic	6-9	3
	Ligustrum ovalifolium Hassk.	Shrub	Exotic	6	3
	Ligustrum ovalifolium Hassk. var. Aureum	Shrub	Exotic	6	3
	Syringa vulgaris L.	Shrub	Exotic	4-5	2
Onagraceae	*Gaura lindheimeri Engelm. & A. Gray 'Siskiyou Pink'*	Shrub	Exotic	5-10	1
	Gaura lindheimeri Engelm. & A. Gray 'Whirling Butterflies'	Shrub	Exotic	5-10	1

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Family	Scientific name	Plant type	Life form	Flowering period (months)	Allergen rate
Pinaceae	*Cedrus deodora (Roxb.) Loud.*	Tree	Exotic	9-11	2
	Picea abies L. Karst.	Tree	Exotic	5-6	1
	Picea orientalis L.	Tree	Natural	4-5	1
	Picea pungens Engelm. 'Glauca'	Tree	Exotic	4-5	1
	Picea pungens Engelm. 'Hoopsii'	Tree	Exotic	4-5	1
	Pinus brutia Ten.	Tree	Natural	5	2
	Pinus mugo 'Mops'	Treelet	Exotic	5-6	2
	Pinus nigra J.F. Arnold	Tree	Natural	5	2
	Pinus nigra 'Pyramidalis'	Tree	Natural	5	2
Platanaceae	*Platanus orientalis L.*	Tree	Natural	3-5	3
Rosaceae	*Cotoneaster coriaceus Franch*	Shrub	Exotic	5-6	1
	Cotoneaster horizontalis Decne	Shrub	Exotic	5-6	1
	Cotoneaster lacteus W.W.Sm.	Shrub	Exotic	6-7	1
	Cotoneaster dammeri C.K. Schneid	Shrub	Exotic	5-6	1
	Diospyros kaki Thunb.	Tree	Exotic	4-6	1
	Malus domestica Borkh.	Tree	Exotic	4-5	1
	Malus floribunda siebold ex. Van Houtte	Tree	Exotic	4-5	1
	Photinia × fraseri Dress 'Little Red Robin	Shrub	Exotic	4-6	1
	Pyracantha coccinea M.Roem.	Shrub	Natural	4-6	1
	Pyracantha angustifolia (Franch.) CK Schneid	Shrub	Exotic	4-6	1
	Prunus cerasifera Ehrh.	Tree	Exotic	3-4	1
	Prunus cerasifera cv. 'Pissardi Nigra'	Tree	Exotic	3-4	1
	Prunus domestica L.	Tree	Natural	4-5	1
	Rosa meilland L.	Shrub	Natural	4-10	1
	Spiraea x vanhouttei (Briot) Zabel.	Shrub	Exotic	4-5	1
Salicaceae	*Populus nigra L.*	Tree	Natural	3-4	3
	Salix babylonica L.	Tree	Exotic	4-5	3
	Salix caprea L.	Tree	Natural	4-5	3
	Salix caprea 'Pendula'	Treelet	Natural	4-5	3
	Salix matsudana Koidz.	Tree	Exotic	4-5	3
	Salix nigra Marshall	Tree	Natural	4-5	3
Sapindaceae	*Acer negundo L.*	Tree	Exotic	3-4	3
	Acer negundo L. 'Flamingo'	Tree	Exotic	3-4	3
	Acer pseudoplatanus L.	Tree	Natural	3-4	3
	Acer saccharinum L.	Tree	Exotic	3-4	3
	Aesculus x carnea Hayne.	Tree	Exotic	3-4	2
	Aesculus hippocastanum L.	Tree	Exotic	4-5	2
	Koelreuteria paniculata Laxm	Tree	Exotic	7-8	1
Scrophulariaceae	*Buddleja davidii Franch*	Shrub	Exotic	7-10	1
Simaroubaceae	*Ailanthus altissima (Mill.) Swingle*	Tree	Exotic	5-6	2
Tamaricaceae	*Tamarix parviflora DC.*	Treelet	Natural	4-5	2
Ulmaceae	*Ulmus glabra Huds.*	Tree	Natural	3-4	2
	Ulmus mınor Mill. 'Umbraculifera'	Tree	Natural	3-4	2
Vitaceae	*Parthenocissus quinquefolia (L.) Planch.*	Climber	Exotic	5-6	1
	Vitis vinifera L.	Climber	Natural	5-6	1

D'Amato et al., 2007; Cariñanos and Casares-Porcel, 2011; Acar, 2013; Cariñanos et al., 2014; Cariñanos et al., 2016; Kasprzyk et al., 2019; Cariñanos and Marinangeli, 2021; Kušen et al., 2022; Ekren and Çorbacı, 2022; Hatipoglu and Ekren, 2022; Tik and Kaya, 2025

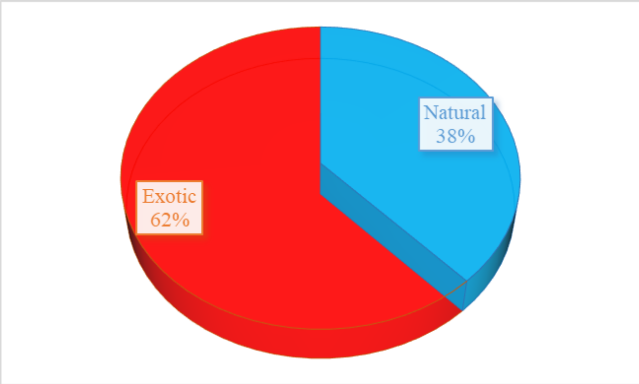

***Figure 2.** Life forms of allergenic plants*

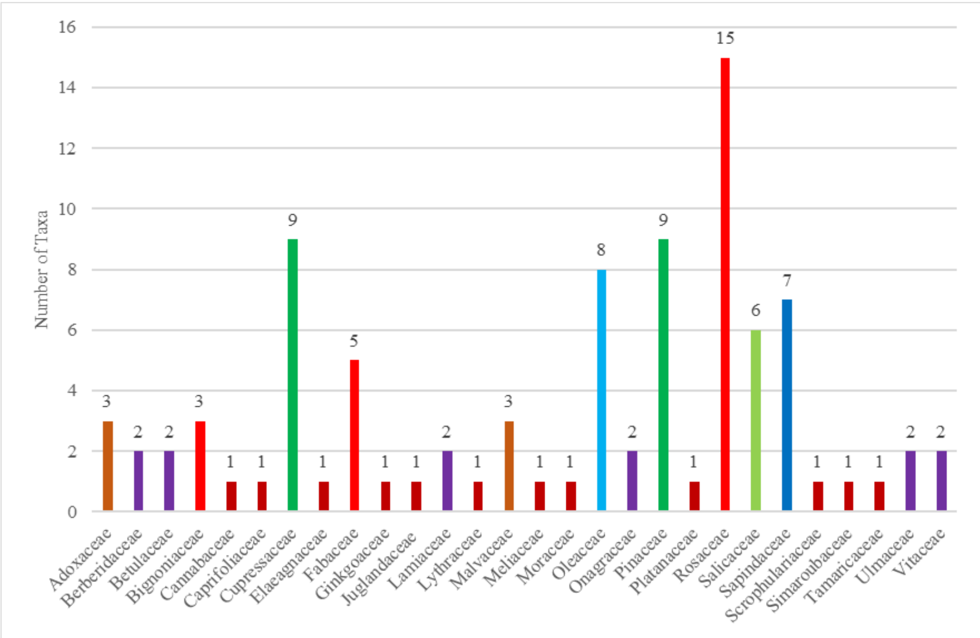

***Figure 3.** Families with allergic properties detected in the study area*

When plant taxa in the study area were examined for their allergenic levels, it was determined that 35 of the total 92 taxa had low allergenic potential, 24 had moderate allergenic potential, and 33 had high allergenic potential (*Figure 4*).

As a consequence of the evaluation, it was determined that 9 out of 35 natural plant taxa have low allergenic potential, 10 have moderate potential, and 16 have high potential. When analyzing the allergenicity rates of exotic plant taxa, it was found that 26 out of 57 plant taxa had low allergenic potential, 14 had moderate allergenic potential, and 17 had high allergenic potential (*Figure 5*).

When the phenological data of the plant taxa found in the research area were examined, it was determined that the most intensive flowering occurred in May and a total of 64 taxa flowered in this period. May was followed by April with 60 taxa, June with 35 taxa, March with 19 taxa and July with 18 taxa (*Figure 6*). These findings reveal that the flowering periods of plant species in the region are largely concentrated in the spring months.

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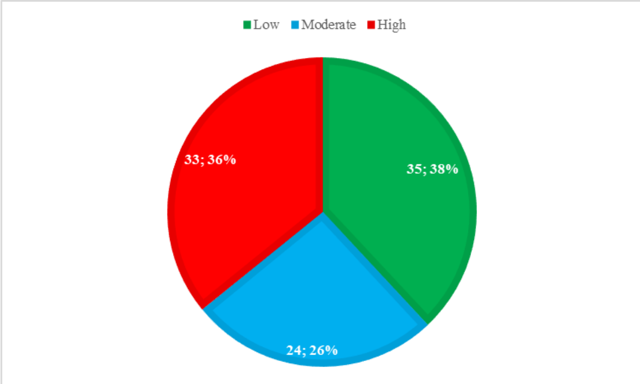

Figure 4. *Allergen ratios of plants in the research area*

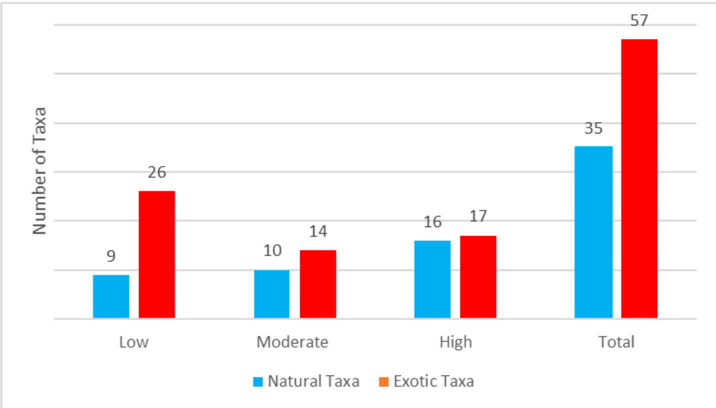

Figure 5. *Individual allergen ratios of detected natural and exotic taxa*

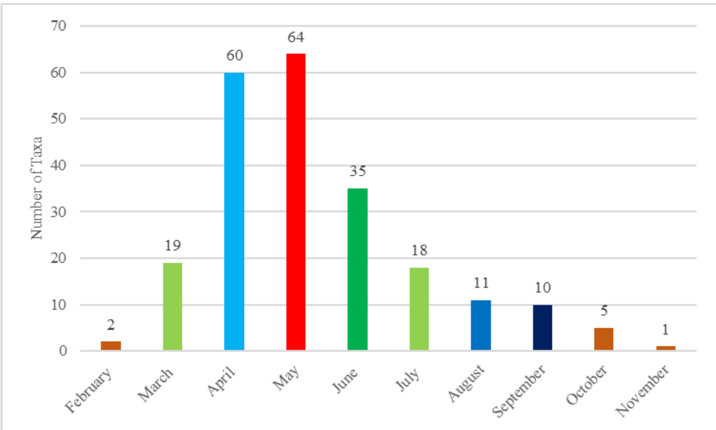

Figure 6. *Flowering periods of allergenic plants in the study areas*

One of the most significant adverse effects of plants on human health is pollen-induced allergic reactions (Hsieh et al., 2019; Kasprzyk et al., 2019; Lara et al., 2019; Aerts et al., 2020). In the investigation conducted according to Ekren and Çorbacı (2022), 110 plant taxa with the potential to cause allergic reactions were identified. These plants were evaluated according to their families, life forms, flowering periods, allergen levels,

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conservation status and distribution areas. Analysis revealed that 42 of 110 taxa exhibited low, 26 moderate, and 42 high allergenic potential. In a separate study conducted at Iğdır University Şehit Bülent Yurtseven Campus, 92 taxa were determined to have allergenic properties. It was determined that 35 of these 92 plant taxa had low allergenic potential, 24 had medium allergenic potential, and 33 had high allergenic potential. The findings indicate that in the studied areas, plant taxa capable of triggering allergic reactions in humans are considerably prevalent.

In the study conducted by Cariñanos et al. (2016), it was reported that among the 100 taxa examined, 83% were broad-leaved species, 13% were coniferous species, and 4% were palm species. According to the evaluation based on allergenicity levels, 49% of the taxa were classified as having a low allergenicity level (ranging from 1 to 6), 15% exhibited a moderate allergenic potential (ranging from 8 to 12), while the remaining 34% showed high (16-24) or very high (27-36) allergenicity values. The very high allergenicity levels were particularly observed in wind-pollinated tree species, especially those belonging to the *Cupressaceae* family, such as *Chamaecyparis lawsoniana* (A. Murray) Parl., *Cupressus* spp., *Juniperus phoenicea* L., *Platycladus orientalis* (L.) Franco, and *Taxus baccata* L. All of these taxa were reported to have exhibited the maximum PAV (Potential Allergenic Value) scores. In the evaluation conducted within the campus area, the distribution of allergenic taxa revealed that 14 were coniferous trees and treelets, 4 were coniferous shrubs, 45 were broad-leaved trees and treelets, 25 were broad-leaved shrubs, and 4 were climbing plants. Furthermore, among the 92 allergenic taxa identified, 35 were found to be of native origin, while 57 were of exotic origin. Species with high allergenic potential included *Cupressus sempervirens* L., *Cupressus arizonica* Greene 'Glauca', *Cuprocyparis leylandii* (A.B. Jacks. & Dallim.) Farjon, *Juniperus horizontalis* Moench, *Juniperus sabina* L., *Juniperus × media* Van Melle 'Mint Julep', *Platycladus orientalis* (L.) Franco, *Thuja orientalis* L. 'Compacta Nana' and *Thuja occidentalis* 'Smaragd'. These species represent some of the most allergenic taxa identified within the study area.

The Potential Allergenic Value (PAV) approach provides a comprehensive quantitative method for assessing the allergenic potential of plant taxa. Developed by Cariñanos et al. (2016), this method integrates various biological and ecological parameters, such as pollen production, pollination type, dispersal capacity, and the biochemical properties of pollen allergens, to assess each species' contribution to the environmental allergen load. PAV values typically range from 0 to 36 and correspond to low, medium, high, and very high allergenicity levels. The authors applied this approach because it allows for a more objective and comparable assessment of allergenic potential, going beyond evaluations based solely on pollen abundance or individual sensitivities. In conclusion, the PAV framework provides a robust scientific basis for classifying the allergenic risk profiles of plant species and supports informed decision-making in urban landscape planning and species selection.

When the allergenicity levels of the species were evaluated in the study by Cariñanos and Marinangeli (2021*),* it was determined that a total of 88 taxa (58.7%) had zero or low allergenicity, while 62 taxa (41.3%) had moderate to very high allergenic potential. The taxa with the highest Potential Allergic value (PAV) values belonged to the Betulaceae, Oleaceae, Cupressaceae, Moraceae and Salicaceae families. These families include the main genus commonly represented in urban forests of the Mediterranean region. Among these, genera such as *Cupressus*, *Morus*, *Olea*, *Juniperus*, *Fraxinus*, *Populus* and *Salix* stand out. When the allergenic plant taxa identified in our study area were evaluated

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according to their families, it was determined that the families with the highest number of taxa were *Rosaceae* (15 taxa), *Cupressaceae* (9 taxa), *Pinaceae* (9 taxa) and *Oleaceae* (8 taxa). In line with these data, the Rosaceae family stands out as the plant group with the highest allergenic potential in the study area, both in terms of the diversity of taxa it contains and the allergenic properties of its species. However, taxa such as *Populus nigra* L., *Salix babylonica* L., *Salix caprea* L., *Salix caprea* 'Pendula', *Salix matsudana* Koidz., *Salix nigra* Marshall, *Fraxinus angustifolia* Vahl, *Fraxinus excelsior* L. and *Fraxinus ornus* L. subsp. ornus were also found in the area. These species have an effect that can cause allergic reactions in sensitive individuals living in the environment, especially during periods of intense pollen spread.

Determining the timing of pollination in plant species is of great importance for the assessment of allergenic pollen effects. It is known that some species with consecutive or overlapping flowering periods (e.g. Cupressaceae, Fraxinus and Acer genus) can also flower in winter (de la Guardia et al., 2006). However, with these exceptions, the majority of plant species in parks and urban green spaces flower in spring, making spring the riskiest time for allergy-sensitive individuals.

Plant composition indices applied in green spaces reveal the general structure of the plant species that are permanently present in these areas, rather than seasonal variations, and therefore do not provide direct information on the potential health risks of spending long periods of time in these areas at certain times of the year. Therefore, it is recommended that current aerobiological data from a nearby sampling station should be shared with the public, if possible, to enable more detailed assessments of pollen density (Cariñanos et al., 2014). In this context, as a result of the field studies conducted at Iğdır University Şehit Bülent Yurtseven Campus, it was determined that the peak flowering period of pollen-emitting plant taxa that may cause allergic effects is May. The 64 different taxa found to bloom in this month indicate the period when pollen-induced allergens reach the highest level in the atmosphere in the campus area. This situation reveals an environmental risk that should be considered for the health of allergy-sensitive individuals on campus, especially in the spring months.

While pollen has a spatial distribution that is not limited to the study area, meteorological factors, wind direction and speed, and vegetation around the campus can carry pollen into the study area, contributing to the total allergen load. However, the area surrounding the study area is relatively poor in terms of vegetation cover, significantly limiting external pollen entry. Consequently, the allergenic taxa identified in this study are largely representative of the local campus flora.

Multivariate analyses

Principal Component Analysis (PCA) was used to investigate the flowering periods and monthly distribution of allergenic pollen-producing plant species in the flora of Iğdır University Şehit Bülent Yurtseven Campus. Early spring (April–May) is dominated by high pollen production from natural woody species, including *Betula pendula* Roth., *Platanus orientalis* L. and *Fraxinus excelsior* L., whereas moderate pollen release is observed in *Pinus brutia* Ten., *Robinia pseudoacacia* L., and *Ailanthus altissima* (Mill.) Swingle between May and June. August June flowering Buddleja davidii Franch with a low allergenic potential. and *Catalpa bignonioides* Walt. it is guided by exotic and ornamental plants such as. August June flowering *Buddleja davidii* Franch with a low allergenic potential. and *Catalpa bignonioides* Walt. it is guided by exotic and ornamental plants such asugust June flowering *Buddleja davidii* Franch with a low allergenic

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potential. and *Catalpa bignonioides* Walt. it is guided by exotic and ornamental plants such as. September October, the overall pollen production decreases, but *Cupressus arizonica* Greene 'Glauca' maintains high pollen production, *Cedrus deodora* (Roxb.) Loud. it shows moderate levels of pollen production, and late flowering coniferous species maintain pollen release. December February winter is characterized by minimal pollen activity, and only a few species produce pollen in small quantities. These results indicate significant seasonal differences in allergenic pollen production in the campus flora and highlight the importance of understanding the phenological characteristics of both local and exotic species for effective landscape management and allergen reduction strategies (*Figure 7*).

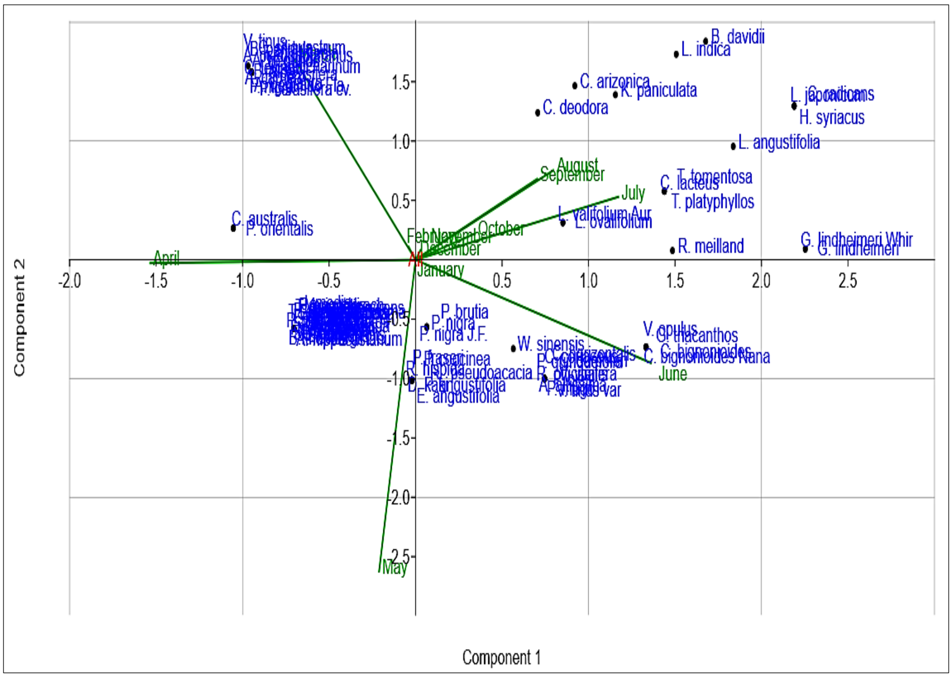

***Figure 7.** Fundamental component analysis*

As a result of hierarchical clustering analysis, plants were grouped into five main groups, with similarities in flowering months and periods being decisive in the clustering. The first group includes species such as *Cedrus deodora* (Roxb.) Loud., *Gaura lindheimeri* Engelm. & A. Gray, and *Buddleja davidii* Franch, which have a long flowering period and remain in bloom until the end of summer and into the fall. The second group includes numerous species with similar phenological characteristics, whose flowering peaks in April–May (*Berberis thunbergii* DC., *Juniperus sabina* L., *Thuja orientalis* L. 'Compacta Nana' and *Fraxinus excelsior* L., etc.). The breadth of this group indicates that allergen load in the region is particularly concentrated in the spring. The third group consists of summer plants that flower between June and August, while the fourth group includes plants that flower in a single month or over a very short period (*Pinus nigra* J.F. Arnold and *Ligustrum ovalifolium* Hassk., etc.). The final group includes typical or very early/late-flowering species, which are clearly distinct from the others. Overall, the dendrogram analysis grouped species with similar flowering periods (*Figure 8*).

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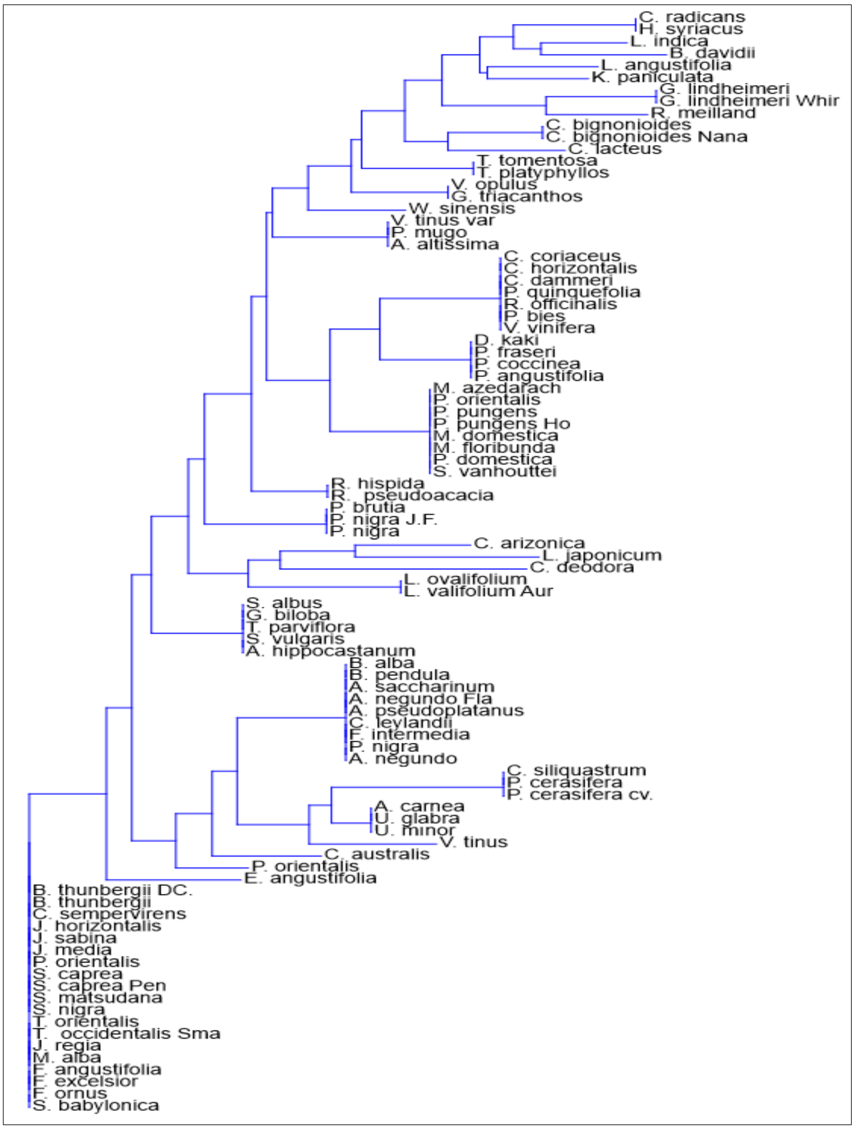

***Figure 8.** Hierarchical clustering analysis*

A Sankey diagram was used to visualize the relationships between the plant taxa in the studied area and their plant families. In this regard, the distribution between the life form of each plant taxon, plant species, and their families was presented in a clear and systematic manner. An online tool called SankeyMATIC was used in the visualization process (*Figure 9*).

The network analysis visualizes similarities in flowering periods between plant species. The network structure reveals that species with similar flowering months are more frequently connected, while species that flower at different times are separated by weak or no connections. The graph shows a dense core network at its center; this core consists of a group of species with flowering periods concentrated between the 4th and 5th months (*Prunus cerasifera* Ehrh., *Prunus domestica* L., *Salix caprea* L., *Thuja orientalis* L. 'Compacta Nana', *Juniperus sabina* L.). These species are strongly connected to each other due to their phenological similarities. On the periphery, species with fewer connections or isolated connections stand out. Species such as *Cedrus deodora* (Roxb.)

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Loud*., Lagerstroemia indica* L. and *Gaura lindheimeri* Engelm. & A. Gray are separated from the central network due to their different or longer flowering periods. Additionally, there are small, tightly connected subgroups within the network. For example, the trio of *Tilia platyphyllos* Scop, *Tilia tomentosa* Moench. and *Cotoneaster lacteus* W.W.Sm. as well as the trio of *Diospyros kaki* Thunb., *Robinia pseudoacacia* L. and *Robinia hispida* L. have formed compact structures within themselves due to their similar flowering characteristics. As a result, this network graph effectively highlights the similarity in flowering periods among plants; species that flower during the same period are clearly grouped together, while those with differing periods are disconnected (*Figure 10*).

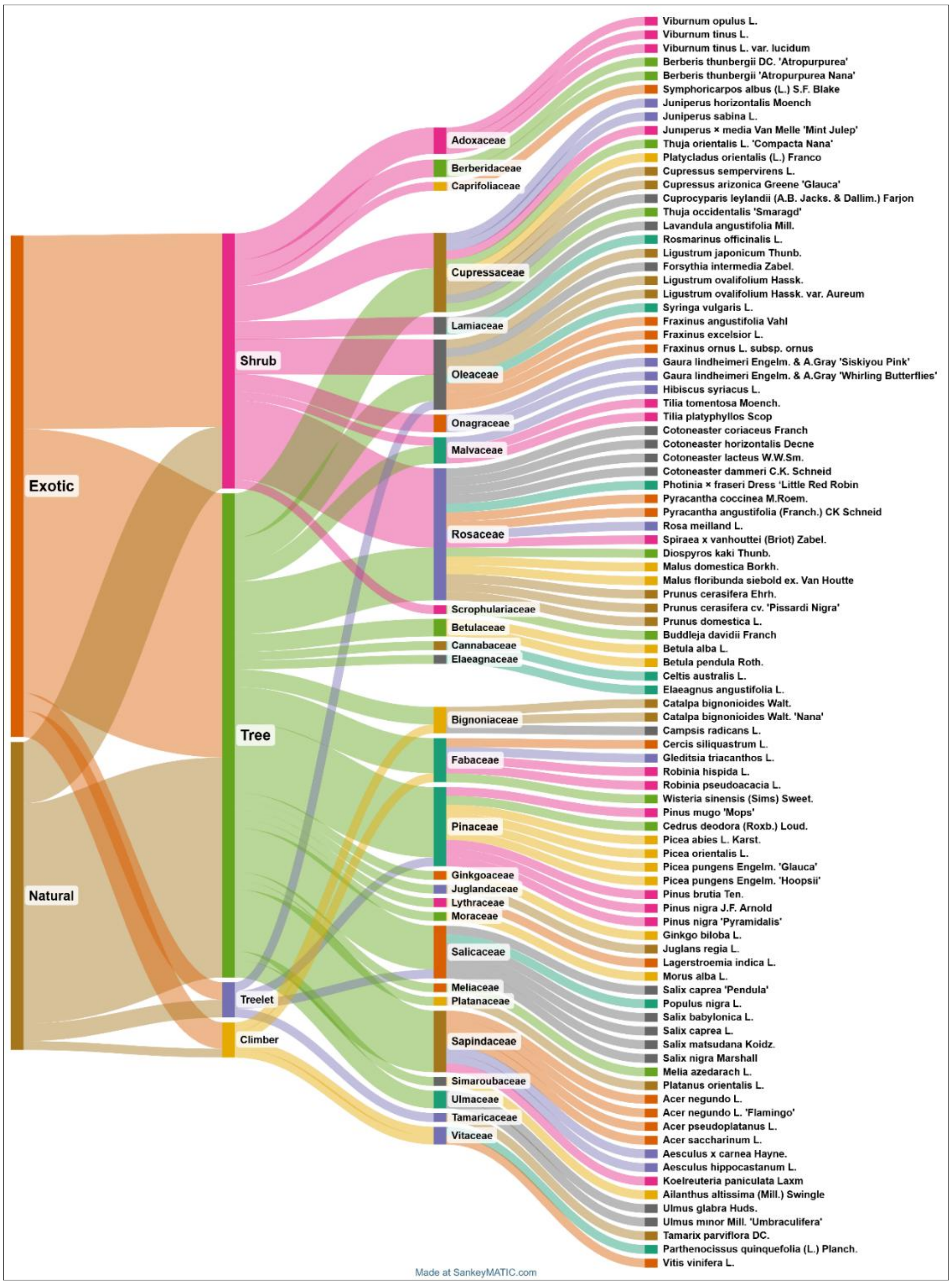

***Figure 9.** Sankey diagram*

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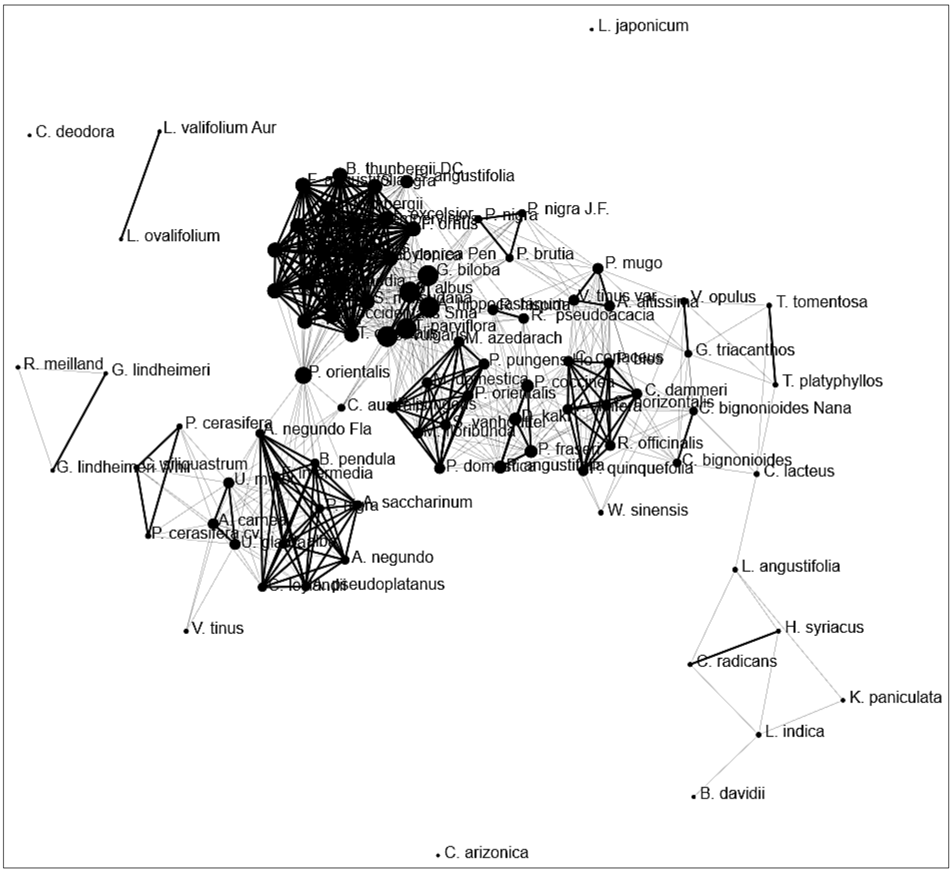

Figure 10. *Network graph analysis*

Similarity decreases from red to blue between matrix values of 0-1. The fact that species such as *Prunus cerasifera* Ehrh., *Prunus domestica* L., *Thuja orientalis* L. 'Compacta Nana' and *Salix caprea* L. show similarity with many species in dark tones on the horizontal and vertical axes indicates that the flowering periods of these plants overlap with a wide group. In contrast, species such as *Cedrus deodora* (Roxb.) Loud. and G *Gaura lindheimeri* Engelm. & A.Gray have lighter-colored similarity lines, indicating that their flowering periods overlap less with other species and are phenologically distinct. The similarity matrix generally shows that the majority of species in the study exhibit more than 60% flowering similarity with each other, but certain species diverge from this common pattern and flower during more unique periods (*Figure 11*).

The color gradient in the image ranges from 0 (non-allergenic) to 3 (highly allergenic), reflecting the allergen load at the plant–month level. In general, the highest allergenic activity is observed in April and May. During this period, many plant species are in bloom, and most of them have allergen values above 2.0. In particular, species such as Thuja orientalis L. 'Compacta Nana', *Prunus cerasifera* Ehrh., *Prunus domestica* L., *Salix caprea* L., *Acer negundo* L., *Acer pseudoplatanus* L., and *Salix babylonica* L. exhibit maximum allergenic potential during these months. The allergen load continues in June–July, but the number of species that are effective during this period decreases; summer-flowering species such as *Buddleja davidii* Franch, *Gaura lindheimeri* Engelm. & A.Gray, *Koelreuteria paniculata* Laxm. and *Ailanthus altissima* (Mill.) Swingleare more prominent. In contrast, the number of species that flower during the winter and fall

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months (October–January) is quite limited, and the allergen load is low. This indicates that the allergic risk in the region is concentrated in the spring and summer months for most of the year. In conclusion, this analysis provides critical information for landscape planning and public health (*Figure 12*).

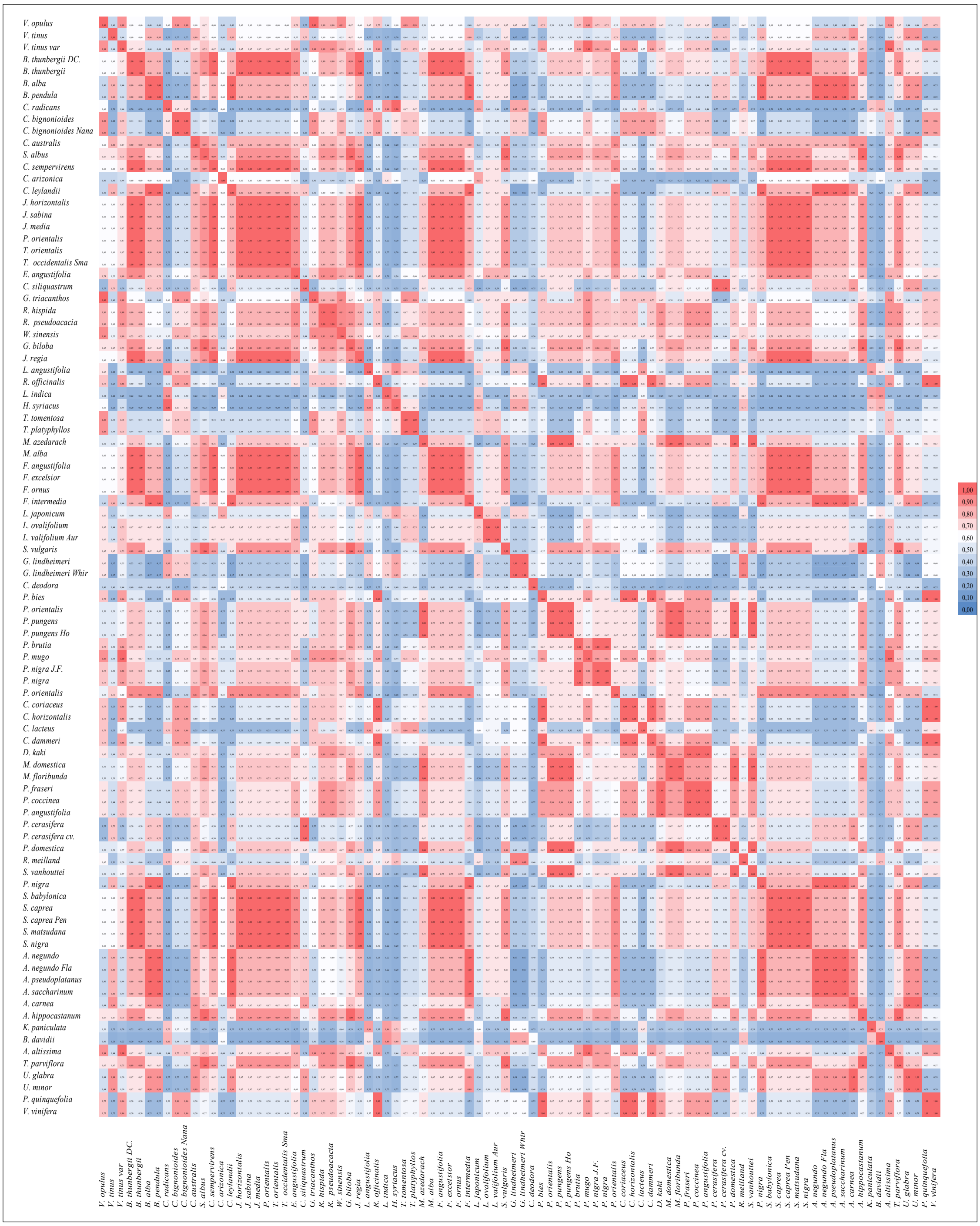

***Figure 11.** Similarity matrix*

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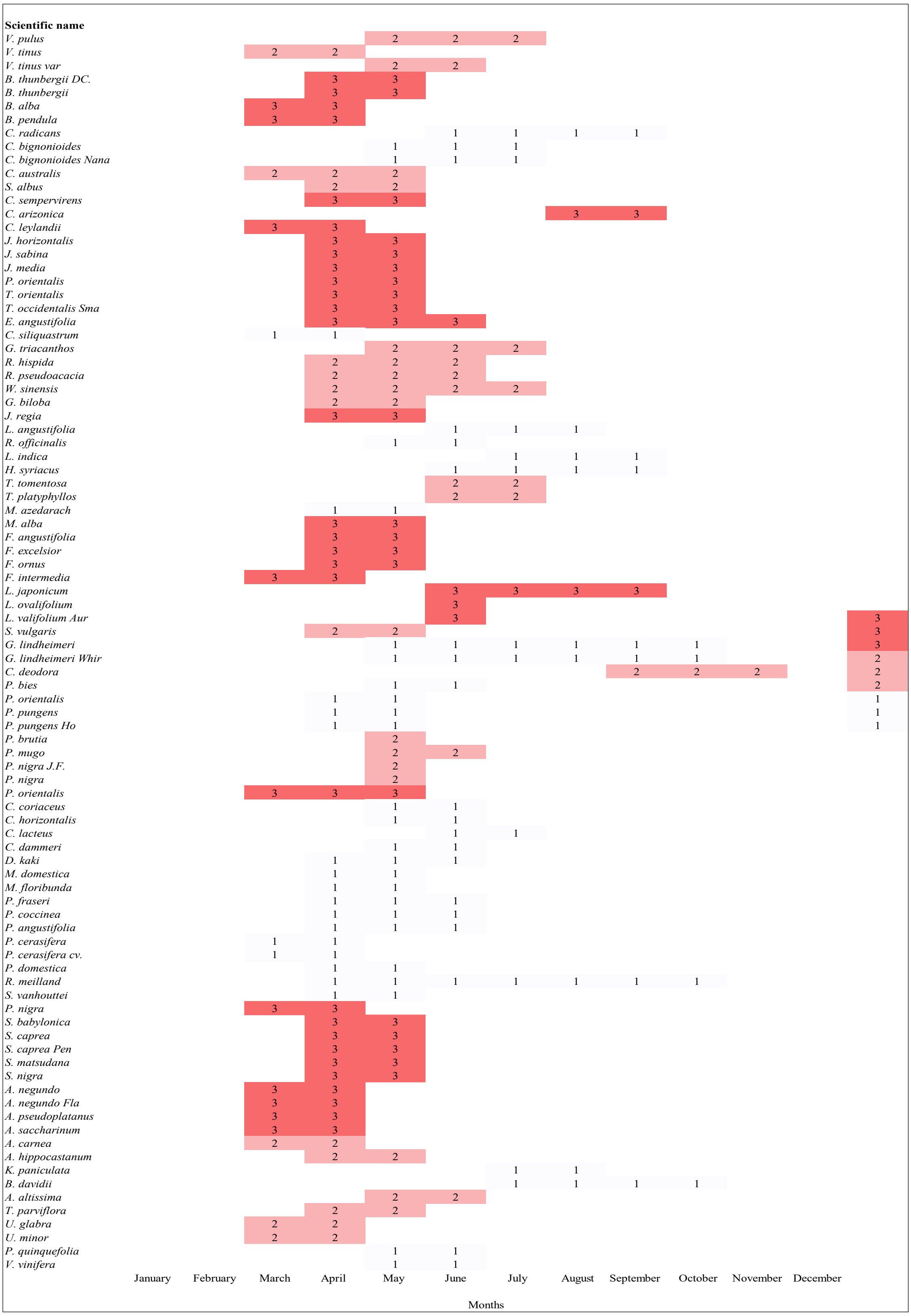

Figure 12. *Heat map of flowering and allergen levels by month*

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Conclusions and recommendations

With the rapid increase in urbanization today, there has been a significant decrease in the amount of open and green spaces, leading to various environmental problems. However, urban green spaces and open spaces are fundamental components that enhance the quality of urban life with their social, environmental and economic benefits. The plants, which form the basic structural elements of these areas, play an important role in supporting urban ecosystems, but in some cases, they can also cause adverse environmental effects. One such effect is allergenic reactions caused by plant pollen, which is a growing concern for urban public health.

Pollen, despite being vital for maintaining ecosystem balance and biodiversity, is also one of the most common airborne allergens that can cause serious health problems in sensitive individuals. Therefore, when developing plant design strategies in urban areas, it is crucial to consider pollen characteristics and the allergenic potential of plant species. The indiscriminate use of highly allergenic species can negatively impact the quality of life for city dwellers, posing a significant environmental and public health risk. In this context, plant taxa used in landscape design should be carefully selected and spatially planned. Limiting the use of highly allergenic species in urban green spaces can help reduce the overall allergenic pollen concentration in the atmosphere.

In this field of research, a total of 92 different plant taxa exhibiting allergic properties have been identified. Among these taxa, it is noteworthy that all species belonging to the Cupressaceae family have a high allergenic potential. In addition, the Rosaceae family stands out as the family containing the highest number of allergenic plant species in the study area due to its large number of taxa. The allergenic properties of both families indicate that these species should be carefully evaluated in urban landscaping applications. Various recommendations have been developed in this context.

In areas with a high density of allergenic plants, landscape arrangements should be re-evaluated and the prevalence of these species should be reduced or replaced with plants with a lower allergenic potential. In areas with a high density of allergenic plants, landscape arrangements should be re-evaluated and the prevalence of these species should be reduced or replaced with plants with a lower allergenic potential. Since pollen distribution is primarily affected by wind, animals and insects, less attractive species for pollinators such as bees, butterflies and birds should be prioritized in the design, and plants with known allergenic effects should be avoided in windy or pedestrian areas with high density. Trees and shrubs used along roadsides or as hedges should be selected based on their low allergenic properties to minimize human exposure.

Pollen monitoring activities should be carried out regularly throughout the campus, and pollen density data should be systematically shared, especially in spring and summer. Educational and awareness-raising activities should be organized to ensure a better understanding of allergy prevention measures by students, staff and visitors. Plant species with a high allergenic potential should be avoided in new landscape projects, especially in places close to intensive public use areas. Campus health units and first aid centers should be informed about pollen-related allergies and the necessary intervention measures should be provided. An inventory of highly allergenic species should be created, their periodic effects should be monitored, and these findings should be integrated into campus management plans. Sustainable, health-oriented landscape planning should be achieved through coordination between academic and environmental management units.

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