Acta Horti Bot. Bucurest. 2025, **51**: 5-15
DOI: 10.62229/ahbb.2025.51/1

BUILDING FOR PLANT CONSERVATION – A CASE STUDY FROM BUCHAREST, ROMANIA

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Abstract: In the big and crowded cities of the world, a large number of rooftops have been transformed into living green areas, small or large, extensive, semi-intensive or intensive, with different uses in the lives of citizens. This contribution presents an example of a small, intensive rooftop garden, created on the rooftop terrace of a private house, in the city of Bucharest, with the aim of conserving plants and reconnecting people with nature. The terrace, located at a height of 10 m, on an area of 40 sqm, was built in 2011, using the ZinCo Technology, which ensures high water storage and a variety of substrates and depths. The current floristic composition (2023) includes 55 taxa of vascular plants (51 non-native species and 4 native species), belonging to 31 families of angiosperms and 3 families of gymnosperms: annual plants, geophytes, perennial herbaceous plants, subshrubs, shrubs, and trees. The criteria used in the selection and grouping of plants pertain to ecological preferences, tolerance to stressful environmental factors, plant importance, growth rate, low maintenance, spatial and seasonal diversity. The results provide an overview of the green rooftop system technology, the development of taxa introduced during a decade since the establishment of the garden and highlight the plants and combinations of plants suitable for local conditions.
Keywords: rooftop garden, native and non-native species, environment

Received: 29 January 2025 / Accepted: 19 May 2025

Introduction

The practice of adopting rooftop gardens as sustainability elements for large urban centres has become more and more frequent, representing a compensatory solution to the progressive reduction of green areas at ground level. There are cities such as Chicago, where there are over 500, generally large, rooftop gardens (Tan 2022). In Europe, the rooftop gardens in Stuttgart, Paris, London and Barcelona (Winnicka-Jaslowska & Tkaczuk 2022) are notable for their size, architecture, the abundance of plant species and variety of uses. As it becomes increasingly accessible, modern technology allows the use of the vertical and high spaces of concrete and glass buildings, which are turned into living green areas. These are incorporated in both the structure of new public and private buildings, as well as in old, modernized buildings.

Surprisingly, decorative, and aesthetically spectacular (Tan 2022), rooftop gardens offer many benefits to the urban environment, as well as to the citizens of major cities. By reducing pollution, increasing air quality, and mitigating the urban heat island effect (Kim et al. 2020, Rahman et al. 2022), green walls and elevated vegetation areas improve environmental conditions in cities. Such approaches also provide economic

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benefits, being a solution to limiting energy consumption (Barreca 2016) and an opportunity to grow agricultural crops (Zheng & Sun 2021). Rooftop gardens are considered areas dedicated to physical and mental relaxation, recreation, and socialization, which provide spiritual comfort to people (Pouya 2019, Tan 2022), while also representing a space where people with intellectual stress can relax and improve the quality of their daily life (Triguero-Mas et al. 2020).

Rooftop gardens also represent a new habitat for plants and invertebrates, with plant diversity positively influencing the number of colonizing invertebrates (Berthon et al. 2023). Plants may be native from the spontaneous urban flora (Madre et al. 2014) or native to the wild regional flora. Relatedly, the concept of conservation gardening, developed in Germany (Munschek et al. 2023), promotes the growth of threatened spontaneous plants in urban refuges, such as balconies and terraces. The study of Munschek et al. (2023) was based on the analysis of the Red Lists of the 16 federal states in Germany and established a number of taxa (five species for each federal state) that are suitable for conservation through cultivation on balconies and terraces. Through the horticulture and gardening activities (Pouya 2019) they promote, rooftop gardens can enable people living in urban areas to reconnect with nature, but also help in the environmental education of children born and raised in such areas (Selzer 2019, Salih et al. 2022).

Although rooftop gardens have become increasingly popular in major cities, in Romania, less attention has been paid to roof gardens for smaller spaces on buildings where people work or live. In Bucharest, but also in other cities in the country, there are especially extensive green roofs (supermarkets, gyms, office buildings, multi-storey car parks) with reduced plant diversity and dominated by *Sedum* species.

Starting from the idea that even a small garden can successfully support a collection of plants, this paper aims to present the experience of creating a small private rooftop garden intended for the conservation of plants, encouraging as many citizens as possible to adopt the practice of green rooftops and to establish gardens on the roofs of their own homes.

Material and methods

Location and climate. The rooftop garden is located on a building in Bucharest, at a height of 10 m. Bucharest, the most populous city in Romania, is located in the S-SE area of Romania at 44°24'49" north latitude and 26°05'48" east longitude, at an average altitude of 70 m above sea level, and benefits of a temperate continental climate, with summers that are dry (average rainfall of 585 mm/year) and warm (average summer temperatures of 23°C, occasionally exceeding 40°C), with relatively cold winters (the temperature rarely drops below -10°C) and normal circulation of air masses, favourable to the maintenance of a relatively stable atmosphere (Meteo Romania, National Meteorological Administration 2023).

Technical aspects. The structure of the rooftop garden was achieved with the ZinCo technology, which uses several construction elements arranged in overlapping layers to ensure high water storage and substrate conditions suitable for different plant categories: protection layer (root barrier and protection mat), drainage layer (ZinColit, Floridin FD60), filter layer (filter sheet) and vegetation layer of a 300 mm substrate, (ZinCo Green roof Systems 2022). An automatic surface drip irrigation system operated over the entire roof garden area. This provided the plants with water (1-3 l/sq m, early morning), during the dry periods of the year, from spring to late autumn.

Plants selection. Several criteria underline the selection of the plants: depth of substrate, ecological preferences of the plants relative to the environmental conditions of the area, diversity of life forms, growth rate and the characteristics of the root system, flowering period and duration, status as non-native species and native species respectively. A number of 51 non-native species cultivated for their ornamental value and 4 native species from the Romanian flora were selected. The later species are also cultivated and marketed for their decorative appearance. Most of the plant material was purchased and some native plants were acquired from nature (non-protected areas). The planting was carried out between 2012 and 2014. The nomenclature of the taxa is according to Royal Botanic Gardens Kew-Plants of the World Online (2023).

Results and discussion

The rooftop gardens is located on the terrace of a residential house. It has a rectangular shape, an area of 40 square meters and includes two wind protected zones: one shielded by a wall on the northern side and the other by an alignment of *Thuja occidentalis* L. 'Smaragd' on the southern side. The eastern and western sides remain unprotected. The foundation of the rooftop garden was built in 2011 using the ZinCo technology, which provides growing conditions as close to the plant's natural environment as possible and ensures a high-water storage (Fig. 1, A-C). The water is stored over the roof area and reaches the plants by capillarity and diffusion. The substrate of 300 mm in depth used for the rooftop garden has allowed the cultivation of several categories of plants (herbaceous, shrubs, small trees) with a shallow root system. The plants (Table 1) were introduced in three successive years (2012-2014) and have developed gradually, covering most of the allocated space by 2023 (Fig. 1, D-I).

The floristic inventory includes 55 taxa (Table 1) belonging to 34 families of vascular plants: 31 families of angiosperms (noteworthy are the families Asteraceae, Amaryllidaceae, Crassulaceae, Ranunculaceae, Brassicaceae, Berberidaceae, Poaceae, Rosaceae) and 3 families of gymnosperms (Cupressaceae, Pinaceae, Taxaceae). Of these taxa, 51 are non-native species and 4 are native species: *Anemonoides nemorosa*, *Leucojum aestivum* - vulnerable/rare in Romania (Oltean et al. 1994), *Pinus mugo*, *Vinca minor* (Table 1). Currently, there are 7 categories of plants in the rooftop garden (Fig. 2), each with a different share in the vegetation structure, ensuring the spatial and seasonal diversity of the area. Best represented are the herbaceous perennials (17 species, 31.0%), shrubs (16 species, 29.0%) and geophytes (14 species, 25.5%), followed by trees (4 species, 7.3%), subshrubs (2 species, 3.6%), climbing perennials (1 species, 1.8%) and annual plants (1 species, 1.8%).

The period during which the garden presents flowering plants is long (March - October), the maximum being recorded in May-August (Fig. 3). In the early spring months many geophytes (*Anemonoides nemorosa*, *Crocus vernus*, *Eranthis hyemalis*, *Muscari armeniacum*, *Narcissus* sp.) bloom, and by late autumn blooming is present especially in certain Poaceae (*Cortaderia selloana*, *Cenchrus alopecuroides*). The additional irrigation ensured an impressive appearance of the vegetation during dry periods and extended the flowering seasons. Taxa such as *Achillea millefolium*, *Armeria maritima*, *Campanula poscharskyana*, *Cenchrus alopecuroides*, *Cortaderia selloana*, *Dianthus chinensis* and *Hylotelephium telephium* achieved longer flowering periods in these conditions.

Table 1. List of species from the rooftop garden (2023): native* and non native

Life form	Taxa	Remarks
Annuals	*Lobularia maritima* (L.) Desv. 'Violet'	Abundant flowering (July-August).
Climbing perennials	*Clematis montana* Buch.-Ham. ex DC. 'Elisabeth'	Full bloom in early June.
Herbaceous perennials	*Achillea millefolium* L. 'Apple Blossom'	Long flowering (June-September).
	Armeria maritima (Mill.) Willd. 'Rosea'	Evergreen plant, sun lover.
	Aubrieta × *cultorum* Bergmans 'Cascade Blue'	Resistant to frost.
	Aurinia saxatilis (L.) Desv. 'Gold Dust'	Full sun plant.
	Campanula poscharskyana Degen 'Purple Violet'	High covering power.
	Cenchrus alopecuroides (L.) Thunb. 'Little Bunny'	Attractive all the year.
	Coreopsis lanceolata L. 'Goldfink'	Maximum bloom in June.
	Cortaderia selloana (Schult. & Schult.f.) Asch. & Graebn. 'White Feather'	Impressive large inflorescences.
	Dianthus chinensis L. 'Angel of Virtue'	Long flowering (May-August).
	Erysimum × *cheiri* (L.) Crantz 'Sugar Rush'	Slow growth rate.
	Festuca glauca Vill. 'Blue'	Evergreen sun lover grass.
	Hylotelephium telephium (L.) H.Ohba 'Purple Emperator'	Attractive to bees and butterflies.
	Jacobaea maritima (L.) Pelser & Meijden 'Silver Dust'	High temperature resistance.
	Lupinus polyphyllus Lindl. 'Blue'	Attractive to pollinators.
	Penstemon heterophyllus Lindl. 'Blue Spring'	Sun lover plant, attractive to butterflies.
	Phlox subulata L. 'White Delight', 'Candy Stripe'	Evergreen, frost tolerance.
	Vinca minor L.*	Native. Long flowering (March-August)
Geophytes	*Allium giganteum* Regel 'Globemaster'	Attractive to bees.
	Anemonoides nemorosa (L.) Holub*	Native. Blooms in spring.
	Begonia × *tuberhybrida* Voss 'White'	Easy to multiply.
	Crocus vernus (L.) Hill 'Vernus King', 'Jeanne d'Arc'	Early flowering (March-April).
	Eranthis hyemalis (L.) Salisb.	Flowering in February-March.
	Gloriosa luxurians Lour. ex B. A. Gomes	Resistance to diseases and pest.
	Leucojum aestivum L.*	Native. Widely cultivated.
	Lilium regale E. H. Wilson	Easy to grow.
	Muscari armeniacum H.J.Veitch 'Tricolor'	Rapid multiplication.
	Narcissus L. 'Trumpet Gelb', 'Bridal Crown'	Easy to grow.
	Paeonia lactiflora Pall. 'Avalanche'	Attracts butterflies.
	Paeonia lactiflora × *Paeonia peregrina* 'Coral Charm'	Robust plant. Many large flowers.

	Ranunculus asiaticus L. 'Bloomingdale Red', 'Buttercup Yellow', 'Vortex Orange'	Sensitive to frost.
	Tulipa gesneriana L. 'Triumf', 'Fringed'	Resistance to low temperatures.
Subshrubs	*Iberis sempervirens* L. 'Alexander's White'	High covering power.
	Lavandula angustifolia Mill. 'Blue Jeans'	Aromatic plant.
Shrubs	*Acer palmatum* Thunb. subsp. *matsumurae* Koidz. 'Garnet'	Slow growth rate.
	Berberis julianae C.K.Schneid.	Frost resistance.
	Berberis thunbergii DC. 'Atropurpurea'	Frost resistance. Spectacular in autumn.
	Ceanothus thyrsiflorus Eschw. 'Repens'	Warm conditions plant.
	Cornus alba L. 'Elegantissima'	Easy to maintain.
	Cotoneaster horizontalis Decne.	Frost resistance. Low care.
	Cytisus x praecox Bean 'Boskoop Rudy'	Abundant flowering in May.
	Euonymus fortunei (Turcz.) Hand.-Mazz. 'Emerald'n Gold'	Evergreen. Decorative all the year.
	Euonymus japonicus Thunb. 'Aureomarginatus'	Evergreen. Easy to maintain.
	Juniperus chinensis L. 'Stricta'	Blue-green decorative foliage.
	Juniperus horizontalis Moench 'Andorra Compacta'	Slow growth rate.
	Nandina domestica Thunb. 'Gulf Stream'	Brightly colored leaves in spring.
	Pinus mugo Turra*	Native. Slow growth rate.
	Platycladus orientalis (L.) Franco 'Aurea Nana'	Frost tolerance. Slow growth rate.
	Punica granatum L. 'California Sunset'	Full sun plant.
	Syringa vulgaris L. 'Sensation'	Moderate growth rate.
Trees	*Cedrus atlantica* (Endl.) Manetti ex Carrière 'Glauca Pendula'	Evergreen. Pendulous habit.
	Magnolia 'Yellow Lantern'	Yelow flower, abundant in May.
	Taxus baccata L. 'Fastigiata'	Evergreen. Slow growth rate.
	Thuja occidentalis L. 'Smaragd'	Moderate soil moisture.

The grouping of plants in the rooftop garden was done primarily by their requirements for light, air temperature and soil humidity (Fig. 4). To meet their needs, the plants were planted either in the central part of the terrace or towards its sides or in the protective shade of larger plants. In the central part, which is directly exposed to sunlight, taxa that prefer full sun, warm, dry to medium humidity conditions were planted. Among these, plants such as *Achillea milllefolium* (Fig.1, E), *Armeria maritima* (Fig.1, F), *Aurinia saxatilis* (Fig.1, H), *Aubrieta* × *cultorum*, *Cenchrus alopecuroides* (Fig.1, D), *Cortaderia selloana* and *Hylotelephium telephium* (Fig.1, G), *Festuca glauca*, *Jacobaea maritima* (Fig.1, I), *Lavandula angustifolia* (Fig.1, E) achieved a particularly good development. Towards the two lateral, protected areas of the terrace, taxa that prefer sun, warm and medium humidity conditions were planted, of which *Allium giganteum (*Fig.1, F), *Clematis montana* (Fig.1, H), *Coreopsis lanceolata*, *Eranthis hyemalis*, *Berberis thunbergii* and *Euonymus fortunei* (Fig.1, I), *Lobularia*

maritima, *Platycladus orientalis* and *Thuja occidentalis* (Fig.1, G), *Juniperus chinensis* (Fig.1, E), *Berberis julianae*, *Pinus mugo* (Fig.1, E) had a notable development.

A third category of plants included taxa that prefer partly sunny, medium warm and medium humidity to moist conditions, such as *Anemonoides nemorosa*, *Begonia* × *tuberhybridia*, *Campanula poscharskyana*, *Crocus vernus*, *Eranthis hyemalis*, *Leucojum aestivum* (Fig.1, H), *Vinca minor*. They were placed in the shade of shrubs and small trees, where the partial shade and humidity provided them good development conditions.

The plants in the rooftop garden were observed almost 10 years, to see how well they survive and adapt to their new environment and the local conditions. All taxa introduced survived with a water supplement, offered during dry periods. Currently, the rooftop garden houses a mix of non-native and native species, which have proven their survival potential, being suitable for the rooftop gardens in the city of Bucharest. Some of these plants are also recommended as successful plants, suitable for the various rooftop gardens: *Achillea milllefolium*, *Euonymus fortunei* (Domoney 2022), *Pinus mugo*, *Cotoneaster horizontalis* (Royal Horticulture Society 2023), *Lavandula angustifolia* (Marouli et al. 2022), *Juniperus chinensis*, *J. horizontalis*, *Coreopsis lanceolata*, *Armeria maritima* (Chicago Botanic Garden 2015), *Cornus alba*, *Syringa vulgaris*, *Taxus baccata* (ODU Green Roof 2021).

The depth of the applied substrate (300 mm) was an important factor in the selection of woody plants (shrubs, small trees). The shrubs were better represented in the vegetation structure, compared to the small trees. The last category developed slowly and reached moderate sizes. In the case of subshrubs, the depth of the substrate did not affect the development of plants. This was also reported by Marouli et al. (2022) for *Lavandula angustifolia*.

Several other criteria were considered in the selection of taxa, such as: importance of pollinators (~30% are pollinator plants), medicinal importance (*Lavandula angustifolia* and *Vinca minor*), drought and/or frost resistance (~40% of taxa), high coverage power (*Campanula poscharskyana, Lobularia maritima*), slow growth (*Pinus mugo, Platycladus orientalis,* 'Aurea Nana'*, Thuja occidentalis* 'Smaragd'*, Cedrus atlantica* 'Glauca Pendula').

Considering that the survival of a garden also depends on the ability of its plants to perpetuate themselves through seeds, rhizomes, and bulbs (Chicago Botanic Garden 2015), the selected plants were as diverse as possible in terms of reproduction.

Special attention was paid to native species, as rooftop gardens have been promoted as potential areas for their conservation (Madre et al. 2014, Munschek et al. 2023). Of the four native plants grown in the rooftop garden, *Pinus mugo* showed a slow but continuous growth, while *Anemonoides memorosa*, *Leucojum aestivum* and *Vinca minor* nearly doubled their coverage area. Next, we decided to introduce five other native species in the space of the rooftop garden, three of which have protection status (Oltean et al. 1994) in Romania (*Galanthus elwesii* Hook. fil., *Hepatica transilvanica* Fuss, *Paeonia peregrina* Mill.).

In addition to conservation value, the rooftop garden offered satisfaction and relaxation, confirming the potential of such spaces to extend the living environment and ensure nature connection in urban areas, an aspect much promoted in recent years (Pouya 2019, Tan 2022).

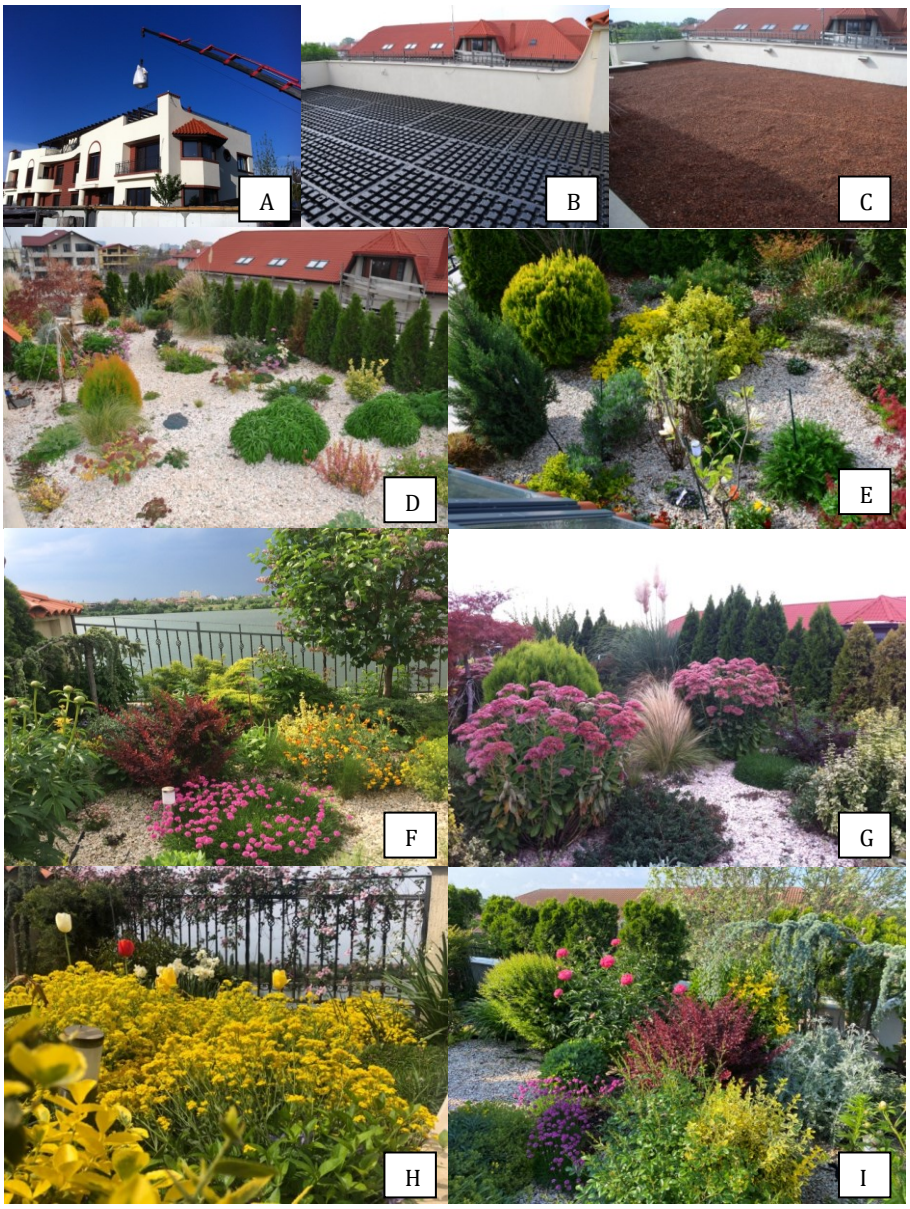

Fig. 1. Progressive development of the rooftop garden across years:
A - location of the terrace, B - drainage layer of the terrace (2011), C - substrate layer of the terrace (2011), D - vegetation in 2013, E - vegetation in 2016, F - vegetation in 2019, G- vegetation 2021, H - vegetation in 2022, I - vegetation in 2023.

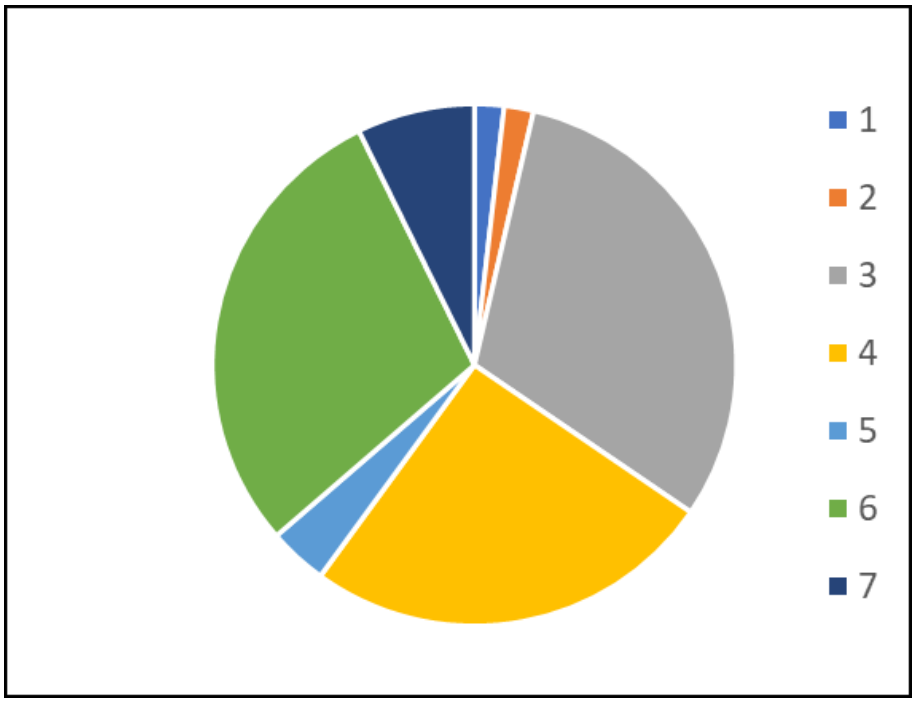

Fig. 2. Categories of plants in the roof garden (2022):
1 - annuals, 2 - climbing perennials, 3 - herbaceous perennials,
4 - geophytes, 5 - subshrubs, 6 - shrubs, 7 - trees.

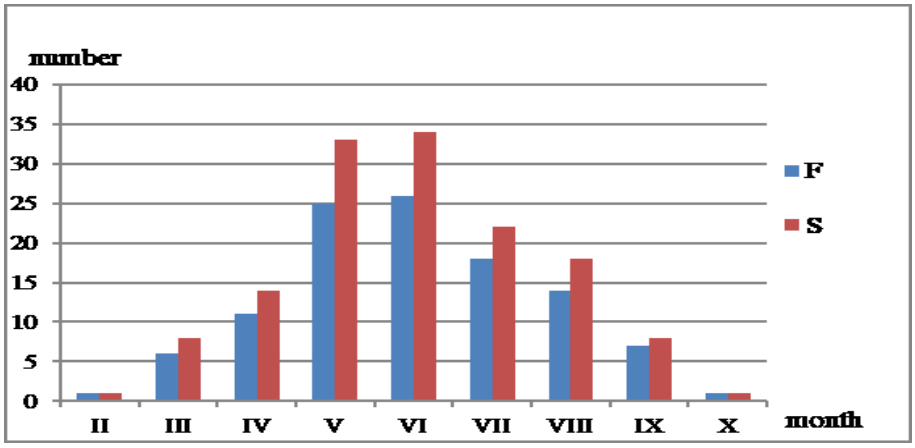

Fig. 3. Flowering distribution (average value 2017-2022):
F - families, S - species.

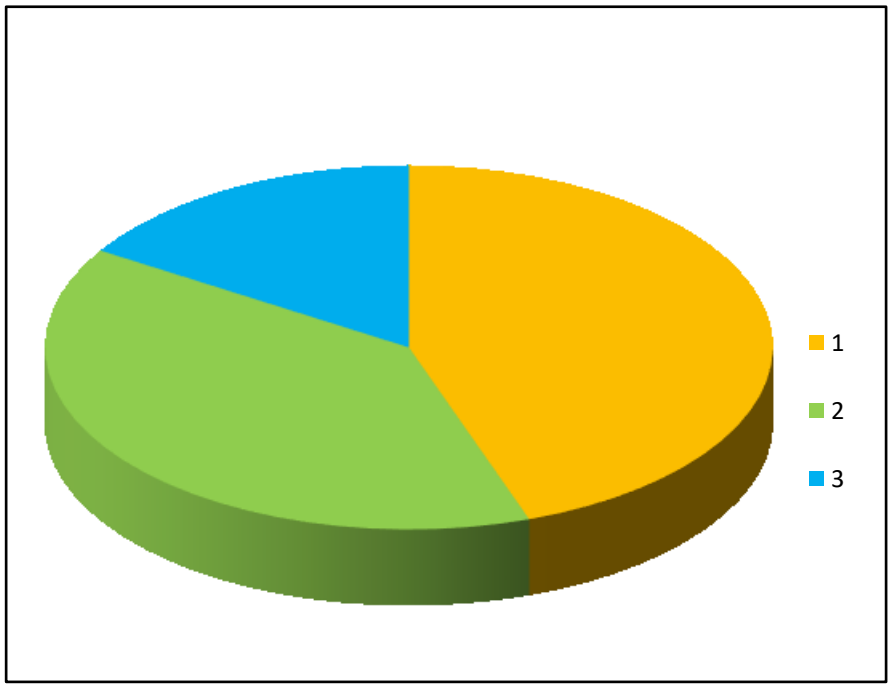

Fig. 4. Ecological preferences of species in the roof garden:
1 - full sun, warm, dry to medium humidity; 2 - sun, warm, medium humidity;
3 - partly sunny, medium warm, medium humidity to moist.

Conclusions

The creation of an intensive roof garden, even of a smaller size, required the use of an appropriate technology associated with the provision of surface irrigation and with choosing plants with the best chance of adaptation.

The selected vegetation included herbaceous and woody plants, both native and non-native, most of which have proven their capacity to grow in the rooftop garden and can be recommended for the city of Bucharest. The plants are varied, mostly sun-loving, resistant to local climatic conditions, have a shallow root system and various ways of perpetuating.

The native plants grown experimentally alongside non-native plants have adapted and well developed in the conditions of the rooftop garden, a fact that supports the practice of roof gardens as an additional way of preserving plants and increasing urban biodiversity.

Through the richness of the plants, with their variety of sizes, shapes and colours, the rooftop garden has acquired aesthetic and recreational characteristics, present almost throughout the year, while the gardening activities it has generated, contribute to reconnecting with nature and the conservation of plants in an urban space.

Acknowledgements. The authors want to thank all those people who supported the achievement of this paper.

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