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Multivariate Evaluation of Medicinal and Aromatic Plant Diversity for Sustainable Campus Landscape Planning in Iğdır, Türkiye

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Abstract

Due to their aesthetic qualities and versatile applications, medicinal and aromatic plants are an important component of landscape systems. The diversity of color, shape, and texture observed in the vegetative and reproductive organs of these plants contributes to visual composition, while their medicinal and aromatic properties enhance their ecological and socio-cultural significance. However, many taxa are underrepresented in landscape planning applications. This study examined the diversity of medicinal and aromatic plant taxa identified at the Iğdır University Şehit Bülent Yurtseven Campus in Iğdır Province, Turkey, using a descriptive approach. Plant taxa were evaluated based on their families, life forms, leaf characteristics, flowering periods, and medicinal and aromatic properties. Multivariate analyses were conducted to examine phenological similarities among the taxa. A total of 98 plant taxa were identified; 66 taxa possess only medicinal properties, one taxon possesses only aromatic properties, and 31 taxa possess both. These findings reveal that the campus is home to a wide variety of medicinal and aromatic plant taxa, with characteristics relevant to planting layout and species selection. Consequently, this study provides a descriptive foundation for further research on how such taxa can be incorporated into campus planting designs and green space planning.

Keywords: biodiversity conservation; medicinal and aromatic plants; sustainable landscape design; urban green infrastructure

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1. Introduction

As in many parts of the world, plants belonging to the natural flora of Türkiye have long been used by local communities for a variety of purposes. These plants are traditionally used in fields such as traditional medicine, food, herbal teas, spices, dyes, insecticides, veterinary medicine, resin and gum extraction, the production of essential and fixed oils, soft drinks, and cosmetics. These traditional uses have been passed down from generation to generation as an important part of cultural heritage. However, this cultural richness has gradually come under threat due to increasing urbanization [1]. As a result, the reduction in open and green spaces in parallel with urban population growth has increased people's desire for contact with nature. Therefore, the protection and expansion of green areas within and around urban settlements are gaining importance day by day. Such areas offer city residents the opportunity to engage in various activities [2,3].

Urban open and green spaces are among the indispensable components of urban life. In addition to supporting social interaction within the city, these spaces contribute to the healthy development of urban environment through their aesthetic and ecological functions. In this context, the importance of ornamental plants in protecting urban open and green areas and ensuring the sustainability of the urban ecosystem has become increasingly important. Ornamental plants integrated into urban life strengthen the human nature relationship, allowing individuals to experience psychological relaxation and contributing to the creation of harmonious and sustainable living spaces [4]. Additionally, in sustainable landscape design, strategically planning green spaces based on climatic data both enhances users' thermal comfort levels and contributes to reducing energy consumption. In this framework, the arrangement of vegetation, tree planting, shading elements, and similar landscape components play a significant role in improving microclimate conditions in urban spaces. In particular, plantings and shading applications contribute to reducing the urban heat island effect by balancing surface and air temperatures, thereby supporting the improvement of thermal comfort conditions for users in open spaces [5].

Medicinal and aromatic plants are valued in landscape design not only for their ecological and functional contributions, but also for their visual, sensory, and cultural qualities [6–8]. Their flowers, leaves, fruits, branches, and bark contribute to planting composition through variations in color, form, and texture, while their fragrance and traditional uses add further value in educational, recreational, and sustainable landscape contexts [9].

Plants contribute to landscape systems not only through their aesthetic attributes but also through the ecosystem services they provide, including microclimatic regulation, erosion control, and support for urban environmental quality. In addition, their sensory and seasonal characteristics enhance the outdoor experience and contribute to the development of functional and resilient urban landscapes [10,11]. In this context, medicinal and aromatic plants constitute an important plant group in terms of sustainable landscaping practices thanks to their low maintenance requirements, ability to adapt to climatic conditions, and biodiversity-supporting properties. At the same time, they are considered both aesthetic and functional landscape elements due to their pleasant scents, visual richness, and health benefits.

Specifically, promoting the use of local and endemic species in landscape design not only contributes to the conservation of regional ecosystems but also facilitates the preservation of traditional knowledge. In this regard, medicinal and aromatic plants hold multifaceted value in sustainable landscape design from ecological, economic, and cultural perspectives [12]. For this reason, it is important to effectively incorporate medicinal and aromatic plants into landscape designs and prioritize their cultivation and production. The widespread use of these plants in landscaping is expected to boost agricultural production and economic activity in the region, thereby supporting local development [13].

Medicinal and aromatic plants have a significant impact on the national economy with their contributions to the health, pharmaceutical and cosmetic industries. These plants not only promote sustainable agricultural practices but also contribute to the conservation of biodiversity and constitute an important source of income for millions of farmers and local communities [14]. The importance of medicinal and aromatic plants is closely associated with their antioxidant and biocidal properties. Nevertheless, the extent of these properties is not uniform and may vary considerably according to species-specific characteristics, plant age, cultivation practices, harvest timing, and environmental conditions such as temperature, ultraviolet radiation, and light intensity [15]. Today, the use of medicinal and aromatic plants extends across many different landscape settings, from specialized garden types to everyday urban planting spaces. Their continued presence in these environments is associated not only with visual appeal but also with their practical and cultural functions. Home gardens are especially noteworthy in this context because they preserve one of

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the most long-standing traditions of plant use while simultaneously offering a range of ecosystem-related benefits. For this reason, they remain an important setting in which medicinal and aromatic plants are maintained within present-day urban life [16].

This research addresses the medicinal and aromatic plant taxa documented on the Şehit Bülent Yurtseven Campus of Iğdır University, located in the Eastern Anatolia Region of Türkiye. The recorded taxa were described with respect to taxonomic affiliation, life form, leaf characteristics, flowering behavior, and medicinal and aromatic properties. Using these descriptive observations, the study discusses how the identified taxa may be considered in relation to planting composition and species selection within campus green-space planning.

2. Materials and Methods

2.1. Materials

The study material comprised the plant taxa established in the open green areas of the Şehit Bülent Yurtseven Campus of Iğdır University within the scope of landscape implementation works carried out between 2017 and 2025. These plantings were progressively incorporated into the campus landscape over an eight-year period. Iğdır University is situated in the Eastern Anatolia Region of Türkiye and lies close to the borders of Armenia, Nakhchivan (Autonomous Republic of Azerbaijan), and Iran. Field observations were undertaken throughout all seasons of the year across the campus, and the plant material used in sports areas, entrance spaces, resting zones, and seating areas was examined on-site. In parallel, routine maintenance practices were monitored in relation to plant adaptation. In this way, the study generated descriptive information on medicinal and aromatic plant taxa that may be relevant to planting-related evaluations in the Eastern Anatolia Region.

Research area and climate

The first higher education institution in Iğdır was the Iğdır Vocational School, established in 1995 as part of Kars Kafkas University. In 2006, the Iğdır Faculty of Agriculture was founded under Kafkas University, followed by the establishment of Iğdır University as an independent institution in 2008, to which additional units were gradually affiliated. The Iğdır University Şehit Bülent Yurtseven Campus began operations in 2014. Numerous buildings were constructed within the campus, and landscape design projects for these areas were completed and made available for use. The landscape project initiated in 2016 at the Iğdır University Şehit Bülent Yurtseven Campus was completed in 2020 (Figure 1).

The climatic characterization of the study area is based on long-term meteorological data from 1940 to 2025. According to records from Iğdır, the average maximum temperatures during the summer and early fall months were 29.6 °C in June, 33.4 °C in July, 33.3 °C in August, and 29.0 °C in September. In terms of precipitation, the highest average monthly precipitation during this period occurred in June (31.2 mm), followed by significant decreases in July (14.1 mm), August (9.4 mm), and September (11.5 mm) [17]. Studies conducted in Iğdır have shown that the region receives low rainfall and is the least rainy province in Türkiye. Evaluations indicate that it exhibits arid and semi-arid characteristics depending on the classification method used. This situation increases the importance of irrigation in landscaping and agricultural activities [18].

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Figure 1. Landscape view of the study area.

2.2. Methods

Taxon inclusion and classification criteria

The methodological framework of the study was structured in three successive stages. Initially, the plant taxa present in the study area were determined through on-site observations with reference to the taxonomic sources of Davis [19] and Akkemik [20,21]. Species identification was based on diagnostic morphological features described in the literature and, when available, supported by certification records. In addition, photographic records were created for the identified individuals during fieldwork. Taxonomic accuracy was subsequently checked by comparing field observations with the relevant literature. In the second phase of the study, medicinal and aromatic plants were identified using research conducted by Mamıkoğlu [22], Çorbacı and Ekren [23], Ekren and Çorbacı [24], Tik and Kaya [25,26]. All planted taxa recorded within the campus landscape area during the observation period were first inventoried and included in the initial evaluation. Subsequently, the medicinal and aromatic status of each taxon was determined through literature-based screening. Taxa documented only for medicinal use were classified as "medicinal," those documented only for aromatic use were classified as "aromatic," and those reported for both uses were classified as "medicinal and aromatic." A documented use reported in the consulted literature was accepted as sufficient for inclusion in the relevant category. The plants identified in the field were classified according to their life forms; in this regard, individuals were examined under four categories: trees, small trees, shrubs, and climbers. In addition to the basic variables presented, the identified taxa were also evaluated in terms of planting composition and design features related to maintenance. In this context, the evergreen or deciduous nature of the plants, their contribution to seasonal ornamentation, the active vegetative growth period, and the likelihood of pruning requirements for growth control were descriptively assessed based on field observations and the general horticultural characteristics of the taxa. These factors were included to enhance the applicability of the findings for year-round landscape composition and sustainable campus planting management.

The third stage of the study focused on analytical evaluation and visual representation of the recorded data. At this stage, the relationships between flowering periods and the medicinal and aromatic properties of the taxa were examined, and similarity patterns among taxa were assessed through multidimensional approaches. To illustrate the connections between plant taxa and their families, a Sankey diagram was generated using the SankeyMATIC program [27,28]. A similarity matrix was created to evaluate structural similarities between taxa using R programming language. This approach aimed to identify specific patterns by grouping taxa that exhibit similar flowering times [29]. Each taxon was represented according to the months in which flowering was recorded, and similarity between taxa was evaluated based on the overlap of these flowering months. In addition, hierarchical clustering analysis was applied to reveal the similarities among plant taxa based on their flowering months. This analysis, performed according to flowering times, enabled the grouping of species that bloom during similar periods in the same clusters, thus identifying plants with similar phenological characteristics. The PAST V4.01 (Paleontological Statistics) software was used in the analysis process [28,29].

3. Results

Table 1 presents the identified taxa together with their family affiliation, life form, leaf characteristics, flowering periods, and medicinal and aromatic properties. The data in this table were prepared based on predefined classification criteria. In this context, plants were classified according to their life forms, while their origins were evaluated as natural or exotic; according to their defoliation status, they were grouped as evergreen or deciduous. In addition, the taxa were classified into three usage categories: medicinal, aromatic, and both medicinal and aromatic. In addition to these core variables, the identified taxa were also interpreted in terms of seasonal ornamental interest and maintenance-related characteristics relevant to landscape design.

Table 1. Plant taxa and characteristics identified in the research.

Family	Scientific Name	Plant Type	Life Form	Flowering Period (Months)	Leaf Condition	Medicinal and Aromatic Value
Adoxaceae	*Viburnum opulus* L.	Shrub	Natural	5–7	Deciduous	Medicinal
	Viburnum tinus L.	Shrub	Natural	2–4	Evergreen	Medicinal
	Viburnum tinus L. var. *lucidum* Aiton	Shrub	Exotic	5–6	Evergreen	Medicinal
Berberidaceae	*Berberis thunbergii* DC. 'Atropurpurea'	Shrub	Exotic	4–5	Deciduous	Medicinal
	Berberis thunbergii 'Atropurpurea Nana'	Shrub	Exotic	4–5	Deciduous	Medicinal
Betulaceae	*Betula pubescens* Ehrh.	Tree	Natural	3–4	Deciduous	Medicinal
	Betula pendula Roth	Tree	Natural	3–4	Deciduous	Medicinal
Bignoniaceae	*Campsis radicans* (L.) Seem.	Climber	Exotic	6–9	Deciduous	Medicinal
	Catalpa bignonioides Walter	Tree	Exotic	5–7	Deciduous	Medicinal and aromatic
	Catalpa bignonioides Walter 'Nana'	Tree	Exotic	5–7	Deciduous	Medicinal and aromatic
Buxaceae	*Buxus sempervirens* L.	Shrub	Natural	3–5	Evergreen	Medicinal
	Buxus microphylla Siebold & Zucc. 'Faulkner'	Shrub	Natural	3–5	Evergreen	Medicinal
Cannabaceae	*Celtis australis* L.	Tree	Natural	3–5	Deciduous	Medicinal
Caprifoliaceae	*Abelia × grandiflora* (Rovelli ex Andre) Rehder	Shrub	Exotic	6–9	Deciduous	Medicinal and aromatic

Table 1. *Cont.*

Family	Scientific Name	Plant Type	Life Form	Flowering Period (Months)	Leaf Condition	Medicinal and Aromatic Value
	Lonicera japonica Thunb.	Climber	Exotic	5–7	Evergreen	Medicinal
	Lonicera nitida E.H.Wilson 'Maigrün'	Shrub	Exotic	5–7	Evergreen	Medicinal
	Symphoricarpos albus (L.) S.F. Blake	Shrub	Exotic	4–5	Deciduous	Medicinal
Celastraceae	*Euonymus japonicus* Thunb. 'Aurea'	Shrub	Exotic	5–7	Evergreen	Medicinal
Cupressaceae	*Cupressus sempervirens* L.	Tree	Natural	4–5	Evergreen	Medicinal and aromatic
	Cupressus arizonica Greene 'Glauca'	Tree	Exotic	8–9	Evergreen	Medicinal and aromatic
	Juniperus horizontalis Moench	Shrub	Exotic	4–5	Evergreen	Medicinal
	Juniperus sabina L.	Shrub	Natural	4–5	Evergreen	Medicinal
	Juniperus × *media* Van Melle 'Mint Julep'	Shrub	Exotic	4–5	Evergreen	Medicinal
	Platycladus orientalis (L.) Franco	Tree	Natural	4–5	Evergreen	Medicinal
	Platycladus orientalis (L.) Franco 'Compacta Nana'	Shrub	Exotic	4–5	Evergreen	Medicinal
	Thuja occidentalis L. 'Smaragd'	Tree	Exotic	4–5	Evergreen	Medicinal
Elaeagnaceae	*Elaeagnus angustifolia* L.	Tree	Natural	4–6	Deciduous	Medicinal and aromatic
Fabaceae	*Cercis siliquastrum* L.	Tree	Natural	3–4	Deciduous	Aromatic
	Gleditsia triacanthos L.	Tree	Exotic	5–7	Deciduous	Medicinal
	Robinia hispida L.	Tree	Exotic	4–6	Deciduous	Medicinal and aromatic
	Robinia pseudoacacia L.	Tree	Exotic	4–6	Deciduous	Medicinal and aromatic
	Wisteria sinensis (Sims) Sweet	Climber	Exotic	4–7	Deciduous	Medicinal and aromatic
Ginkgoaceae	*Ginkgo biloba* L.	Tree	Exotic	4–5	Deciduous	Medicinal and aromatic
Juglandaceae	*Juglans regia* L.	Tree	Natural	4–5	Deciduous	Medicinal and aromatic
Lamiaceae	*Lavandula angustifolia* Mill.	Shrub	Natural	6–8	Evergreen	Medicinal and aromatic
	Salvia rosmarinus Spenn.	Shrub	Natural	5–6	Evergreen	Medicinal and aromatic
Lythraceae	*Lagerstroemia indica* L.	Tree	Exotic	7–9	Deciduous	Medicinal
Malvaceae	*Hibiscus syriacus* L.	Shrub	Exotic	6–9	Deciduous	Medicinal
	Tilia tomentosa Moench	Tree	Natural	6–7	Deciduous	Medicinal and aromatic
	Tilia platyphyllos Scop.	Tree	Natural	6–7	Deciduous	Medicinal and aromatic

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Table 1. *Cont.*

Family	Scientific Name	Plant Type	Life Form	Flowering Period (Months)	Leaf Condition	Medicinal and Aromatic Value
Meliaceae	*Melia azedarach* L.	Tree	Exotic	4–5	Deciduous	Medicinal and aromatic
Moraceae	*Morus alba* L.	Tree	Natural	4–5	Deciduous	Medicinal
	Ficus carica L.	Tree	Natural	6–8	Deciduous	Medicinal
Oleaceae	*Fraxinus angustifolia* Vahl	Tree	Natural	4–5	Deciduous	Medicinal
	Fraxinus excelsior L.	Tree	Natural	4–5	Deciduous	Medicinal
	Fraxinus ornus L.	Tree	Natural	4–5	Deciduous	Medicinal
	Ligustrum japonicum Thunb.	Small tree	Exotic	6–9	Evergreen	Medicinal
	Ligustrum ovalifolium Hassk.	Shrub	Exotic	6	Evergreen	Medicinal
	Ligustrum ovalifolium Hassk. 'Aureum'	Shrub	Exotic	6	Evergreen	Medicinal
	Syringa vulgaris L.	Shrub	Exotic	4–5	Deciduous	Medicinal and aromatic
Pinaceae	*Cedrus deodara* (Roxb. ex D.Don) G.Don	Tree	Exotic	9–11	Evergreen	Medicinal
	Picea abies (L.) H.Karst.	Tree	Exotic	5–6	Evergreen	Medicinal
	Picea orientalis (L.) Peterm.	Tree	Natural	4–5	Evergreen	Medicinal
	Picea pungens Engelm. 'Glauca'	Tree	Exotic	4–5	Evergreen	Medicinal
	Picea pungens Engelm. 'Hoopsii'	Tree	Exotic	4–5	Evergreen	Medicinal
	Pinus brutia Ten.	Tree	Natural	5	Evergreen	Medicinal
	Pinus mugo Turra	Small tree	Exotic	5–6	Evergreen	Medicinal
	Pinus nigra J.F.Arnold	Tree	Natural	5	Evergreen	Medicinal
	Pinus nigra J.F.Arnold 'Pyramidalis'	Tree	Natural	5	Evergreen	Medicinal
Platanaceae	*Platanus orientalis* L.	Tree	Natural	3–5	Deciduous	Medicinal
Rosaceae	*Cotoneaster coriaceus* Franch.	Shrub	Exotic	5–6	Evergreen	Medicinal
	Cotoneaster horizontalis Decne.	Shrub	Exotic	5–6	Deciduous	Medicinal
	Cotoneaster lacteus W.W.Sm.	Shrub	Exotic	6–7	Evergreen	Medicinal
	Cotoneaster dammeri C.K.Schneid.	Shrub	Exotic	5–6	Evergreen	Medicinal
	Diospyros kaki L.f.	Tree	Exotic	4–6	Deciduous	Medicinal and aromatic
	Crataegus laevigata (Poir.) DC. 'Paul's Scarlet'	Small tree	Exotic	4–5	Deciduous	Medicinal
	Malus domestica (Suckow) Borkh.	Tree	Exotic	4–5	Deciduous	Medicinal and aromatic
	Malus floribunda Siebold ex Van Houtte	Tree	Exotic	4–5	Deciduous	Medicinal and aromatic
	Pyracantha coccinea M.Roem.	Shrub	Natural	4–6	Evergreen	Medicinal

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Table 1. *Cont.*

Family	Scientific Name	Plant Type	Life Form	Flowering Period (Months)	Leaf Condition	Medicinal and Aromatic Value
	Pyracantha angustifolia (Franch.) C.K. Schneid.	Shrub	Exotic	4–6	Evergreen	Medicinal
	Prunus amygdalus Batsch	Tree	Exotic	3–4	Deciduous	Medicinal and aromatic
	Prunus armeniaca L.	Tree	Natural	3–4	Deciduous	Medicinal and aromatic
	Prunus cerasifera Ehrh.	Tree	Exotic	3–4	Deciduous	Medicinal and aromatic
	Prunus cerasifera Ehrh. 'Pissardii'	Tree	Exotic	3–4	Deciduous	Medicinal and aromatic
	Prunus cerasus L.	Tree	Exotic	4–5	Deciduous	Medicinal and aromatic
	Prunus domestica L.	Tree	Natural	4–5	Deciduous	Medicinal and aromatic
	Prunus persica (L.) Batsch	Tree	Exotic	4–5	Deciduous	Medicinal and aromatic
	Prunus serrulata Lindl. 'Kanzan'	Tree	Exotic	4–5	Deciduous	Medicinal
	Rosa L. 'Meilland'	Shrub	Natural	4–10	Deciduous	Medicinal and aromatic
Salicaceae	*Populus nigra* L.	Tree	Natural	3–4	Deciduous	Medicinal and aromatic
	Salix babylonica L.	Tree	Exotic	4–5	Deciduous	Medicinal
	Salix caprea L.	Tree	Natural	4–5	Deciduous	Medicinal
	Salix caprea L. 'Pendula'	Small tree	Natural	4–5	Deciduous	Medicinal
	Salix matsudana Koidz.	Tree	Exotic	4–5	Deciduous	Medicinal
	Salix nigra Marshall	Tree	Natural	4–5	Deciduous	Medicinal
Sapindaceae	*Acer negundo* L.	Tree	Exotic	3–4	Deciduous	Medicinal
	Acer negundo L. 'Flamingo'	Tree	Exotic	3–4	Deciduous	Medicinal
	Acer pseudoplatanus L.	Tree	Natural	3–4	Deciduous	Medicinal
	Aesculus × *carnea* Hayne	Tree	Exotic	3–4	Deciduous	Medicinal
	Aesculus hippocastanum L.	Tree	Exotic	4–5	Deciduous	Medicinal
	Koelreuteria paniculata Laxm.	Tree	Exotic	7–8	Deciduous	Medicinal
Scrophulariaceae	*Buddleja davidii* Franch.	Shrub	Exotic	7–10	Deciduous	Medicinal and aromatic
Simaroubaceae	*Ailanthus altissima* (Mill.) Swingle	Tree	Exotic	5–6	Deciduous	Medicinal and aromatic
Tamaricaceae	*Tamarix parviflora* DC.	Small tree	Natural	4–5	Deciduous	Medicinal
Ulmaceae	*Ulmus glabra* Huds.	Tree	Natural	3–4	Deciduous	Medicinal
	Ulmus minor Mill. 'Umbraculifera'	Tree	Natural	3–4	Deciduous	Medicinal
Vitaceae	*Parthenocissus quinquefolia* (L.) Planch.	Climber	Exotic	5–6	Deciduous	Medicinal
	Vitis vinifera L.	Climber	Natural	5–6	Deciduous	Medicinal

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Within the scope of the research, a total of 98 different medicinal and aromatic plant taxa were identified. 40 of these taxa were naturally distributed and 58 were of exotic origin. In line with the data obtained, it was determined that approximately 40% of the plants used in the study areas consisted of natural taxa, whereas 60% consisted of exotic taxa. When the morphological forms of the taxa were examined, 59 were trees, 5 were small trees, 29 were shrubs and 5 were climbers. Based on leaf characteristics, 64 taxa were deciduous while 34 taxa were evergreen. Additionally, 27 of these tree taxa were of natural origin, and 32 were of exotic origin. Among the 59 tree taxa, 34 were medicinal, 1 was aromatic, and 24 were both medicinal and aromatic. Of the 29 shrub taxa identified, 10 were deciduous and 19 were evergreen. A total of 9 shrub taxa were of natural origin, while 20 were of exotic origin. Among shrub taxa, 23 were medicinal and 6 were both medicinal and aromatic. Of the 5 small tree taxa, 3 were deciduous and 2 were evergreen. This group included 2 natural and 3 exotic taxa, all of which were medicinal. Of the 5 climber taxa, 4 were deciduous and 1 was evergreen. Only 1 climber taxon was of natural origin, while 4 were of exotic origin. Among climber taxa, 4 were medicinal and 1 was both medicinal and aromatic (Figure 2).

At the family level, Rosaceae was the most represented group with 19 taxa, followed by Pinaceae (9), Cupressaceae (8), and Oleaceae (7). Rosaceae also ranked first in the number of medicinal and aromatic taxa recorded in the campus flora (Figure 3).

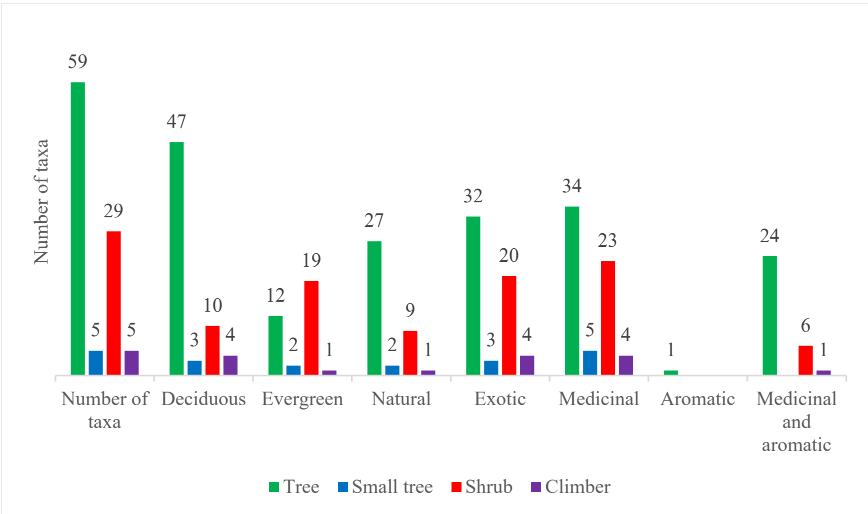

Figure 2. General assessment of taxa.

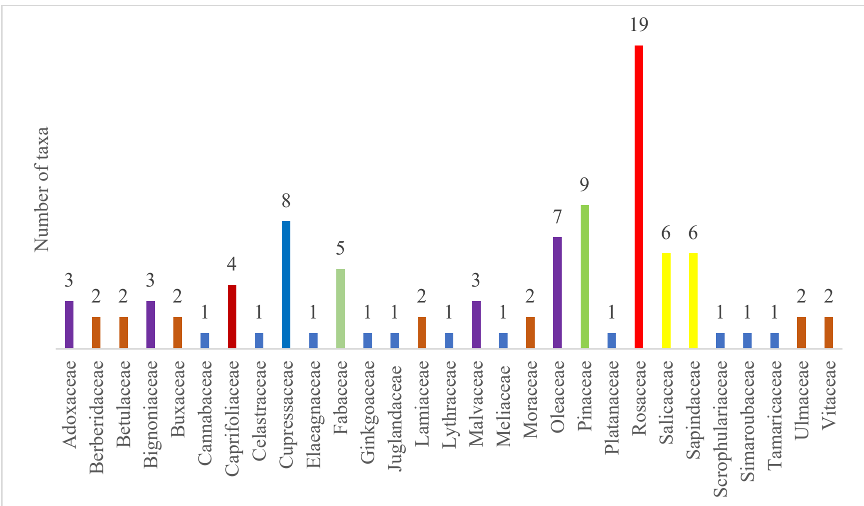

Figure 3. Distribution of medicinal and aromatic plant taxa by family in the study area.

4. Discussion

Medicinal and aromatic plants (MAPs) represent a diverse group of taxa distinguished by their bioactive potential and characteristic aromatic compounds. These plants are used in a range of contexts, including medicinal, culinary, aromatic, and therapeutic applications [30].

In their study conducted in Balıkesir, Türkiye, Tanfer and Yener [31], identified a total of 75 plant families to which the naturally occurring medicinal and aromatic plants in the region belong. The family with the highest number of taxa was Asteraceae (daisy family), comprising 40 plant taxa. This was followed by Lamiaceae (mint family) with 29 taxa, Rosaceae (rose family) with 21 taxa, Apiaceae (parsley family) with 13 taxa, Brassicaceae (mustard family) with 10 taxa, Cucurbitaceae (gourd family) and Poaceae (grass family) with 9 taxa each, Boraginaceae (borage family) with 8 taxa, Fabaceae (legume family) with 7 taxa, and Ericaceae (heath family), Hypericaceae (St. John's wort family), and Moraceae (mulberry family) each included 4 taxa. Çorbacı and Ekren [23] identified Rosaceae (20 taxa), Cupressaceae (16 taxa), and Pinaceae (16 taxa) as the families with the greatest taxonomic richness. Within Rosaceae, 18 species were reported to possess medicinal properties, 12 were aromatic, and 12 exhibited both medicinal and aromatic characteristics. A comparable pattern was observed in Cupressaceae, where 14 species were medicinal, while 7 displayed aromatic traits and an equal number exhibited both properties. In Pinaceae, the flora was overwhelmingly characterised by medicinal species (15 taxa), with only a limited representation of aromatic or dual-purpose taxa. Taken together, these findings underscore the relative prominence of Rosaceae in terms of species exhibiting both medicinal and aromatic qualities. This pattern is broadly consistent with the findings from the Şehit Bülent Yurtseven Campus of Iğdır University, where Rosaceae (19 taxa), Pinaceae (9 taxa), Cupressaceae (8 taxa), and Oleaceae (7 taxa) were identified as the most taxonomically diverse families. In that study, 8 Rosaceae species were exclusively medicinal, whereas 11 exhibited both medicinal and aromatic characteristics. All recorded Pinaceae species (9 taxa) were medicinal, while in Cupressaceae, 6 species were medicinal and 2 displayed both properties. Similarly, within Oleaceae, 6 species were identified as medicinal and 1 as possessing both medicinal and aromatic attributes.

Çorbacı and Ekren [23], evaluated medicinal and aromatic plants in their study in terms of greening periods, user impacts, and their contribution to spatial occupancy balances. In this context, they identified 115 evergreen and 97 deciduous plant taxa in the area. They also recorded 4 tuberous, 3 bulbous and 4 seasonal plant taxa that develop during specific periods. These species were evaluated by considering the periods in which they were prominent in the field. Their findings showed that 52% of the plants used in the study areas were evergreen, 43% deciduous, 2% tuberous, 2% seasonal, and 1% bulbous. The high rate of evergreen plant use allows medicinal and aromatic properties to be perceived more consistently throughout the year, thereby enhancing the effectiveness of these features. Similarly, in the study conducted at Iğdır University Şehit Bülent Yurtseven Campus, 34 evergreen and 64 deciduous plant taxa were identified. These data show that the use of deciduous plants is more common in the campus landscape. The high number of deciduous species allows seasonal changes to be felt more clearly in the area and makes important contributions in terms of visual dynamism. However, this may create some limitations regarding sustainability of the continuous green texture and the year-round perception of medicinal-aromatic effects. On the other hand, the strategic use of evergreen plants, despite their smaller proportion, is important for maintaining landscape vitality, especially in winter, and ensuring that medicinal and aromatic properties remain perceivable throughout all four seasons. From the perspective of year-round visual continuity, the use of evergreen medicinal and aromatic plants may be considered as a complementary strategy in campus-scale landscape design. From a landscape design perspective, however, the contribution of these taxa cannot be evaluated solely on the basis of evergreen or deciduous character. Their value in planting design also depends on the duration of visual effect throughout the year, the timing of active vegetative development, and the level of maintenance required to preserve plant form and compositional balance. In this respect, considering such supplementary characteristics enhances the practical relevance of the present study for landscape architects and designers, particularly in relation to year-round planting continuity and sustainable management of campus green spaces.

In addition to seasonal visual performance, the long-term success of medicinal and aromatic plant use in campus landscapes is also associated with plant lifespan and basic maintenance requirements, particularly irrigation and fertilization needs. Differences among species in terms of longevity and resource demand may influence maintenance intensity, sustainability, and the continuity of planting performance over time. Therefore, taking these characteristics into account during species selection can contribute to more balanced, functional, and manageable planting designs in university landscapes.

According to Tuna et al. [13], Malatya Province hosts 189 naturally distributed medicinal and aromatic plant species. The species inventory was established through the combined use of ethnobotanical and floristic sources supported by field-based observations. Their results further showed that herbaceous taxa formed the dominant group, with 157 species, highlighting the marked importance of herbaceous medicinal and aromatic plants within the flora of the region. Çorbacı and Ekren [23], reported that 207 (93%) of the 223 plant taxa identified in the areas examined in the study had medicinal properties. They also determined that 102 taxa (46%) of them had both medicinal and aromatic properties, while 105 taxa (47%) were used solely for medicinal purposes. The number of plants with only aromatic properties was considerably low, with 6 taxa (3%), and 10 taxa (4%) without any medicinal or aromatic properties were also recorded in the area. These findings indicate that the plants used for medicinal purposes constitute the majority of the study areas and that aromatic properties are most often found in combination with medicinal qualities. A similar evaluation was made for Iğdır University Şehit Bülent Yurtseven Campus. A total of 98 plant taxa identified in the campus area were classified based on their usage characteristics. As a result of this classification, it was determined that 66 taxa (67%) were utilized solely for medicinal purposes, while 31 taxa (32%) possessed both medicinal and aromatic properties, making them suitable for multipurpose use. The number of plant taxa with only aromatic properties was limited to 1 (1%). These results indicate that a considerable proportion of the taxa identified on the campus are reported in the literature as having medicinal properties, while aromatic characteristics frequently occur alongside medicinal attributes. Therefore, the plant diversity of the area may be considered noteworthy not only in terms of aesthetic and landscape value, but also in relation to its documented medicinal and functional characteristics. In this context, planning approaches that take into account the multifaceted functions of plants may contribute to user experience and support planting and management decisions in campus landscapes. Beyond their ecological, aesthetic, and functional contributions, such plantings may also generate important educational benefits for both campus users and visitors. The presence of medicinal and aromatic taxa in university landscapes can support informal learning by raising awareness of plant diversity, traditional uses of plants, and the cultural significance of local flora. Within educational settings, these species may also contribute to observation-based learning, practical training, and research-oriented activities, thereby reinforcing the role of campus landscapes as living environments for both knowledge exchange and recreation.

Another important consideration in the use of medicinal and aromatic plants in public landscapes is the management of pests and diseases under conditions of continuous human

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presence. In such settings, plant protection practices should be evaluated not only in terms of effectiveness, but also with regard to public health, user safety, and the limitations associated with chemical control in frequently used spaces. Therefore, species selection and planting design should, as far as possible, take into account plant resilience and manageable maintenance requirements in order to support both landscape sustainability and safe use of campus green areas.

In their study on medicinal and aromatic plants used in the landscape of the Cairo Festival City, Abdelnaby et al. [32] found that different plant species vary in terms of growth habits (herbaceous, climbers, shrubs, and trees), flowering times, and landscape values. However, they reported that the species *Nerium oleander*, *Tagetes erecta*, *Pelargonium graveolens*, *Rosmarinus officinalis* (*Salvia rosmarinus* Spenn), *Cassia fistula*, *Jasminum grandiflorum*, and *Cymbopogon citrates*, had the highest priority landscape value for use in garden design. *Salvia rosmarinus* Spenn. (*Rosmarinus officinalis*) was also highly preferred at the Iğdır University Şehit Bülent Yurtseven Campus.

Medicinal and aromatic plants are widely regarded as important components in discussions of natural resource use and biodiversity conservation. The selective and versatile biological activities of essential oils, in particular, provide remarkable potential for the utilization of these plants in sustainable agricultural practices. Studies in this direction reveal that medicinal and aromatic plants can create new agricultural opportunities that are environmentally and economically sustainable, extending beyond their traditional use in the field of health. This potential necessitates increased research on the cultivation of these plants [33]. In addition, the value of aromatic and medicinal plants as tools in urban design for improving the urban microclimate has been emphasized. These plants may be considered more broadly in urban design approaches aimed at supporting sustainable and healthy cities. Future studies suggest applying similar solutions in larger urban areas to improve environmental quality and create more resilient and functional microclimates [34]. In this context, medicinal and aromatic plants may also be considered within broader sustainability-oriented production and landscape frameworks, beyond their traditional uses. Therefore, more comprehensive research on the biological characteristics of these plants will support rural development and contribute to the protection of ecosystem health.

Multivariate analyses

The relationships between plant taxa and their families are illustrated using a Sankey diagram to provide a clear visual representation. In this context, the life form, leaf condition and medicinal and aromatic properties of each plant taxon were presented in a clear and systematic manner, along with their distribution at both the species and family level. The online tool SankeyMATIC [27] was utilized in the visualization process (Figure 4).

In this analysis, the degrees of similarity in the flowering periods between plant taxa are presented in a numerically expressed similarity matrix (Figure 5). The values in the matrix cells reflect the degree of overlap in flowering times between taxa; green indicates high similarity, whereas red indicates low similarity. While the color intensity facilitates visual interpretation, quantitative values are also provided in the cells. This matrix reveals both the taxonomic and ecological dimensions of flowering-period overlap among species. The high levels of similarity observed among certain species belonging to the same genus or family indicate that genetic proximity and habitat similarity serve as important factors influencing flowering phenology. Conversely, the fact that some species from different genera also exhibit similar flowering times highlights the significant role of environmental factors (e.g., temperature, light duration, and altitude) in shaping phenology.

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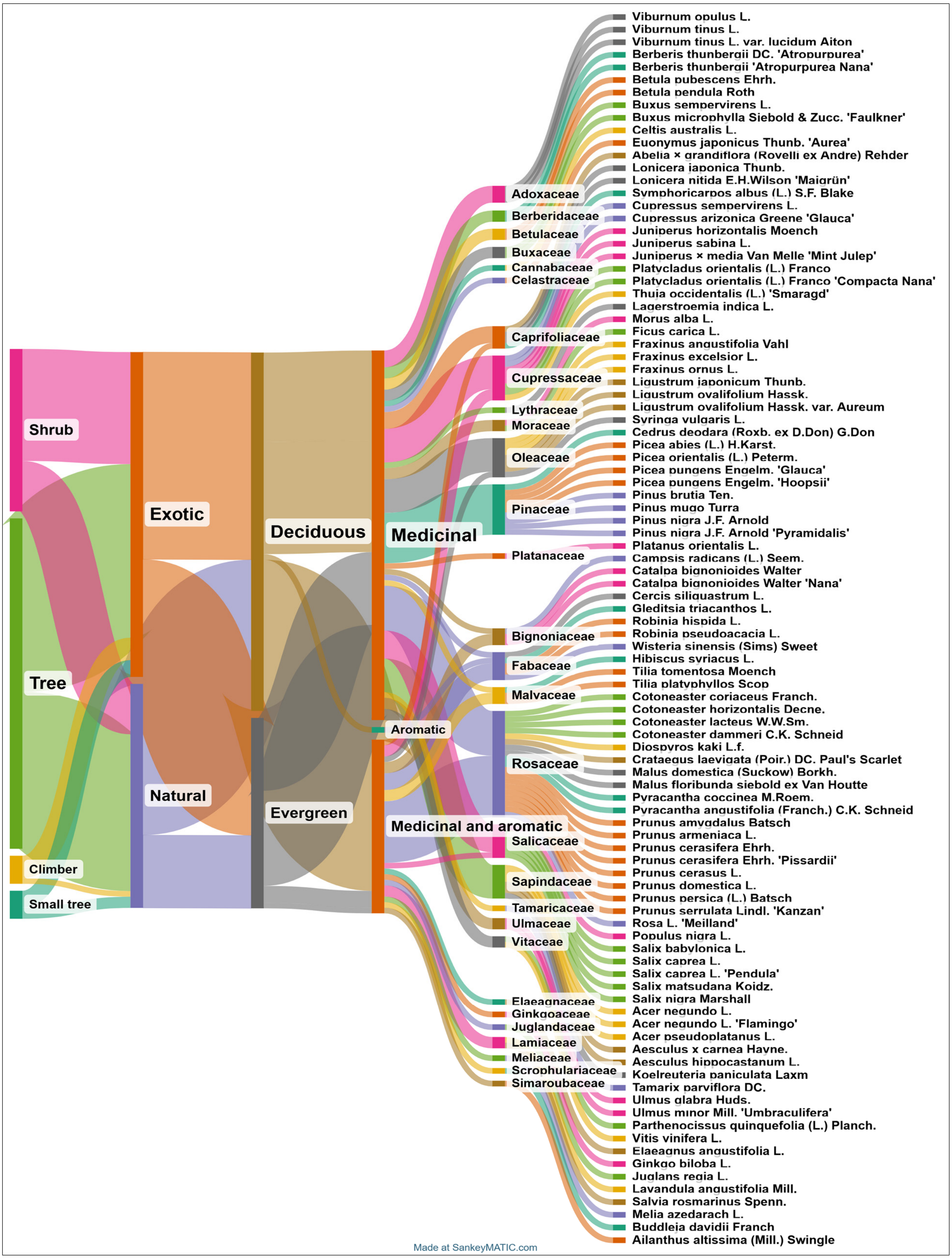

Figure 4. Sankey diagram.

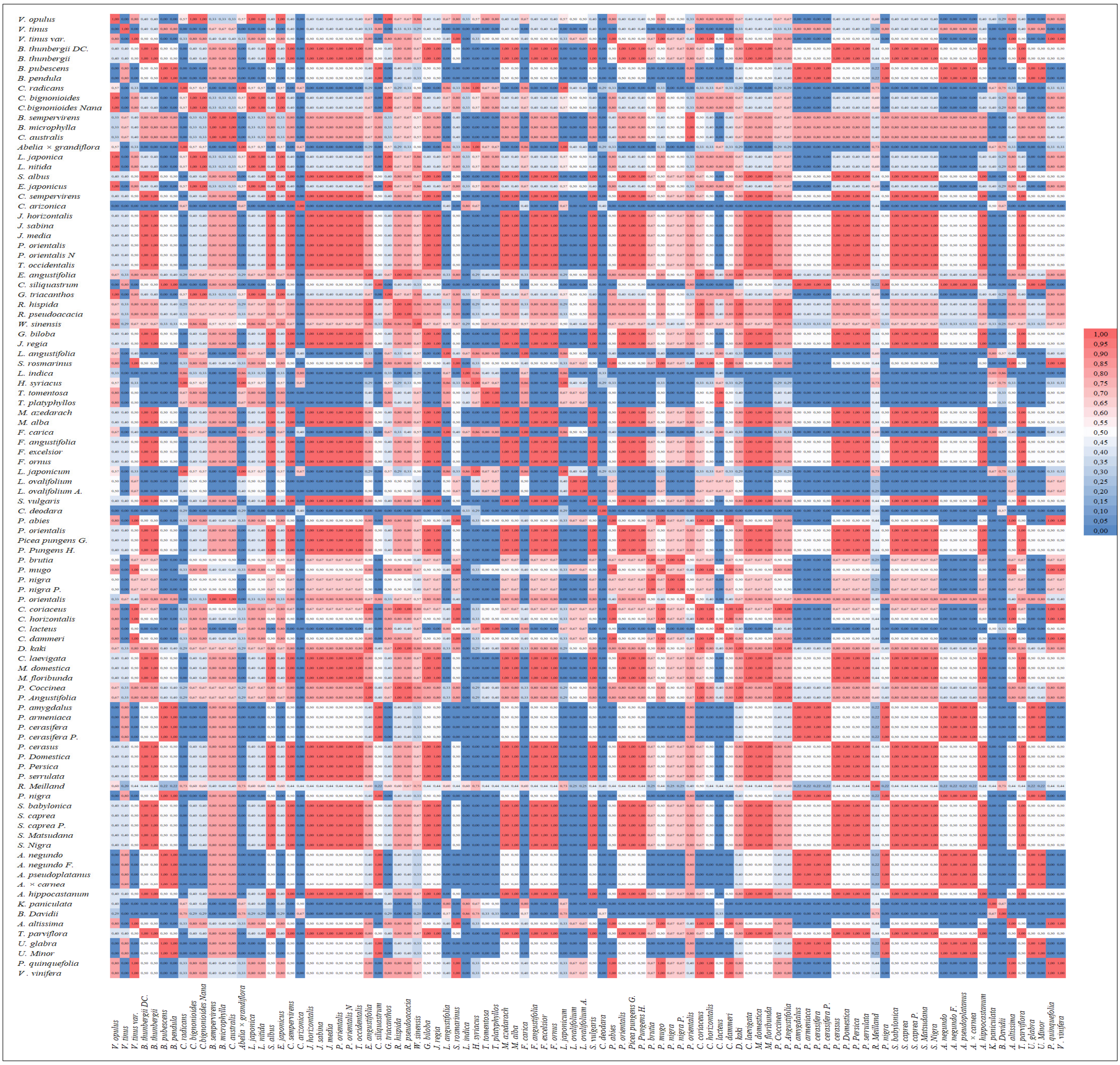

Figure 5. Similarity matrix.

The assessment of the similarity matrix shows that the flowering periods of some species included in the study substantially overlap with those of other taxa, whereas some species flower at distinctly different times. In particular, the observation that species such as *Prunus cerasifera* Ehrh., *Prunus cerasifera* Ehrh. 'Pissardii', *Prunus domestica* L., *Prunus amygdalus* Batsch, *Salix caprea* L., and *Platycladus orientalis* (L.) Franco 'Compacta Nana' show a high degree of similarity with numerous other species in both the horizontal and vertical axes of the similarity matrix indicates that their flowering periods overlap with a broad range of taxa and that they occupy a wide phenological time window. These species typically flower in spring, coinciding with many other plants and exhibiting a high degree of temporal similarity. In contrast, the dominance of lighter tones in the similarity rows and columns of species such as *Cedrus deodara* (Roxb. ex D.Don) G.Don, *Buddleja davidii* Franch., and *Rosa* L. 'Meilland' indicates that the flowering periods overlap less with those of other species, rendering them phenologically distinct. This suggests that these species flower either earlier or later in the season and therefore do not coincide temporally with many other taxa. In general, the similarity matrix shows that most of the plant species included in the study have similar flowering periods.

In this research, hierarchical cluster analysis was performed to reveal the phenological similarities among plant taxa based on their flowering periods, and the results were visualized using the PAST (Paleontological Statistics) program (Figure 6).

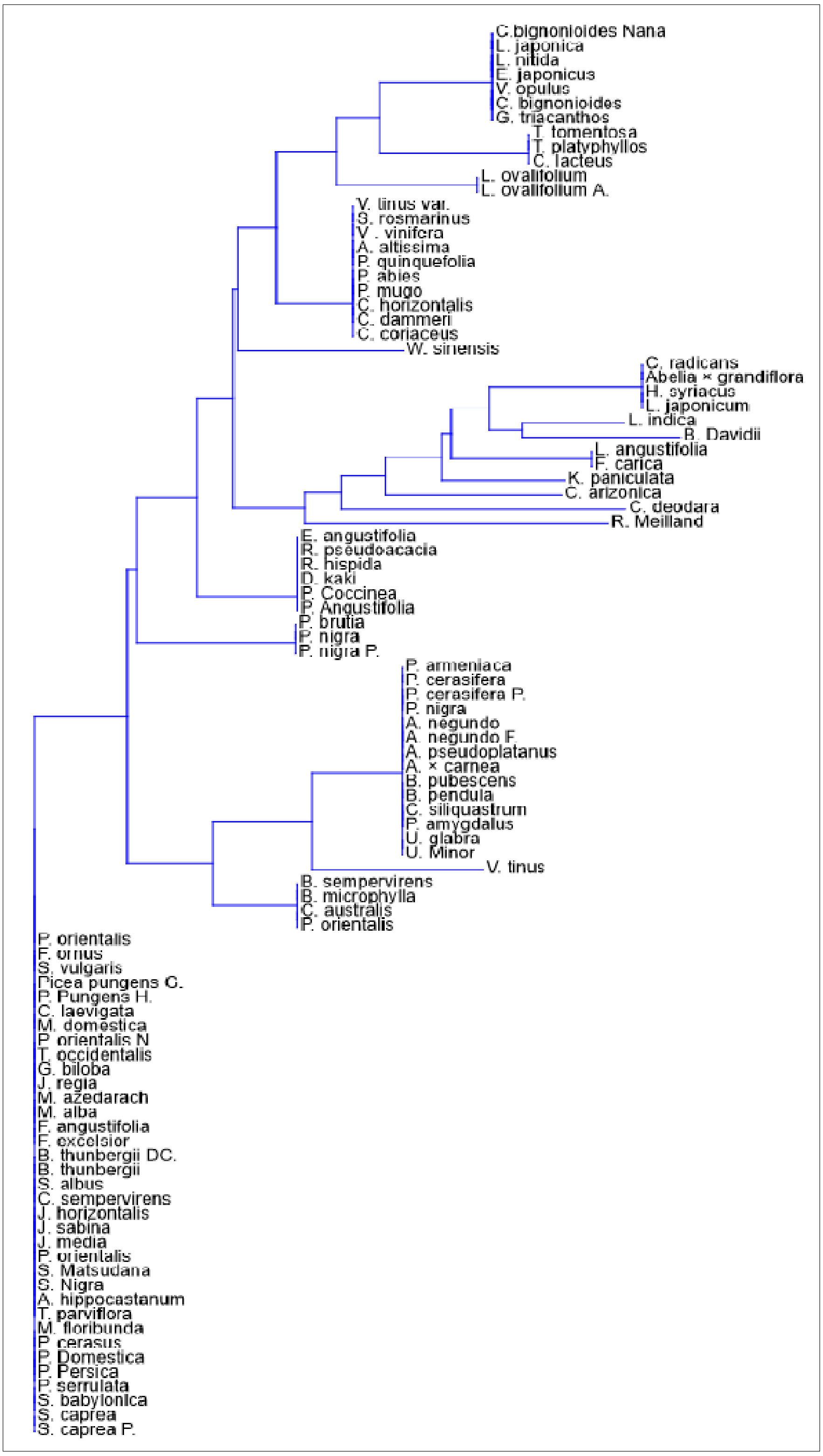

Figure 6. Hierarchical clustering analysis.

The analysis results show that taxa with similar flowering times are grouped within the same subclusters. This indicates that flowering-time data serve as an effective and discriminating variable in assessing phenological relationships among taxa. Specifically, *Catalpa bignonioides* Walter, *Catalpa bignonioides* Walter 'Nana', *Lonicera japonica* Thunb., *Viburnum opulus* L., *Gleditsia triacanthos* L., and *Euonymus japonicus* Thunb. 'Aurea' were observed to cluster together. This clustering indicates that these species bloom at similar times and exhibit a high degree of phenological similarity. Furthermore, the fact that *Tilia tomentosa* Moench, *Tilia platyphyllos* Scop, and *Cotoneaster lacteus* W.W.Sm are also located within the same subcluster and show a close phenological relationship with the above-mentioned cluster supports the observation that the flowering periods of these species are closely aligned. In general, hierarchical cluster analysis stands out as an effective method for comparing flowering periods, and the resulting clusters allow for the evaluation of phenological similarities between taxa in ecological and landscape planning contexts. At the same time, similar phenological patterns appear across other clusters identified in the analysis. In contrast, species from different genera and those with different life forms, which exhibit greater variation in flowering times, are positioned in more distant clusters and form distinct branches on the dendrogram. This suggests that in addition to taxonomic proximity, ecological adaptation, climatic conditions, and habitat-specific phenological strategies influence cluster structure

In conclusion, this hierarchical cluster analysis stands out as a powerful tool for the phenological comparisons of flowering periods, successfully reflecting both the temporal similarities among species belonging to the same genus and the phenological divergence among species of different genera and life forms. The resulting cluster structure constitutes an important reference for landscape planning, species selection, agricultural practices, and phenological monitoring in the context of climate change.

5. Conclusions

Medicinal and aromatic plants have increasingly gained attention in landscape design due to their diverse morphological and chromatic characteristics and their multifunctional attributes, including their aesthetic, health-related, aromatic, and environmental value. Despite Türkiye's rich native flora, the use of local taxa in urban green spaces remains limited, which may reduce both the visibility of biodiversity and public awareness of these valuable species. This study shows that the Şehit Bülent Yurtseven Campus of Iğdır University hosts a diverse assemblage of plant taxa, comprising 98 taxa in total, of which 66 taxa (67%) were identified as medicinal, 31 taxa (32%) as both medicinal and aromatic, and 1 taxon (1%) as solely aromatic. Notably, only 40% of these taxa are native, suggesting that the predominance of exotic taxa may warrant further consideration from the perspective of biodiversity-oriented planting approaches.

The present study reveals that the Şehit Bülent Yurtseven Campus possesses a notable diversity of medicinal and aromatic plant taxa, which is relevant for plant composition and species selection for campus landscape design. The results obtained within the scope of this study provide descriptive information regarding the life form distribution, flowering periods, and identified medicinal and aromatic uses of these taxa. From this perspective, the Şehit Bülent Yurtseven Campus provides a valuable basis for further research on the integration of medicinal and aromatic plants into campus planting strategies and green-space planning.

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