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Alien flora of the city of Sarajevo (Bosnia and Herzegovina)

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***Abstract*:**

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

This paper presents the inventory and brief analysis of 82 alien vascular plant taxa of the urban and suburban area of the city of Sarajevo. The checklist is based on field work that has been carried out from summer 2015 to autumn 2017. Each taxon is given with information concerning its life-form, time and mode of introduction, geographic origin and previously reported occurrence in the area. Most alien plants were the members of the Asteraceae (incl. Cichoriaceae), therophytes, neophytes, originated from North and South America and deliberately introduced. The values of indicators of anthropogenic changes showed the considerable anthropogenic influence on the total flora.

Key words: Alien plants, urban flora, Sarajevo

***Apstrakt*:**

Sarajlić, N., Jogan, N.: ***Alohtona flora grada Sarajeva (Bosna i Hercegovina). Biologica Nyssana, 8 (2), Decembar, 2017: 129-136.***

U radu je dat spisak i kratka analiza 82 alohtona taksona vaskularnih biljaka zabeleženih u urbanom i suburbanom delu grada Sarajeva od leta 2015. do jeseni 2017. godine. Za svaki takson navedeni su podaci o životnoj formi, vremenu i načinu introdukcije, poreklu i najraniji objavljeni podatak o njegovom prisustvu na istraživanom području. Izračunati su indikatori antropogene promene flore. Najbrojnije alohtone vrste zabeležene tokom ovog istraživanja su pripadnici porodice Asteraceae (uključujući Cichoriaceae), terofite, neofite poreklom iz Severne i Južne Amerike, koje su u Evropu unesene namerno. Vrednosti indeksa antropogene promene pokazuju značajan antropogeni uticaj na ukupnu floru grada Sarajeva.

Ključne reči: Alohtone biljke, urbana flora, Sarajevo

Introduction

Urban habitats are generally characterized by high levels of disturbance, high fertility and heterogeneity of habitats, suitable for development of numerous plant species, including many alien plants. Alien (exotic, adventive, introduced, allochthonous, non-indigenous, non-native) plants are those whose presence in a certain area is due to intentional or accidental introduction as a result of human activities (Pyšek, 1995; Richardson et al., 2000; Pyšek et al., 2004). According to their spreading ecology in a certain territory, alien plants can be divided in three groups: casual, naturalized and invasive. According to the time when they were introduced into Europe, alien plants can be classified as archaeophytes (introduced before the year 1500) and neophytes (introduced after the year 1500) (Pyšek, 1995, Kowarik, 1995; Pyšek et al., 2002; Preston et al., 2004; La Sorte et al., 2007). Some of them were introduced deliberately, as ornamental, edible or medicinal plants, and others came to Europe accidentally, without the deliberate actions of humans.

The city of Sarajevo was founded in the 15th century, but expanded, mostly towards the west, only during the post-World War II era. Intense exchange of goods since ancient times and further urbanization, construction of roads and railway enabled the introduction of new plants, some of which slowly become naturalized part of the flora. Literature on alien flora of the city of Sarajevo is scarce, and the presence of some alien plants is either mentioned in general floristic studies (Komša, 1928; Pavlović, 1987; Tomović-Hadžiavdić & Šoljan, 2006), or studies focused on particular species (Slavnić, 1960; Abadžić, 1986/87; Šoljan & Muratović, 2000; Šoljan, 2011; Memišević-Hodžić et al., 2015; Sarajlić et al., 2016; Suljić et al., 2016).

This paper presents a list of hitherto recorded alien species and a brief analysis of the alien flora of the city of Sarajevo. The inventory of 82 taxa is provided based on the field work performed in 2015, 2016 and 2017, updating previous floristic knowledge for the investigated area.

Material and methods

Study area

The city of Sarajevo is located in the Sarajevo valley, on the banks of Miljacka river, at an average altitude between 520 and 750 m a. s. l. (**Fig. 1**). The central parts of the city are situated in the lower parts of

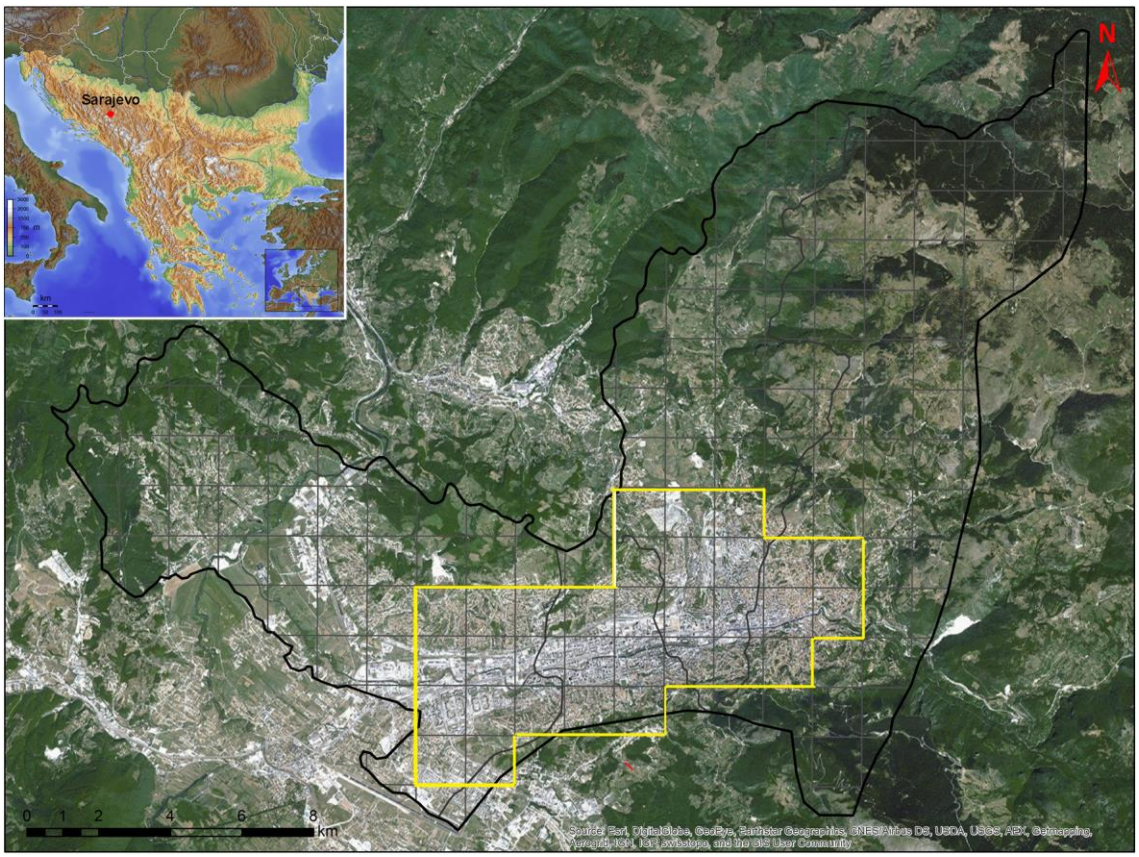

Fig. 1. Geographical position of investigated area (the yellow line limits the area in which the survey was performed)

Table 1. Indicators of anthropogenic changes (An – total number of alien species, Sp – number of native species, Mt – number of permanently established alien species (Ar + Kn - Df), Ar – number of archaeophytes, Kn – number of kenophytes (neophytes), Df – number of diaphytes (casual aliens)).

Indicator	Formula for calculation
Indicator of total anthropophytization	IAnt = An/(Sp+An) ×100%
Indicator of permanent anthropophytization	IAnp = Mt/(Sp+Mt) ×100%
Indicator of total archaeophytization	IArt = Ar/(Sp+An) ×100%
Indicator of permanent archaeophytization	IArp = Ar/(Sp+Mt) ×100%
Indicator of total kenophytization	IKnt = Kn/(Sp+An) ×100%
Indicator of permanent kenophytization	IKnp = Kn/(Sp+Mt) ×100%
Indicator of modernization	IM = Kn/Mt ×100%
Indicator of fluctuation changes	IF = Df/(Sp+An) ×100%

Sarajevo polje, and the suburbs are scattered on the slopes of surrounding hills and mountains. The area of Sarajevo is under influence of mid-European continental climate from the North, and the Mediterranean from the South.

Field investigation

The field survey was performed in the urban part of four municipalities (Novi Grad, Novo Sarajevo, Centar, Stari Grad) of the city of Sarajevo (**Fig. 1**), in an area of 32 km^2, from the summer of 2015 to the autumn of 2017. Only taxa that had not been deliberately planted were recorded.

Data analysis

The nomenclature follows Euro+Med PlantBase and The International Organization for Plant Information Database. Asteraceae family was considered in wider sense (incl. Cichoriaceae). The taxa are listed in alphabetic order, followed by designations for life form (phanerophyte - Ph, chamaephyte - Ch, hemicryptophyte - H, geophyte - G, hydrophyte - Hy and therophyte - T), period of introduction (archaeophytes - ARC and neophytes – NEO), estimated mode of introduction into the region (deliberate, by planting – DEL, accidental – ACC or in both modes - D-A) geographic origin and reported first record for the Sarajevo area. Life forms were given according to Raunkiaer (1934), and time and mode of introduction and geographic origin according to Pyšek et al. (2002), Mosyakin & Yavorska (2003) and Ignatieva & Konechnaya (2004). First records for the area of Sarajevo were given according to available literature sources (see References and Appendix 1).

The indicators of anthropogenic changes in the flora of Sarajevo were calculated after Jackowiak (1990, 2006), according to Witosławski & Bomanowska (2009) as in **Tab. 1**.

Results

During this research, a total of 82 alien plant taxa from 71 genera and 38 families were recorded. The families with the highest number of alien taxa were Asteraceae (21%), Poaceae (10%), Brassicaceae (7%), Fabaceae (6%), Amaranthaceae (5%) and Solanaceae (5%) (**Tab. 2**). The other families were represented only with one or two taxa.

Table 2. The most abundant families in the alien flora of the city of Sarajevo

Family	No. of taxa	% of total alien flora
Asteraceae	17	20.73
Poaceae	8	9.75
Brassicaceae	6	7.31
Fabaceae	5	6.09
Amaranthaceae	4	4.88
Solanaceae	4	4.88

Analysis of life forms showed the domination of therophytes with 47 taxa (57%), followed by phanerophytes with 14 taxa (17%) geophytes (10 taxa, 12%), hemicryphophytes (10 taxa, 12%), and chamaephytes (1 or 1%). The alien flora of the city of Sarajevo consisted of 28 (34%) archaeophytes and 54 (66%) neophytes.

Analysis of the geographical origin of the alien flora of Sarajevo (**Tab. 3**) showed that the majority of species originated from N. and S. America (37 taxa, 45%), followed by those originating from Asia (24 taxa, 24%), Mediterranean (13 taxa, 16%), Eurasia (10 taxa, 12%) and Africa (2 taxa, 2%).

Table 3. An analysis of the geographical origin of the alien flora of the city of Sarajevo

Region Subregion	**No. of taxa**	**% of total alien flora**
Africa	**2**	**2.44**
East (Af-E)	1	1.22
North (Af-N)	1	1.22
America	**37**	**45.12**
South (Am-S)	7	8.54
North (Am-N)	30	36.58
Asia	**24**	29.27
Asia (As)	4	4.88
Central (As-C)	1	1.22
East (As-E)	8	9.76
South-West (As-SW)	4	4.88
West (As-W)	3	3.66
Eurasia (Eu-As)	**10**	**12.19**
Mediterranean (M)	**13**	**15.85**
TOTAL	**82**	**100.00**

Indicators of anthropogenic changes values in the flora of Sarajevo are presented in **Tab. 4**.

Table 4. Indicators of anthropogenic changes in the city of Sarajevo

Indicator	**%**
IAnt	12.09
IAnp	8.17
IArt	4.13
IArp	4.31
IKnt	7.96
Iknp	8.32
IM	65.85
IF	4.45

According to our research, which has been taking place since summer 2015, the urban flora of Sarajevo consists of 678 taxa. The indicators of anthropophytization (IAnt = 12.09%; IAnp = 8.17%) showed the considerable anthropogenic influence on the total flora of Sarajevo, and higher indicator values of kenophytization (IKnt = 7.96%; IKnp = 8.32%) showed that the flora of Sarajevo is more influenced by neophytes than by archaeophytes (IArt = 4.13%; IArp = 4.31%). In both archaeophytes and neophytes, the values of total and permanent indicators were similar, showing that alien flora is well established. This was confirmed by the low value of the indicator of fluctuating changes (IF = 4.45%).

Discussion

Cities usually contain large proportion of alien plants (Wittig, 2004), due to developed transport network and diversity of habitats that can be easily colonized by alien species. During this research, we found that the families with the highest number of taxa were Asteraceae and Poaceae. Those two families were also dominant in alien flora of Zagreb (Hudina et al., 2012), Sisak (Pruša et al., 2013), Podgorica (Stešević et al., 2014) and Mostar (Maslo, 2015), probably due to high reproduction rate and specialised dispersion structures on the seeds (Pyšek, 1997).

In alien flora of Sarajevo, therophytes were the dominant life-form. The same was recorded in Sisak (Croatia) by Pruša et al. (2013) and in Mostar by Maslo (2015). The domination of therophytes is due to the warm and dry microclimate (the "urban heat-island effect") that characterize urban environments, providing conditions that allow many alien species with higher temperature requirements and tolerance for arid environments to become established. All mentioned cities have the significant share of phanerophytes in their alien flora, mostly due to woody ornamental aliens escaping from cultivation.

During this research, neophytes were more numerous than archaeophytes. More neophytes (55%) were also recorded in alien flora of Mostar by Maslo (2015). According to del Tredici (2010), the ratio of neophytes to archaeophytes rises in direct relation to the intensity of human disturbance. This is due to the fact that archaeophytes are typically associated with traditional rural environments or intermediate levels of anthropogenic activities (Preston et al., 2004), and neophytes are more common in highly disturbed modern anthropogenous habitats covering huge areas with little vegetation coverage and with developed transport facilities and industrial infrastructure contributing to the 'urban heat-island effect', which provides distinctive environmental conditions that favor the establishment of species from warmer and drier areas (Pyšek, 1998; Pyšek et al., 2002; Godefroid & Koedam, 2007; La Sorte et al., 2007). Also, the cultivation of numerous foreign species along roads, in parks and gardens, presents the source for neophyte colonization (Wittig, 2004).

The analysis of the geographical origin of the alien flora of Sarajevo showed that the most plants originated from N. and S. America and Asia. The same was found in the city of Podgorica (Stešević et al., 2014) and Mostar (Maslo, 2015). The alien plants originating from N. and S. America and Asia

also dominate in urban flora of Italian cities (Celesti Grapow & Blasi, 1998). This is in a relation with the increased number of neophytes in urban areas, due to the fact that archaeophytes originate primarily from southern Europe and the Near East, and neophytes from North America and Eastern Asia (Pyšek et al., 2002; La Sorte et al., 2007).

The indicators of anthropophytization (IAnt = 12.09%; IAnp = 8.17%) showed considerable anthropogenic influence on the total flora of the city of Sarajevo, but were not as high as in Savica park area near Zagreb (IAnt = 28.78%; IAnp = 26.76%) calculated by Alegro et al. (2013) or Rzeszów Foothills in Poland (IAnt = 21.3%) by Jaźwa & Stadnicka-Futoma (2015). This is probably due to the fact that some habitats in the city of Sarajevo (forests and natural grasslands in the suburban parts of city) had very small number of aliens in comparison to the native plants.

According to available literature sources, the first alien plants reported from the area of Sarajevo were *Panicum miliaceum*, *Linum usitatissimum*, *Aesculus hippocastanum*, *Capsella bursa-pastoris*, *Conyza canadensis*, *Helianthus annuus*, *H. tuberosus*, *Juglans regia*, *Phalaris canariensis*, *Pyrus communis*, *Sinapis arvensis* and *Syringa vulgaris* (Hofmann, 1882). On the other hand, species recorded only recently before our study were *Acer negundo*, *Ailanthus altissima*, *Antirrhinum majus*, *Oenothera biennis* (Tomović-Hadžiavdić & Šoljan, 2006), *Sedum sarmentosum* (Šoljan, 2011) and *Reynoutria japonica* (Sarajlić et al., 2016). During our research, 37 taxa for which there was no earlier data for the area of Sarajevo were found (Appendix 1).

Conclusion

The results of 3-years research showed that the alien flora of the city of Sarajevo consisted of 82 species from 71 genera and 38 families, of which the Asteraceae (21%) were the most numerous, followed by Poaceae (10%) and Brassicaceae (7%). The analysis of life forms showed the domination of therophytes (57%), followed by phanerophytes (17%). Neophytes (66%) were more numerous than archaeophytes (34%). Analysis of the mode of introduction showed that most aliens (49%) were introduced to Europe deliberately, as horticultural or agricultural plants. Most alien plants recorded in the area of the city of Sarajevo originated from N. and S. Americas (45%) and Asia (24%). During this research, 37 taxa for which there was no earlier data for the area of Sarajevo were found. The values of indicators of anthropogenic changes showed the considerable anthropogenic influence on the total flora of Sarajevo.

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Appendix 1.

Alien flora of the city of Sarajevo (LF-life form, PI-period of introduction, MI-mode of introduction, O-origin)

	Species	Family	LF	PI	MI	O	1st record
1.	*Abutilon theophrasti* Medik.	Malvaceae	T	ARC	ACC	As-E	
2.	*Acer negundo* L.	Aceraceae	Ph	NEO	DEL	Am-N	Tomović-Hadžiavdić & Šoljan (2006)
3.	*Aesculus hippocastanum* L.	Hippocastanaceae	Ph	NEO	DEL	M	Hofmann (1882)
4.	*Ailanthus altissima* (Mill.) Swingle	Simaroubaceae	Ph	NEO	DEL	As-E	Tomović-Hadžiavdić & Šoljan (2006)
5.	*Alcea rosea* L.	Malvaceae	H	NEO	DEL	M	
6.	*Amaranthus albus* L.	Amaranthaceae	T	NEO	ACC	Am-N	Maly (1919)
7.	*Amaranthus caudatus* L.	Amaranthaceae	T	NEO	DEL	Am-S	
8.	*Amaranthus graecizans* L.	Amaranthaceae	T	NEO	ACC	Af-E	
9.	*Amaranthus retroflexus* L.	Amaranthaceae	T	ARC	ACC	Am-N	Beck (1887a)
10.	*Ambrosia artemisiifolia* L.	Asteraceae	T	NEO	ACC	Am-N	Maksimović (1990)
11.	*Anagallis arvensis* L.	Primulaceae	T	ARC	ACC	M	Beck (1887b)
12.	*Angelica archangelica* L.	Apiaceae	H	ARC	D-A	As-E	
13.	*Antirrhinum majus* L.	Scrophulariaceae	T	ARC	D-A	M	Tomović-Hadžiavdić & Šoljan (2006)
14.	*Armoracia rusticana* Gaertn, May & Scherb.	Brassicaceae	G	ARC	D-A	Eu-As	Beck (1916)
15.	*Artemisia annua* L.	Asteraceae	T	NEO	ACC	As-E	Beck (1887b)
16.	*Bassia scoparia* (L.) A. J. Scott	Chenopodiaceae	T	NEO	DEL	As-C	Maly (1910)
17.	*Bidens frondosus* L.	Asteraceae	T	NEO	ACC	Am-N	
18.	*Brassica rapa* (L.) L.	Brassicaceae	T	ARC	DEL	M	Maly (1904)
19.	*Calendula officinalis* L.	Asteraceae	T	ARC	DEL	M	
20.	*Capsella bursa-pastoris* (L.) Medik.	Brassicaceae	H	ARC	ACC	Eu-As	Hofmann (1882)
21.	*Catalpa bignonioides* Walter	Bignoniaceae	Ph	NEO	DEL	Am-N	
22.	*Commelina communis* L.	Commelinaceae	G	NEO	DEL	As-E	
23.	*Cuscuta campestris* Yuncker	Cuscutaceae	T	NEO	ACC	Am-N	
24.	*Datura stramonium* L.	Solanaceae	T	NEO	ACC	Am-N	Beck (1887b)
25.	*Eleusine indica* (L.) Gaertn.	Poaceae	T	NEO	ACC	As	
26.	*Erigeron annuus* (L.) Desf.	Asteraceae	T	NEO	ACC	Am-N	Maly (1910)
27.	*Erigeron canadensis* L.	Asteraceae	T	NEO	ACC	Am-N	Hofmann (1882)
28.	*Euphorbia prostrata* Aiton	Euphorbiaceae	T	NEO	ACC	Am-N	
29.	*Galinsoga parviflora* Cav.	Asteraceae	T	NEO	ACC	Am-N	Maly (1933)
30.	*Galinsoga quadriradiata* Ruiz & Pav.	Asteraceae	T	NEO	ACC	Am-N	
31.	*Gleditsia triacanthos* L.	Fabaceae	Ph	NEO	DEL	Am-N	Šoljan et al. (2006)
32.	*Helianthus annuus* L.	Asteraceae	T	NEO	DEL	Am-N	Hofmann (1882)
33.	*Helianthus tuberosus* L.	Asteraceae	G	NEO	DEL	Am-N	Hofmann (1882)

34.	*Hemerocallis fulva* (L.) L.	Xanthorrhoeaceae	G	NEO	DEL	As-E	Maly (1928)
35.	*Hesperis matronalis* L.	Brassicaceae	H	ARC	ACC	Eu-As	
36.	*Impatiens balfourii* Hook. f.	Balsaminaceae	T	NEO	DEL	As	
37.	*Impatiens glandulifera* Royle	Balsaminaceae	T	NEO	DEL	As	
38.	*Iris germanica* L.	Iridaceae	G	ARC	DEL	Eu-As	
39.	*Juglans regia* L.	Juglandaceae	Ph	ARC	DEL	As-SW	Hofmann (1882)
40.	*Juncus tenuis* Willd.	Juncaceae	H	NEO	ACC	Am-N	
41.	*Lepidium virginicum* L.	Brassicaceae	T	NEO	ACC	Am-N	
42.	*Linum usitatissimum* L.	Linaceae	T	ARC	D-A	As-W	Formanek (1889)
43.	*Lonicera nitida* E.H. Wilson	Caprifoliaceae	Ph	NEO	DEL	Az-SW	
44.	*Lycopersicon esculentum* Mill.	Solanaceae	T	NEO	DEL	Am-S	
45.	*Matricaria discoidea* DC	Asteraceae	T	NEO	ACC	Am-N	Maly (1912)
46.	*Medicago arabica* (L.) Huds.	Fabaceae	T	ARC	ACC	M	Beck (1887b)
47.	*Medicago sativa* L.	Fabaceae	H	ARC	ACC	Eu-As	Beck (1896)
48.	*Morus nigra* L.	Moraceae	Ph	ARC	DEL	As-SW	
49.	*Oenothera biennis* L.	Onagraceae	H	NEO	DEL	Am-N	Tomović-Hadžiavdić & Šoljan (2006)
50.	*Oenothera erythrosepala* Borbas	Rosaceae	H	NEO	DEL	Am-N	
51.	*Oxalis dillenii* Jacq.	Oxalidaceae	H	NEO	ACC	Am-N	Maly (1928)
52.	*Oxalis fontana* Bunge	Oxalidaceae	H	NEO	ACC	Am-N	
53.	*Panicum capillare* L.	Poaceae	T	NEO	ACC	Am-N	
54.	*Panicum miliaceum* L.	Poaceae	T	ARC	D-A	As-E	Formanek (1888)
55.	*Papaver rhoeas* L.	Papaveraceae	T	ARC	ACC	M	Beck (1916)
56.	*Parthenocissus quinquefolia* (L.) Planch.	Vitaceae	Ph	NEO	DEL	Am-N	
57.	*Paspalum dilatatum* Poir.	Poaceae	T	NEO	ACC	Am-S	
58.	*Petunia* × *hybrida* (Hook.) Vilm.	Solanaceae	T	NEO	DEL	Am-S	
59.	*Persicaria maculosa* Gray	Polygonaceae	T	ARC	ACC	Eu-As	Komša (1928)
60.	*Phalaris canariensis* L.	Poaceae	T	NEO	ACC	M	Hofmann (1882)
61.	*Platycladus orientalis* (L.) Franco	Cupressaceae	Ph	ARC	DEL	Eu-As	
62.	*Portulaca oleracea* L.	Portulacaceae	T	ARC	ACC	M	Beck (1906)
63.	*Pyrus communis* L.	Rosaceae	Ph	ARC	DEL	Eu-As	Hofmann (1882)
64.	*Ranunculus arvensis* L.	Ranunculaceae	T	ARC	ACC	M	Beck (1891)
65.	*Reynoutria japonica* Houtt.	Polygonaceae	G	NEO	DEL	As-E	Sarajlić et al. (2016)
66.	*Rhus typhina* L.	Anacardiaceae	Ph	NEO	DEL	Am-N	
67.	*Robinia pseudoacacia* L.	Fabaceae	Ph	NEO	DEL	Am-N	Maly (1928)
68.	*Sedum sarmentosum* Bunge	Crassulaceae	Ch	NEO	DEL	As	Šoljan (2011)
69.	*Senecio inaequidens* DC.	Asteraceae	T	NEO	ACC	Af-S	
70.	*Sinapis arvensis* L.	Brassicaceae	T	ARC	D-A	M	Hofmann (1882)
71.	*Solanum tuberosum* L.	Solanaceae	G	NEO	DEL	Am-S	
72.	*Solidago canadensis* L.	Asteraceae	G	NEO	DEL	Am-N	
73.	*Solidago gigantea* Aiton	Asteraceae	G	NEO	DEL	Am-N	
74.	*Sorghum halepense* (L.) Pers.	Poaceae	G	ARC	ACC	M	
75.	*Syringa vulgaris* L.	Oleaceae	Ph	ARC	DEL	Eu-As	Hofmann (1882)
76.	*Tagetes patula* L.	Asteraceae	T	NEO	DEL	Am-S	
77.	*Tanacetum parthenium* (L.) Sch.Bip.	Asteraceae	T	NEO	DEL	As-W	Maly (1904)
78.	*Trifolium arvense* L.	Fabaceae	T	ARC	DEL	Eu-As	Maly (1904)
79.	*Triticum aestivum* L.	Poaceae	T	ARC	DEL	As-SW	
80.	*Veronica persica* Poir.	Scrophulariaceae	T	NEO	ACC	As-W	Beck (1887b)
81.	*Xanthium strumarium* L.	Asteraceae	T	NEO	ACC	Am-N	Maly (1912)
82.	*Zea mays* L.	Poaceae	T	NEO	DEL	Am-S	Beck (1887a)

Abbreviations: Life forms: Ph - Phanerophyte, Ch - Chamaephyte, H - Hemicryptophyte, G - Geophyte, T - Therophyte; Period of introduction: ARC - Archaeophyte, NEO – Neophyte; Mode of introduction: ACC - Accidental, DEL - Deliberate, D-A - in both ways.