New plants on the block: a comparison of the neophyte flora in Banja Luka, Mostar and Sarajevo (Bosnia and Herzegovina)

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Abstract. This article offers a comparison of the neophyte flora in three cities in Bosnia and Herzegovina: Banja Luka, Mostar and Sarajevo, in order to assess the role of neophytes in the flora of cities located in different phytoclimatic regions. The results indicate low similarity of the neophyte flora in the investigated cities. A total of 123 neophytes have been recorded, only 27 (21.95%) of which are common for all three cities. The invasive component includes 58 taxa (47.15%), 20 (34.48%) of which are common for all three cities. The highest percentage of invasive plants was recorded in Banja Luka (58% of the neophyte flora of the city), followed by Mostar (55.55%) and Sarajevo (53.12%). A total of 43 families have been recorded, with *Compositae* being the richest (31 taxa), followed by *Poaceae* (9), *Amaranthaceae* and *Solanaceae* (7 taxa each). A comparison of the biological spectrum reveals that therophytes are represented best in all three cities: Banja Luka (27 taxa – 54%), Mostar (50 taxa – 55%), and Sarajevo (34 taxa, –53.12%). A study of the geographical origin shows dominance of the taxa originating from the Americas in all three cities (34 taxa – 68% in Banja Luka; 62 taxa – 68.89% in Mostar and 39 taxa – 60.94% in Sarajevo).

Key words: alien flora, Balkan Peninsula, neophytes, urban flora

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Introduction

According to the definition proposed by Pyšek & al. (2004), alien plants (also referred to as exotic, introduced, non-native, non-indigenous) are plant taxa in a given area (see below) present there due to intentional or unintentional human interference, or which have arrived there without the help of people from an area in which they are alien. Neophytes are alien plant species introduced to a region after the discovery of America, approx. 1500 AD (Pyšek & al. 2012). According to data presented in the *Overview and Status of Biological and Landscape Diversity in Bosnia and Herzegovina* (Redžić & al. 2008), a total of 4569 vascular plant taxa have been registered in Bosnia and Herzegovina, approximately 500 of which can be clas-

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sified as aliens. However, a complete list of alien plant species is not provided in this study. A recently published preliminary list of alien plant species in Bosnia and Herzegovina (Maslo & al. 2020b) comprises 273 taxa, including 193 neophytes. Subsequently, findings of seven new neophytes for the country have bee nreported (Jovanović & al. 2018; Maslo & al. 2020a; Maslo & Šarić 2020, 2021, 2022; Maslo & Verloove 2020), resulting in a preliminary list of 200 neophytes recorded in Bosnia and Herzegovina. Literature on the alien flora of Bosnia and Herzegovina is generally limited. Since the 1950s, only a few studies reporting findings of alien plants from various areas in Bosnia and Herzegovina were published (Maslo 2014), and the lists of alien flora (including neophytes) for some cities in Bosnia and Herzegovina have been published recently (Maslo 2015; Sarajlić & Jogan 2017; Lubarda & Topalić-Trivunović 2020).

The aim of this paper is to compare the neophyte flora in three cities of the Western Balkans: Mostar, situated in the Mediterranean region of Herzegovina, and Banja Luka and Sarajevo, both located in continental Bosnia, in order to assess the level of similarity of the neophyte flora in these cities located in distinct climatic zones within Bosnia and Herzegovina, and to analyze the present plant groups in terms of their life forms, mode of introduction, naturalization status, and origin.

Materials and methods

Survey sites

The survey was conducted in Bosnia and Herzegovina, in the western region of the Balkan Peninsula of Southeast Europe. Three urban centres located in different climate zones (Fig. 1) were chosen for this study.

Banja Luka (44°46′21″N 17°11′33″E) lies on the banks of river Vrbas, in an expansive basin at the intersection of the Pannonian Plain and Dinaric Mountains. The basin of Banja Luka, ranging in altitude from 130 m to 170 m a.s.l., stretches from the

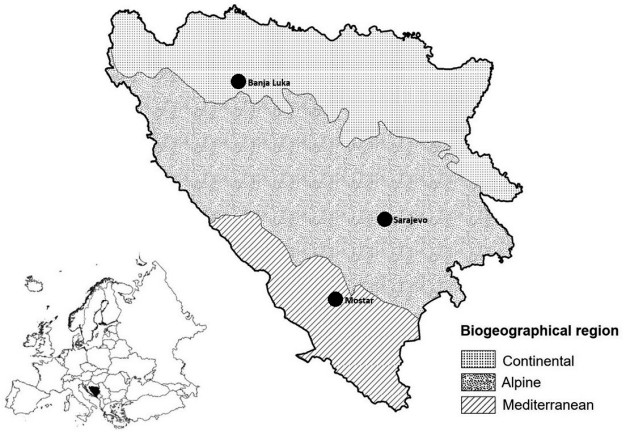

Fig. 1. Geographic location of the surveyed cities.

southwest to the north and northeast. The narrowest section of the city is in the south, near the point where river Vrbas exits the gorge and enters the plain (Lubarda & Topalić-Trivunović 2020). Banja Luka is situated in the Continental biogeographical region (EEA 2022), with characteristic Central European deciduous forests (Horvat & al. 1974). Geographically, that region corresponds to the Peri-Pannonian Zone, which marks the southern border of the Pannonian Plain. It is known for fragments of deciduous and floodplain forests, with a significant presence of agroecosystems.

Sarajevo (43°51′23″N 18°24′47″E) is positioned in the Sarajevo Valley, along the banks of river Miljacka. The central areas of the city are situated at an altitude of 511 m a.s.l., while the surrounding suburbs are scattered across the slopes of nearby hills and mountains, ranging from 700 m to 900 m a.s.l. (Anonymus 2017). The city is located in the Sarajevo Alpine biogeographical region (EEA2022), which corresponds to the Mountain-Valley Zone, with medium-high and high mountains and deep valleys, and characteristic Central European mixed beech-fir forests (Horvat & al. 1974).

Mostar (43°20′37″N 17°48′27″E) is located at an altitude ranging from 40 m to 70 m a.s.l., on the banks of the rivers Neretva and Radobolja, approximately 60 km from the Adriatic Sea, in the Mostar Valley. The region's geomorphology is dominated by alluvial formations. Mostar lies within the Mediterranean biogeographical region (EEA 2022), which encompasses

the low-lying areas along the River Neretva Gorge, in the vegetation zone of sub-Mediterranean deciduous forests (Horvat & al. 1974). The area is crisscrossed by a well-developed network of roads, railways, various watercourses, artificial reservoirs, and settlements.

Data collection and analysis

The lists of neophyte flora in the three cities in Bosnia and Herzegovina were compiled on the basis of field studies and available literature. Fieldwork for the flora inventory took place from the spring of 2013 to the end of 2023. Cultivated, ornamental or forestry taxa, which have not been observed to occur spontaneously, have been excluded.

In Table 1, the neophytes are listed alphabetically, along with information in which of the studied cities they have been found, followed by information on life forms, degree of naturalization, mode of introduction, and native range. Plant names conform with the Euro+Med (2006-), except for *Petunia* × *atkinsiana* (Sweet) W.H. Baxter, *Reynoutria* × *bohemica* Chrtek & Chrtková and *Viola sororia* Willd., which were not found in the Euro+Med (2006-), and were sourced from POWO (2024). In Table 1, these taxa are marked with an asterisk (*).

Life-form categories follow Raunkiaer (1934), with standard abbreviations used in the list. Data on the origin of listed taxa have been taken mostly from the available literature (see References). Clas-

Table 1. List of neophytes in the investigated cities.

Taxon	Family	BL	MO	SA	Life form	DN	MI	Origin
1. *Acer negundo* L.	*Sapindaceae*	+	+	+	P	INV	del	Am-C & N
2. *Acer saccharinum* L.	*Sapindaceae*	+	-	-	P	CAS	del	Am-N
3. *Aesculus hippocastanum* L.	*Sapindaceae*	+	+	+	P	CAS	del	M
4. *Ailanthus altissima* (Mill.) Sw.	*Simaroubaceae*	+	+	+	P	INV	del	As-E
5. *Albizia julibrissin* Durazz.	*Fabaceae*	-	+	-	P	CAS	del	As
6. *Alcea biennis*Winterl	*Malvaceae*	+	+	-	H	NAT	del	M
7. *Alcea setosa* (Boiss.) Alef.	*Malvaceae*	-	+	-	H	CAS	del	M
8. *Amaranthus albus* L.	*Amaranthaceae*	-	+	+	T	INV	acc	Am-N
9. *Amaranthus caudatus* L.	*Amaranthaceae*	-	+	+	T	CAS	del	Am-S
10. *Amaranthus deflexsus* L.	*Amaranthaceae*	-	+	-	T	INV	acc	Am-S
11. *Amaranthus graecizans* L.	*Amaranthaceae*	-	+	+	T	CAS	acc	Af-E
12. *Amaranthus hybridus* L.	*Amaranthaceae*	+	+	-	T	INV	acc	Am-N
13. *Amaranthus powellii* S. Watson	*Amaranthaceae*	-	-	+	T	CAS	acc	Am-N
14. *Amaranthus retroflexus* L.	*Amaranthaceae*	+	+	+	T	INV	acc	Am-N
15. *Ambrosia artemisiifolia* L.	*Compositae*	+	+	+	T	INV	acc	Am-N
16. *Amorpha fruticosa* L.	*Fabaceae*	+	+	-	P	INV	acc	Am-N
17. *Artemisia annua* L.	*Compositae*	+	+	+	T	INV	acc	As-E
18. *Artemisia verlotiorum* L.	*Compositae*	-	+	-	H	INV	acc	As-E
19. *Bassia scoparia* (L.) Beck	*Chenopodiaceae*	+	-	+	T	CAS	acc	As-C
20. *Bidens frondosa* L.	*Compositae*	-	+	+	T	INV	acc	Am-N
21. *Bidens subalternans* DC.	*Compositae*	-	+	-	T	INV	acc	Am-S
22. *Broussonetia papyrifera* (L.) Vent.	*Moraceae*	-	+	-	P	INV	del	As-E
23. *Buddleja davidii* Franch.	*Scrophulariaceae*	-	+	-	P	INV	del	As-E
24. *Callistephus chinensis* (L.) Nees	*Compositae*	+	-	-	T	CAS	del	As-E
25. *Catalpa bignonioides* Walter	*Bignoniaceae*	-	+	+	P	CAS	del	Am-N

Taxon	Family	BL	MO	SA	Life form	DN	MI	Origin
26. *Cerastium tomentosum* L.	*Caryophyllaceae*	-	-	+	H	CAS	del	Eu-As
27. *Chaenomeles speciosa* (Sweet) Nakai	*Rosaceae*	-	-	+	P	CAS	del	As
28. *Commelina communis* L.	*Commelinaceae*	+	+	+	T	INV	del	As-E
29. *Cosmos bipinnatus* Cav.	*Compositae*	+	-	-	T	CAS	del	Am-C
30. *Cotoneaster horizontalis* Decne.	*Rosaceae*	-	-	+	P	CAS	del	As
31. *Cucurbita pepo* L.	*Cucurbitaceae*	+	+	-	T	CAS	del	Am-C
32. *Cuscuta campestris* Yunck.	*Cuscutaceae*	-	+	+	T	INV	acc	Am-N
33. *Datura stramonium* L.	*Solanaceae*	+	+	+	T	INV	acc	Am-N
34. *Datura wrightii* Regel	*Solanaceae*	-	+	-	T	CAS	del-acc	Am-N
35. *Dysphania ambrosioides* (L.) Mosyakin & Clemants	*Chenopodiaceae*	-	+	-	T	INV	acc	Am-C, S & N
36. *Echinocystis lobata* (Michx.) Torr. & A. Gray	*Cucurbitaceae*	+	-	-	T	INV	acc	Am-N
37. *Eleusine indica* (L.) Gaertn.	*Poaceae*	-	+	+	T	INV	acc	As
38. *Erigeron annuus* (L.) Desf.	*Compositae*	+	+	+	T	INV	acc	Am-N
39. *Erigeron bonariensis* L.	*Compositae*	-	+	-	T	INV	acc	Am-C
40. *Erigeron canadensis* L.	*Compositae*	+	+	+	T	INV	acc	Am-N
41. *Erigeron sumatrensis* Retz.	*Compositae*	-	+	-	T	INV	acc	Am-S
42. *Eschscholzia californica* Cham.	*Papaveraceae*	-	+	-	T	CAS	del	Am-N
43. *Euphorbia maculata* L.	*Euphorbiaceae*	-	+	-	T	INV	acc	Am-N
44. *Euphorbia nutans* Lag.	*Euphorbiaceae*	-	+	-	T	INV	acc	Am-N
45. *Euphorbia prostrata* Aiton	*Euphorbiaceae*	-	+	+	T	INV	acc	Am-N
46. *Fallopia baldschuanica* (Regel) Holub	*Polygonaceae*	-	+	-	P	CAS	del	As-E
47. *Galinsoga parviflora* Cav.	*Compositae*	+	+	+	T	INV	acc	Am-S
48. *Galinsoga quadriradiata* Ruiz & Pav.	*Compositae*	+	+	+	T	INV	acc	Am-S
49. *Gleditsia triacanthos* L.	*Fabaceae*	+	+	+	P	CAS	del	Am-N
50. *Guizotia abyssinica* (L. f.) Cass.	*Compositae*	-	+	-	T	CAS	del-acc	Af-E
51. *Helianthus annuus* L.	*Compositae*	-	+	+	T	CAS	del	Am-S
52. *Helianthus tuberosus* L.	*Compositae*	+	+	+	G	INV	del	Am-N
53. *Hemerocallis fulva* (L.) L.	*Asphodelaceae*	-	-	+	G	CAS	del	As-E
54. *Hypericum calycinum* L.	*Clusiaceae*	-	-	+	G	CAS	del	Eu-As
55. *Impatiens balsamina* L.	*Balsaminaceae*	-	+	-	T	CAS	del	As
56. *Impatiens balfourii* Hook. f.	*Balsaminaceae*	-	+	+	T	INV	del	As
57. *Impatiens glandulifera* Royle	*Balsaminaceae*	+	-	+	T	INV	del	As
58. *Ipomoea indica* (Burm.) Merr.	*Convolvulaceae*	+	-	-	T	CAS	del	Am-S
59. *Ipomoea purpurea* (L.) Roth	*Convolvulaceae*	+	+	-	T	CAS	del	Am-S
60. *Juncus tenuis* Willd.	*Juncaceae*	+	-	+	H	INV	acc	Am-N
61. *Lepidium virginicum* L.	*Brassicaceae*	+	+	+	T	INV	acc	Am-N
62. *Lonicera nitida* E.H. Wilson	*Caprifoliaceae*	-	-	+	P	CAS	del	As-W
63. *Lycium barbarum* L.	*Solanaceae*	-	-	+	P	CAS	del	As
64. *Lycopersicon esculentum* Mill.	*Solanaceae*	+	+	+	T	CAS	del	Am-S
65. *Maclura pomifera* (Raf.) C.K. Schneid.	*Moraceae*	-	+	-	P	CAS	del	Am-N
66. *Mahonia aquifolium* (Pursh) Nutt	*Berberidaceae*	-	-	+	P	CAS	del	Am-N
67. *Malcolmia maritima* (L.) W.T. Aiton	*Brassicaceae*	-	-	+	T	CAS	del	M
68. *Matricaria discoidea* DC.	*Compositae*	+	-	+	T	INV	acc	As-S

Taxon	Family	BL	MO	SA	Life form	DN	MI	Origin
69. *Melia azedarach* L.	*Meliaceae*	-	+	-	P	CAS	del	As-E
70. *Mirabilis jalapa* L.	*Nyctaginaceae*	-	+	-	G	CAS	del	Am-C&S&N
71. *Oenothera biennis* L.	*Onagraceae*	+	+	+	H	INV	del	Am-N
72. *Oenothera glazioviana* Micheli	*Onagraceae*	-	+	+	H	INV	del	Am-N
73. *Opuntia humifusa* (Raf.) Raf.	*Cactaceae*	-	+	-	Ch	INV	del	Am-N
74. *Oxalis articulata* Savigny	*Oxalidaceae*	-	+	-	G	CAS	del	Am-S
75. *Oxalis dillenii* Jacq.	*Oxalidaceae*	+	+	+	H	NAT	acc	Am-N
76. *Oxalis stricta* L.	*Oxalidaceae*	-	+	+	H	CAS	acc	Am-N
77. *Panicum capillare* L.	*Poaceae*	+	-	+	T	INV	acc	Am-N
78. *Panicum dichotomiflorum* Michx.	*Poaceae*	-	+	-	T	INV	acc	Am-N
79. *Parthenocissus quinquefolia* (L.) Planch.	*Vitaceae*	+	+	+	P	INV	del	Am-N
80. *Parthenocissus tricuspidata* (Siebold & Zucc.) Planch.	*Vitaceae*	+	+	-	P	CAS	del	As-E
81. *Paspalum dilatatum* Poir.	*Poaceae*	-	+	+	T	INV	acc	Am-S
82. *Paspalum distichum* L.	*Poaceae*	-	+	-	G	INV	acc	Am-N
83. *Persicaria orientalis* (L.) Spach	*Polygonaceae*	+	-	-	T	CAS	del	As
84. **Petunia* × *atkinsiana* (Sweet) W.H. Baxter	*Solanaceae*	-	+	+	T	CAS	del	Hybrid
85. *Phalaris canariensis* L.	*Poaceae*	+	+	+	T	NAT	acc	Af
86. *Phytolacca americana* L.	*Phytolaccaceae*	-	+	-	G	INV	del-acc	Am-N
87. *Platanus* × *hispanica* Münchh.	*Platanaceae*	-	+	-	P	NAT	del	Hybrid
88. *Portulaca grandiflora* Hook.	*Portulacaceae*	-	+	-	T	CAS	del	Am-S
89. *Potentilla indica* (Andrews) Th. Wolf	*Rosaceae*	-	+	-	H	INV	acc	As-E
90. *Pueraria montana* var. *lobata* (Willd.) Sanjappa & Predeep	*Fabaceae*	-	+	-	P	INV	del	As-E
91. *Reynoutria japonica* Houtt.	*Polygonaceae*	+	+	+	G	INV	del	As-E
92. **Reynoutria* × *bohemica* Chrtek & Chrtková	*Polygonaceae*	+	+	+	G	INV	del	As
93. *Rhus typhina* L.	*Anacardiaceae*	-	-	+	P	CAS	del	Am-N
94. *Robinia pseudoacacia* L.	*Fabaceae*	+	+	+	P	INV	del	Am-N
95. *Rudbeckia hirta* L.	*Compositae*	-	+	-	H	CAS	del	Am-N
96. *Rudbeckia triloba* L.	*Compositae*	-	-	+	H	CAS	del	Am-N
97. *Rudbeckia laciniata* L.	*Compositae*	+	-	-	G	INV	del	Am-N
98. *Sedum sarmentosum* Bunge	*Crassulaceae*	-	+	+	Ch	CAS	del	As
99. *Sedum spurium* M. Bieb	*Crassulaceae*	+	-	-	Ch	CAS	del	As
100. *Senecio inaequidens* DC.	*Compositae*	-	+	+	T	INV	acc	Af-S
101. *Setaria faberi* R.A.W. Herrm.	*Poaceae*	-	-	+	T	CAS	acc	As
102. *Solanum elaeagnifolium* Cav.	*Solanaceae*	-	+	-	T	CAS	acc	Am-S
103. *Solanum tuberosum* L.	*Solanaceae*	+	+	+	G	CAS	del	Am-S
104. *Solidago canadensis* L.	*Compositae*	-	-	+	H	INV	acc	Am-N
105. *Solidago gigantea* Aiton	*Compositae*	+	-	-	H	INV	acc	Am-N
106. *Spiraea japonica* L. f.	*Rosaceae*	-	-	+	P	CAS	del	As
107. *Sporobolus vaginiflorus* (A. Gray) Alph. Wood	*Poaceae*	-	+	-	T	INV	acc	Am-N
108. *Symphoricarpos albus* (L.) S.F. Blake	*Caprifoliaceae*	-	+	-	P	CAS	del	Am-N
109. *Symphyotrichum novi-belgii* (L.) G.L. Nesom	*Compositae*	+	-	-	H	CAS	acc	Am-N
110. *Symphyotrichum salignum* (Willd.) G.L. Nesom	*Compositae*	+	-	-	H	CAS	acc	Am-N

Taxon	Family	BL	MO	SA	Life form	DN	MI	Origin
111. *Symphyotrichum squamatum* (Spreng.) G.L. Nesom	*Compositae*	-	+	-	T	INV	acc	Am-C&S
112. *Tagetes minuta* L.	*Compositae*	-	+	-	T	NAT	acc	Am-S
113. *Tagetes patula* L.	*Compositae*	+	+	+	T	CAS	del	Am-S
114. *Tradescantia fluminensis* Vell.	*Commelinaceae*	-	+	-	G	CAS	del	Am-S
115. *Tropaeolum majus* L.	*Tropaeolaceae*	-	+	-	T	CAS	del	Am-S
116. *Veronica persica* Poir.	*Plantaginaceae*	+	+	+	T	INV	acc	As -W
117. **Viola sororia* Willd.	*Violaceae*	-	-	+	H	CAS	del	Am-N
118. *Wisteria sinensis* (Sims) DC.	*Fabaceae*	-	+	-	P	CAS	del	As-E
119. *Xantthium spinosum* L.	*Compositae*	-	+	-	T	INV	acc	Am-S
120. *Xanthium orientale* subsp. *italicum* (Moretti) Greuter	*Compositae*	+	+	+	T	INV	acc	Am-N&S
121. *Yucca gloriosa* L.	*Asparagaceae*	-	+	-	P	CAS	del	Am-N
122. *Zea mays* L.	*Poaceae*	-	+	+	T	CAS	del	Am-S
123. *Zinnia elegans* Jacq.	*Compositae*	+	-	-	H	CAS	del	Am-N

BL, Banja Luka; **MO**, Mostar; **SA**, Sarajevo.
DN – degree of naturalization: CAS, casual; Inv, invasive; NAT, naturalized.
MI – mode of introduction: acc, accidental; del, deliberata; del-cc, in both ways.
Origin: Af, Africa; Am, America; As, Asia; Eu, Europe; M, Mediterranean; E, East; N, North; S, South; W, West; C, Central.

sification of the alien species follows Richardson & al. (2000) and Pyšek & al. (2004), distinguishing between archaeophytes and neophytes based on the residence time, and between naturalized and casual species based on the invasion status. Modes (pathways) in which the species have been introduced into the area have been arranged according to Pyšek & al. (2012) and marked by the following abbreviations: del – deliberate (by planting) and acc – accidental. Naturalization status (casual, naturalized, invasive) has been determined using the terminology from Richardson & al. (2000), further elaborated by Pyšek & al. (2004). The taxa considered as invasive alien species in Bosnia and Herzegovina (Maslo 2016, 2023) are accompanied by the abbreviation "inv".

Euclidean Similarity Index between the neophytefloras in the surveyed cities were calculated and graphically presented by PAST software (Hammer & al. 2001).

Results and discussion

In the course of the present research, a total of 123 neophyte taxa (species, subspecies and hybrids) from 43 families were recorded (Table 1).

The highest number of neophytes was registered in Mostar (90), followed by Sarajevo (65) and Banja Luka (50). Twenty-four taxa were common to all three cities, while 65 taxa were recorded in only one city (Table 1). Families with the highest number of taxa in all three cities were *Compositae*, *Poaceae*, *Solanaceae*, *Amaranthaceae*, and *Fabaceae*. Also, *Compositae* were recorded with more than 15 taxa in all three cities (Fig. 2). Similar taxonomic structure was documented in the urban flora of Bosnia and Herzegovina (Lubarda & al. 2024).

Analysis of life forms revealed dominance of the therophytes with more than 50% in all three cities (Mostar 56%, Banja Luka 54% and Sarajevo 53%), followed by phanerophytes (Mostar 22%, Sarajevo

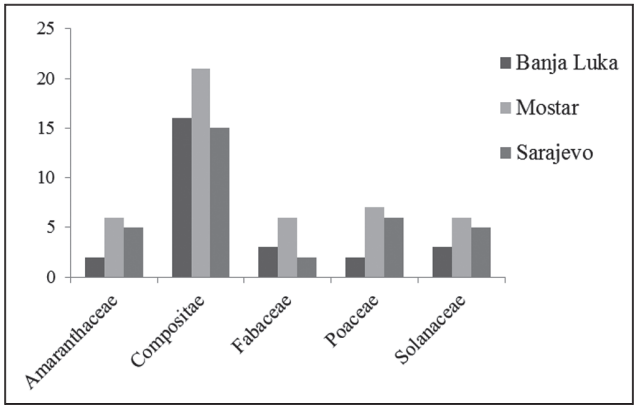

Fig. 2. Families with the highest number of species in the neophyte flora of the cities in Bosnia and Herzegovina.

22%, and Banja Luka 18%) (Table 2). On the other hand, hydrophytes were not recorded in any of the investigated cities.

The high share of therophytes is a result of the instability (ephemerality) of most urban habitats, where occasional or constant anthropogenic pressure hinders the development of perennial plants. Therophytes easily occupy barren areas and abandoned places and, in addition, they are characterized by ample production of seeds, so they spread very easily to new habitats. Therophytes are generally quick to complete their ontogenetic cycle, thereby avoiding the unfavorable anthropozoogenic influences (Jovanović 1994, unpubl.).

The high participation of phanerophytes can be explained by the fact that many woody species were deliberately introduced into the settlements as ornamentals, and have later naturalized.

Most neophytes originate from the Americas (Mostar 69%, Banja Luka 68%, and Sarajevo 61%), followed by the taxa of Asian origin (Sarajevo – 27%, Banja Luka – 24%, and Mostar – 21%). Other elements have poor representation (Table 3). The highest number of neophytes originating from the Americas has been recorded in Mostar, while those originating from Asia have been most numerous in Sarajevo. The widest participation of neophytes, originally from the Americas, has been also recorded in the urban flora of Novi Sad in Serbia (Gavrilović 2016).

Most neophytes were introduced deliberately (69 of the taxa – 56.10%), but 51 taxa (41.46%) were introduced accidentally. The least number of taxa (3 taxa – 2.44%) were introduced in both ways. The highest number of deliberately introduced neophytes was recorded in Mostar (47 taxa), followed by Sarajevo (36 taxa) and the least number was encountered in Banja Luka (27 taxa). The corresponding figures for accidentally introduced neophytes were: Mostar – (40 taxa, Sarajevo – 29 taxa and Banja Luka – 23 taxa (Table 1).

Out of the total of 123 taxa of neophyte plants, which have been the subject of this research, 58 taxa could be considered invasive plants (Maslo 2023). Among them, 50 invasive plants were recorded in Mostar, 34 in Sarajevo and 29 in Banja Luka. Only 20 invasive plants are common for all three cities (Table 1).

There are still no literature data on the neophyte flora in the cities in the neighbouring countries to Bosnia and Herzegovina. On the other hand, the neophyte flora has been described in detail in some cities of Central Europe (Austria, the Czech Republic, Germany, and Poland), where the highest number of neophytes is reported for the city of Vienna – 616 taxa (Pyšek 1998). According to the same author, the number of neophytes increases with the size of the city, which is not the case in our study. According

Table 2. Overview of life forms in the studied neophyte floras.

City	T	H	P	G	Ch
Banja Luka	27 (54)	8 (16)	9 (18)	5 (10)	1 (2)
Mostar	50 (56)	9 (10)	20 (22)	9 (10)	2 (2)
Sarajevo	34 (53)	9 (14)	14 (22)	6 (9)	1 (2)

Notes: Each urban flora is represented by number of recorded species per group, and in percentage (%, in parentheses): **T**, therophyte; **H**, hemicryptophyte; **P**, phanerophyte; **G**, geophyte; **Ch**, chamaephyte.

Table 3. Origin of the neophyte flora in the investigated cities.

Origin		Banja Luka	Mostar	Sarajevo	Total
Asia					
	All	4	6	10	14
	East	6	13	5	15
	West	1	1	2	2
	South	1	-	1	1
	Central	1	-	1	1
America					
	All	1	3	1	3
	North	23	34	26	49
	South	7	20	9	21
	Central	2	2	-	3
	Central & North	1	1	1	1
	Central & South	-	1	1	1
Africa					
	All	1	1	1	1
	East	-	2	1	2
	South	-	1	1	1
Mediterranean		2	3	2	4
Eurasia		-	-	2	2
Hybrids		-	2	1	2
Total		**50**	**90**	**65**	**123**

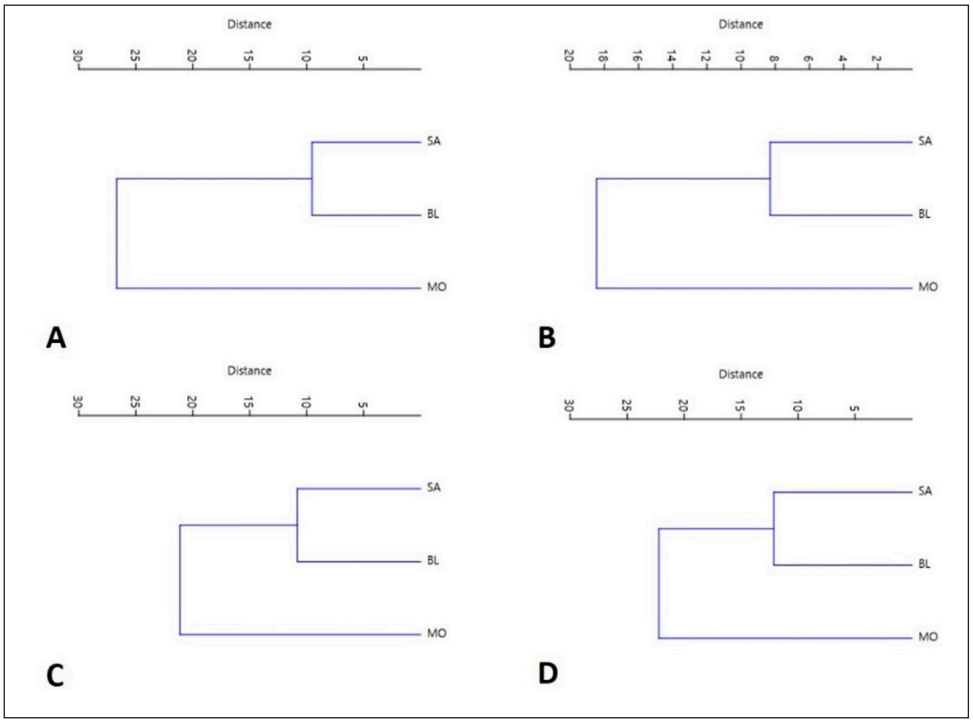

Fig. 3. Clustering based on the Euclidean Similarity Index with data for: **A**, the life forms; **B**, origin; **C**, mode of introduction; **D**, naturalization status.

to Nobis & al. (2019), the mean annual temperature and the length of the vegetation period may influence directly the occurrence of neophytes, which explains why the neophyte flora of Mostar is different from the neophyte floras of the other two cities in terms of representation of the life forms, origin, mode of introduction, and naturalization status (Fig. 3). This can be justified by the fact that the geographical position of Mostar encourages development of neophytes originating from the warmer regions, namely, *Albizia julibrissin*, *Artemisia verlotiorum*, *Bidens subalternans*, *Broussonetia papyrifera*, *Opuntia humifusa*, and *Paspalum distichum*. These taxa have not been observed in the other two cities, as they are sensitive to frost.

4. Conclusions

Analysis of the geographic origin suggests that most alien species in this study originate from the Americas, both North and South (63.41% total), which has been recorded in all three investigated cities (Mostar – 68.69%, Banja Luka – 68% and Sarajevo – 60.94%). These data, as well as the fact that *Compositae* are the richest family and therophytes are the widest spread life form among the neophytes in all three investigated cities, indicate the similarity of the neophyte flora in the investigated area. On the other hand, the highest number of neophytes was recorded in Mostar, and some taxa have been present only there, most likely due to the Mediterranean influence.

References

Anonymus. 2017. Cantonal Plan for Nature Protection of Sarajevo Canton. Ministry of Spatial Development and Nature Protection of Sarajevo Canton (in Bosnian).

EEA. 2022**.** European Environmental Agency. Biogeographical regions in Europe. Available online: https://www.eea.europa.eu/data-and-maps/figures/biogeographical-regions-in-europe-2 (accessed on 15 March 2023).

Euro+Med. 2006-. Euro+Med PlantBase – the information resource for Euro-Mediterranean plant diversity. Published on the Internet: http://ww2.bgbm.org/EuroPlusMed/(accesed on 17 April 2024).

Gavrilović, M. 2016. Ruderal flora of Novi Sad as a potential natural resource of medicinal plants. *PhD Thesis*. Univ. Novi Sad (in Serbian, unpubl.).

Hammer, Ø., Harper, D.A.T. & Ryan, P.D. 2001. PAST: Paleontological Statistics Software Package for Education and Data Analysis. – Palaeontol. Electronica, **4**: 1-9.

Horvat, I., Glavač, V. & Ellenberg, H. 1974. Vegetation Südosteuropas Geobotanica Selecta 4. G. Fischer-Verlag, Stuttgart.

Jovanović, S., Hlavati-Širka, V.M., Lakušić, D., Jogan, N., Nikolić, T., Anastasiu, P., Vladimirov, V. & Šinžar-Sekulić, J. 2018. *Reynoutria* niche modelling and protected area prioritization for restoration and protection from invasion: A Southeastern Europe case study. – J. Nat. Conservation, **41**: 1-15.

Lubarda, B., Rat, M., Petronić, S., Sarajlić, N., Marić, N., Maksimović, T. & Anačkov, G. 2024. Urban floristic diversity in Bosnia and Herzegovina – the reflection of nature. – Urban Ecosystems, 1-17.

Lubarda, B. & Topalić-Trivunović, Lj. 2020. Alien flora of the city of Banja Luka (Bosnia and Herzegovina). – Nat. Croatica, **29**(2): 217-226.

Maslo, S. 2014. The urban flora of the city of Mostar (Bosnia and Herzegovina). – Nat. Croatica, **23**(1): 101-145.

Maslo, S. 2015. Alien flora of the city of Mostar (Bosnia and Herzegovina). – Herbologia, **15**(2): 1-16.

Maslo, S. 2016. Preliminary list of invasive alien plant species (IAS) in Bosnia and Herzegovina. – Herbologia, **16**(1): 1-14.

Maslo, S. 2023. A proposal for updating the list of invasive alien plant species in Bosnia and Herzegovina. – Phytol. Balcan., **29**(3): 405-430.

Maslo, S. & Šarić, Š. 2020. *Salvia hispanica* L. (*Lamiaceae*), a new alien species in the flora of Bosnia and Herzegovina and the Balkans. – Thaiszia, **30**(1): 31-36.

Maslo, S. & Šarić, Š. 2021. *Physalis philadelphica* Lam. (*Solanaceae*), a new alien species in the flora of Bosnia and Herzegovina. – Thaiszia, **31**(1): 81-86.

Maslo, S. & Šarić, Š. 2022. Two new neophytes in the flora of Bosnia and Herzegovina: *Oenothera fruticosa* and *Phacelia campanularia*. – Glasilo Future, **5**(3): 31-38.

Maslo, S., Šarić, Š. & Sarajlić, N. 2020a. Rough-fruit amaranth *Amaranthus tuberculatus* (*Amaranthaceae*): a new alien species in the flora of Bosnia and Herzegovina and the Balkans. – Phytol. Balcan., **26**(1): 25-28.

Maslo, S. & Verloove, F. 2020. *Datura wrightii* Regel. – In: **Raab-Straube, E. von & Raus, Th.** (eds), Euro+Med-Checklist Notulae, 12. [Notulae ad floram euro-mediterraneam pertinentes No. 41]. – Willdenowia, **50**: 305-341.

Maslo, S., Wong, L.J. & Pagad, S. 2020b. GRIIS Checklist of Introduced and Invasive Species. Bosnia and Herzegovina. Vol. 1.3. Invasive Species Specialist Group ISSG. Dataset/Checklist. – www.gbif.org (accessed on 24th Jan 2023).

Nobis, M.P., Jaeger, J.A.G. & Zimmermann, N.E. 2019. Neophyte species richness at the landscape scale under urban sprawl and climate warming. – Diveristy & Distrib., **15**: 928-939.

POWO. 2024. Plants of the World Online. Facilitated by the Royal Botanic Gardens, Kew. Published on the Internet: http://www.plantsoftheworldonline.org/ (accesed 17 April 2024).

Pyšek, P. 1998. Alien and native species in Central European urban floras: a quantitative comparison. – J. Biogeogr., **25**: 155-163.

Pyšek, P., Danihelka, J., Sádlo, J., Chrtek, J. Jr., Chytrý, M., Jarošík, V., Kaplan, Z., Krahulec, F., Moravcová, L., Pergl,

J., Štajerová, K. & Tichý, L. 2012. Catalogue of alien plants of the Czech Republic (2nd ed.): checklist update, taxonomic diversity and invasion patterns. – Preslia, **84**: 155-255.

Pyšek, P., Richardson, D.M., Rejmanek, M., Webster, G.L., Williamson, M. & Kirschner, J. 2004. Alien plants in checklists and floras: towards better communication between taxonomists and ecologists. – Taxon, **53**(1): 131-143.

Raunkiaer, C. 1934. The Life Forms of Plants and Statistical Plant Geography. Clarendon Press, Oxford.

Redžić, S., Barudanović, S. & Radović, M. (eds). 2008. Bosnia and Herzegovina – Land of Diversity. Federal Ministry of Environment and Tourism, Sarajevo, Bosnia and Herzegovina.

Richardson, D.M., Pyšek, P., Rejmánek, M., Barbour, M.G., Panetta, F.D. & West, C.J. 2000. Naturalization and invasion of alien plants: concepts and definitions. – Diversity & Distrib., **6**: 93-107.

Sarajlić, N. & Jogan, N. 2017. Alien flora of the city of Sarajevo (Bosnia and Herzegovina). – Biologica Nyssana, **8**(2): 129-136.