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NEOPHYTES IN THE FLORA OF BEDEKOVČINA (NORTHWESTERN CROATIA)

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In the flora of Bedekovčina, 43 species of neophytes were recorded, or 8.5% of the 507 wild plant species recorded in total. Among the neophytes, 11 invasive species were identified, representing 2% of the total flora; the most common being *Solidago gigantea* Aiton, *Erigeron annuus* (L.) Desf., *Echinocystis lobata* (Michx.) Torr. & A. Gray, *Robinia pseudoacacia* L., and *Ambrosia artemisiifolia* L. Most neophytes grow in anthropogenic habitats, but to a lesser extent also in semi-natural and natural vegetation. The species that grow in the greatest number of habitats are *Solidago gigantea* and *Erigeron annuus*. Both species dominate abandoned agricultural lands, *Erigeron annuus* in the early stages and *Solidago gigantea* in the later stages of succession. The neophytes were analysed for various characteristics. The results showed that the neophyte flora was dominated by species native to North America (63%), accidentally introduced (86%), belonging to therophytes (49%), annual herbs (47%), good competitors (42%), which reproduce only by seeds (58%), and disperse with autochory (53%).

Key words: alien species, CSR strategies, growth forms, habitats, invasive species, life forms, reproduction, seed dispersal

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U flori Bedekovčine zabilježene su 43 vrste neofita što čini 8.5 % od ukupno 507 samoniklih biljnih vrsta. Među neofitima utvrđeno je 11 invazivnih vrsta što čini 2 % ukupne flore, a najčešće su: *Solidago gigantea* Aiton, *Erigeron annuus* (L.) Desf., *Echinocystis lobata* (Michx.) Torr. & A. Gray, *Robinia pseudoacacia* L. i *Ambrosia artemisiifolia* L. Većina neofita raste na antropogenim staništima, a manji dio u sastavu poluprirodne i prirodne vegetacije. Vrste koje rastu na najvećem broju staništa su *Solidago gigantea* i *Erigeron annuus*. Obje vrste se kao dominantne pojavljuju na napuštenim poljoprivrednim površinama, *Erigeron annuus* u početnim, a *Solidago gigantea* u kasnijim fazama sukcesije. Neofitska flora analizirana je s obzirom na različita svojstva. Kao rezultat dobiveno je da među neofitima dominiraju vrste koje potječu iz Sjeverne Amerike (63%), slučajno unesene (86%), koje pripadaju terofitima (49%), jednogodišnjim zeljastim biljkama (47%), imaju karakteristike kompetitora (42%), koje se razmnožavaju samo pomoću sjemena (58%) te koje imaju svojstvo autohorije (53%).

Ključne riječi: CSR strategije, forme rasta, invazivne vrste, rasprostranjivanje sjemena, razmnožavanje, staništa, životni oblici

INTRODUCTION

Non-native plant species are found with increasing frequency world-wide. They spread intentionally or unintentionally. The general view is that such species pose a threat to the survival of native (indigenous) plant species and plant communities, and lead to the global homogenization of biota (Rabitsch & Essl, 2006). Additionally, alien species can also be vectors for the entry of pathogens, parasites, and because they are

weeds cause economic losses, while some have adverse effects on human health (e.g. *Ambrosia artemisiifolia* L. and *Heracleum mantegazzianum* Sommier et Levier).

Because of the possible negative effects, non-native species have been studied from different aspects. In Croatian botanical literature there are a number of works dealing with non-native species, from those that describe neophyte species in the flora of Croatia for the first time (Košćec, 1913; Devidé, 1956; Hodak, 1959; Trinajstić, 1973; Marković & Ruščić, 1999; Buzjak & Sedlar, 2018; and many others), provide data on new localities (Pandža *et al.*, 2001; Boršić *et al.*, 2015; and many others), analyse non-indigenous species in the flora of a particular area (Šilić & Šolić, 1999; Milović, 2001; Tafra *et al.*, 2013), represent taxonomic works providing detailed descriptions of species useful for identification (Milović, 2004; Vuković *et al.*, 2019), and provide information about habitats and plant communities in which they grow (Marković, 1984; Marković & Lukač, 1993; Trinajstić *et al.*, 2001). In the paper by Mitić *et al.* (2008), a classification of alien plant species is proposed, while Boršić *et al.* (2008) provide a preliminary list of invasive alien species in Croatia, and in the book "Flora of Croatia: Invasive Plants" (Nikolić *et al.*, 2014) detailed descriptions of 70 species are presented.

Lists of alien plant species have been published in some European countries: in the Czech Republic (Pyšek *et al.*, 2002, 2012), which should be emphasised for its quality and completeness, in Austria (Essl & Rabitsch, 2002), Germany (Klotz *et al.*, 2002), Hungary (Mihály & Botta-Dukát, 2004), Switzerland (Wittenberg, 2005), a preliminary list of invasive alien species in neighbouring Bosnia and Herzegovina (Maslo, 2016), etc.

At the European level, an analysis of alien flora was first made by Weber (1997), listing 1568 species. Subsequently Lambdon *et al.* (2008) recorded as many as 5789 alien plant species. At the regional level, in the area of the Pannonian Plain in neighboring Serbia, an analysis of alien invasive neophytes was carried out by Anačkov *et al.* (2013).

In Europe, there is a specialized database of alien species, DAISIE (Roy *et al.*, 2020), and there are also floristic databases with data on alien species such as Euro + Med PlantBase (2022), BiolFlor (Klotz *et al.*, 2002), Pladias (Chytrý *et al.*, 2021), Flora Croatica Database (FCD) (Nikolić, 2021) and others.

A very useful analysis of the occurrence of alien plant species in different habitat types using a large data set from the Czech National Phytosociological Database was presented by Chytrý *et al.* (2005). There are works dealing with specific vegetation types known to contain a large proportion of alien species, such as by Šilc *et al.* (2012), who analysed the proportion of alien species in ruderal vegetation in the area of former Yugoslavia. Lososová *et al.* (2006) studied the distribution patterns of archaeophytes and neophytes in annual weed and ruderal vegetation in Central Europe. Furthermore, some of the papers deal with various traits that influence invasiveness, for example in a study by Moravcová *et al.* (2010). There are also many other works on alien species, mainly published in the last 20 years.

The introduction of alien species, their monitoring and treatment are also embodied in regulations in the European Union (EU, 2014, 2016, 2017, 2019; Boršić *et al.*, 2018) and in Croatia (NN, 2018).

Given the importance of alien species, the aim of this work was to provide an overview of neophytes in the Bedekovčina area and to determine the patterns of their distribution. For this purpose, the neophyte species were analysed with respect to the following criteria: (i) plant family affiliation, (ii) geographic origin, (iii) invasive status,

(iv) mode of introduction, (v) Raunkiaer life forms, (vi) growth forms, (vii) Grime's CSR strategies, (viii) reproduction types, (ix) seed dispersal, (x) vegetation groups, and (xi) habitat types.

MATERIALS AND METHODS

Study area

The study area covers about 30 km² and includes the settlement Bedekovčina and its surroundings (Fig. 1). Bedekovčina has about 3400 inhabitants and is located in northwestern Croatia. The relief is characterized by hills and the lowlands of the river Krapina and its tributaries. The altitude ranges from 148 to 237 meters above sea level. The landscape is very mosaic in structure, which is partly due to the very small areas of privately owned land that are characteristic of this part of Croatia. There is also a great variety of habitats: private houses with backyards, industrial area, road network, railroad station and railroad, arable land (with annual crops, vineyards, orchards), rarely mowed meadows, abandoned arable land and meadows, shrubs, forests, aquatic habitats (river Krapina, numerous tributaries and canals and five artificial lakes with an area of about 11.2 ha). The climate is temperate continental, belonging to the Cfwbx type according to the Köppen classification, and to humid climate according to Thornthwaite, with an average annual air temperature between 10 and 11°C and an average annual precipitation of 900 to 1000 mm (Zaninović *et al.*, 2008).

Fig. 1. Study area of Bedekovčina in NW Croatia.

Data collection

Field research into the flora was conducted sporadically from 1992 to 2021. The identification of plant species was carried out using the following literature: Flora Europaea (Tutin *et al*., 1964-1980, 1993) and Exkursionsflora von Österreich (Adler *et al*., 1994). Some specimens collected for identification are stored in the private herbarium of the author of this work. The nomenclature of the plant species and the affiliation of the species to plant families were determined according to Euro+Med PlantBase (2022). A complete list of the vascular flora of Bedekovčina is presented by Stančić & Fiket (2022).

The affiliation of plant species to the group of neophytes (species introduced after 1500 AD) and their geographical origin were determined according to Pyšek *et al.* (2002, 2012), FCD (Nikolić, 2021) and Pladias (2021). Hybrids between native and alien species are considered as aliens (Pyšek *et al*., 2002).

In terms of invasion status, neophytes are divided into three categories according to Pyšek *et al.* (2002): (i) casual, (ii) naturalised non-invasive (hereafter abbreviated as naturalised), and (iii) naturalised invasive (hereafter abbreviated as invasive). It is important to note that the classification of species according to their invasive status is based on the results of field research into the local flora and the author's own assessment, but not on the generally accepted status at the country level (Boršić *et al*., 2008) or the European Union (EU, 2014, 2016, 2017, 2019; Boršić *et al*., 2018).

The mode of introduction is divided into the categories accidental and deliberate.

Raunkiaer life forms are taken from FCD (Nikolić, 2021) and Pladias (2021), and classified into: H - hemicryptophytes, T - therophytes, G - geophytes, P - phanerophytes, Ch - chamaephytes, Hy - hydrophytes.

The growth forms were adopted from Pladias (2021) and classified into the following categories: annual herb, clonal herb, perennial non-clonal herb, shrub, tree and woody liana.

Grime plant life strategies were adopted from Vuković *et al.* (2014), Pladias (2021) and BiolFlor (2022) and divided into: competitors (C), ruderals (R), stress tolerators (S) and their combinations.

The reproduction types and seed dispersal strategies and their classifications were taken from Pladias (2021) and BiolFlor (2022). Reproduction types are divided into: (i) only by seeds, (ii) by seeds and vegetatively, (iii) mostly by seeds, rarely vegetatively, and (iv) mostly vegetatively, rarely by seeds. Seed dispersal strategies were classified into the following categories: anemochory, autochory, endozoochory, epizoochory, hydrochory, no dispersal.

Species are classified into the following vegetation groups based on field observations:

- forest vegetation without the effects of floods (FAG *Carpino-Fagetea sylvaticae* Jakucs ex Passarge 1968, QUE *Quercetea robori-petraeae* Br.-Bl. et Tx. ex Oberd.1957, ROB *Robinietea* Jurko ex Hadač et Sofron 1980),
- floodplain forests and shrubs (PUR *Salicetea purpureae* Moor 1958, ALN *Alnetea glutinosae* Br.-Bl. et Tx. ex Westhoff et al. 1946, FRA *Franguletea* Doing ex Westhoff in Westhoff et Den Held 1969),

- vegetation of forest edges (EPI *Epilobietea angustifolii* Tx. et Preising ex von Rochow 1951, GER *Trifolio-Geranietea sanguinei* T. Müller 1962),
- wet and mesic grassland vegetation (MOL *Molinio-Arrhenatheretea* Tx. 1937),
- marsh vegetation (PHR *Phragmito-Magnocaricetea* Klika in Klika et Novák 1941),
- ruderal vegetation (POL *Polygono-Poetea annuae* Rivas-Mart. 1975, ART *Artemisietea vulgaris* Lohmeyer et al. in Tx. Ex von Rochow1951, BID *Bidentetea* Tx. et al. ex von Rochow 1951, SIS *Sisymbrietea* Gutte et Hilbig 1975),
- weed vegetation (PAR *Papaveretea rhoeadis* S. Brullo et al. 2001, CHE *Chenopodietea* Br.-Bl. in Br.-Bl. et al. 1952, DIG *Digitario sanguinalis-Eragrostietea minoris* Mucina, Lososová et Šilc 2016).

Next to each vegetation group, codes and corresponding syntaxonomic units are listed in parentheses according to Mucina *et al.* (2016).

Habitat types are divided into three groups according to human influence (Pyšek *et al.*, 2002): (i) natural (vegetation developing without human influence), (ii) semi-natural (vegetation created and maintained by human activities - grasslands), (iii) anthropogenous (arable land and ruderal habitats of human settlements).

RESULTS AND DISCUSSION

The proportion of neophytes

In the Bedekovčina area 43 species of neophytes have been identified, one of which is a hybrid (Tab. 1). The proportion of neophytes in the flora of some area is a variable characteristic. In the flora of Bedekovčina (Stančić & Fiket, 2022), 8.5% neophytes (43 species) and 11.8% archaeophytes (60 species) were found, making a total of 20.3% non-native species. For comparison, in other parts of continental Croatia, 9.7% neophytes and 16.6% archaeophytes were found in the flora of Savica (suburb of the city of Zagreb) (Alegro *et al.*, 2013), while 3.7% neophytes were found in the rural flora of Stupnik (Mitić *et al.*, 2007). In the Mediterranean part of Croatia, Milović & Mitić (2012) for the area of the city of Zadar recorded 19.22% of non-native species, and Tafra *et al.* (2013) for the area of the city of Omiš recorded 13.68% of non-native species; archaeophytes and neophytes are not distinguished either work. It can be seen that the larger urban area of Zadar with 70,000 inhabitants has more non-native species than Omiš with 6,400 inhabitants. The available studies show that urban areas host more neophytes than rural areas. The proportion of non-native species, both archaeophytes and neophytes, depends on the extent of anthropogenic impacts on habitats, which cause the introduction and spread of aliens.

At the country level, for example in the Czech Republic, neophytes (including hybrids) make up 25% of the total flora (Pyšek *et al.*, 2002), while in Austria neophytes make up 27% of the total vascular flora (Rabitsch & Essl, 2006). Alien species tend to be more prevalent in developed countries where humans have a long history of impacting ecosystems.

The proportion of non-native flora registered has increased greatly over time. For example, for Europe Weber (1997) recorded 1568 alien plant species, whereas Lambdon *et al.* (2008) recorded 5789 alien plant species 11 years later. Lambdon *et al.* (2008) note that 6.2 species capable of being naturalised arrive each year.

Tab. 1. Neophytes in the flora of Bedekovčina listed in alphabetical order. For each species the following data are given: family affiliation; origin (Af - Africa, As - Asia, W As - Western Asia, Au - Australia, C Am - Central America, N Am - North America, S Am - South America, Med - Mediterranean); inv. stat. - invasion status (cas - casual, nat - naturalised non-invasive, inv - naturalised invasive); m. of intr. - mode of introduction (a - accidental, d - deliberate); life form (H -hemicryptophyte, T - therophyte, G - geophyte, P - phanerophyte); growth form (ann h - annual herb, clo h - clonal herb, per n-clo h - perennial non-clonal herb, sh - shrub, t - tree, w l - woody liana); Grime's life strategy (C - competitor, R - ruderal, S - stress tolerator, and their combinations); repr. type - reproduction type (s - only by seeds, sv - by seeds and vegetatively, ssv - mostly by seeds, rarely vegetatively, vvs - mostly vegetatively, rarely by seeds); seed dispersal strategy (Anemoch - anemochory, Autoch - autochory, Endozooch - endozoochory, Epizooch - epizoochory, Hydroch - hydrochory, no dispersal); vegetation group (F edges v - vegetation of forest edges, Flood F&S - floodplain forests and shrubs, Forest v - forest vegetation without the effects of floods, Grass v - wet and mesic grassland vegetation, Marsh v - marsh vegetation, Ruderal v - ruderal vegetation, Weed v - weed vegetation); habitat type (A - anthropogenous, SN - semi-natural, N - natural).

No. of taxa	Taxon name	Family	Origin	Inv. stat.	M. of intr.	Life form	Growth form	Grime's life strategy	Repr. type	Seed dispersal strategy	Vegetation group	Habitat type
1	*Abutilon theophrasti* Medik.	*Malvaceae*	Med, As	nat	a	T	ann h	CR	s	Autoch	Weed v	A
2	*Acer negundo* L.	*Sapindaceae*	N Am	nat	a	P	t	C	sv	Anemoch / Autoch	Ruderal v	A
3	*Ailanthus altissima* (Mill.) Swingle	*Simaroubaceae*	As	nat	a	P	t	C	sv	Anemoch / Autoch	Ruderal v, Forest v	A, N
4	*Amaranthus retroflexus* L.	*Amaranthaceae*	N and C Am	inv	a	T	ann h	CR	s	Autoch	Weed v	A
5	*Ambrosia artemisiifolia* L.	*Compositae*	N Am	inv	a	T	ann h	CR	s	Autoch	Weed v, Ruderal v	A
6	*Amorpha fruticosa* L.	*Fabaceae*	N Am	cas	a	P	sh	C	s	Autoch	Ruderal v	A
7	*Asclepias syriaca* L.	*Apocynaceae*	N Am	nat	a	H	clo h	C	sv	Anemoch / Autoch	Ruderal v	A
8	*Bassia scoparia* (L.) A. J. Scott	*Chenopodiaceae*	Med, As	cas	a	T	ann h	CR	s	Autoch	Ruderal v	A
9	*Bidens frondosa* L.	*Compositae*	N Am	nat	a	T	ann h	CR	s	Autoch /Epizooch	Marsh v	N
10	*Commelina communis* L.	*Commelinaceae*	As	nat	a	T	ann h	-	s	Autoch	Ruderal v	A
11	*Echinocystis lobata* (Michx.) Torr. & A. Gray	*Cucurbitaceae*	N Am	inv	a	T	ann h	CR	s	Autoch	Flood F&S	N
12	*Eleusine indica* (L.) Gaertn.	*Poaceae*	As, Af	nat	a	T	ann h	C	s	Autoch	Weed v, Ruderal v	A
13	*Erigeron annuus* (L.) Desf.	*Compositae*	N Am	inv	a	H	per n-clo h	CR	s	Anemoch / Autoch	Ruderal v, Weed v, Grass v, Forest v	A, SN, N
14	*Erigeron canadensis* L. (syn. *Conyza canadensis* (L.) Cronquist)	*Compositae*	N Am	inv	a	T	ann h	CR	s	Anemoch / Autoch	Ruderal v	A
15	*Euphorbia lathyris* L.	*Euphorbiaceae*	Med	cas	a	T	ann h	C	s	Autoch	Ruderal v	A
16	*Euphorbia maculata* L.	*Euphorbiaceae*	N Am	nat	a	T	ann h	R	s	Autoch	Ruderal v	A
17	*Galinsoga parviflora* Cav.	*Compositae*	N Am	inv	a	T	ann h	CR	s	Anemoch / Autoch	Weed v	A
18	*Galinsoga quadriradiata* Ruiz & Pav. (syn. *Galinsoga ciliata* (Raf.) S.F.Blake)	*Compositae*	C and S Am	inv	a	T	ann h	CR	s	Anemoch / Autoch	Weed v	A
19	*Gleditsia triacanthos* L.	*Fabaceae*	N Am	cas	d	P	t	-	s	Autoch / Endozooch	Ruderal v	A

Tab. 1. Continued

No. of taxa	Taxon name	Family	Origin	Inv. stat.	M. of intr.	Life form	Growth form	Grime's life strategy	Repr. type	Seed dispersal strategy	Vegetation group	Habitat type
20	*Helianthus tuberosus* L.	*Compositae*	N Am	nat	a	G	clo h	C	vvs	no dispersal	Ruderal v, Flood F&S	A, N
21	*Impatiens balfourii* Hook. f.	*Balsaminaceae*	As	nat	a	T	ann h	R/CR	s	Autoch	F edges v, Ruderal v	N, A
22	*Juncus tenuis* Willd.	*Juncaceae*	N Am	nat	a	H	clo h	CSR	ssv	Autoch	Ruderal v	A
23	*Lepidium virginicum* L.	*Brassicaceae*	N and C Am	nat	a	H, T	ann h	R	s	Autoch	Ruderal v	A
24	*Maclura pomifera* (Raf.) C. K. Schneid.	*Moraceae*	N Am	cas	d	P	t	-	sv	-	Ruderal v	A
25	*Mahonia aquifolium* (Pursh.) Nutt.	*Berberidaceae*	N Am	cas	d	P	sh	C	sv	Autoch / Endozooch	Ruderal v	A
26	*Matricaria discoidea* DC.	*Compositae*	As	nat	a	T	ann h	R	s	Autoch	Ruderal v	A
27	*Medicago* × *varia* Martyn	*Fabaceae*	Hybrid	cas	a	H	per n-clo h	C	s	-	Grass v	SN
28	*Oenothera biennis* agg.	*Onagraceae*	?	nat	a	H	per n-clo h	CR	s	Autoch	Ruderal v	A
29	*Oxalis corniculata* L.	*Oxalidaceae*	Med, As, Au	inv	a	H, T	ann h	R	sv	Autoch	Weed v, Ruderal v	A
30	*Oxalis dillenii* Jacq.	*Oxalidaceae*	N Am	nat	a	H, T	ann h	R	sv	Autoch	Weed v, Ruderal v	A
31	*Oxalis fontana* Bunge in Mém. (syn. *Oxalis stricta* L.)	*Oxalidaceae*	N Am	nat	a	H, T	clo h	R	sv	Autoch	Weed v, Ruderal v	A
32	*Panicum capillare* L.	*Poaceae*	N Am	nat	a	T	ann h	CR	s	Autoch	Weed v, Ruderal v	A
33	*Parthenocissus quinquefolia* agg.	*Vitaceae*	N Am	cas	d	P	w l	C	s	Autoch / Endozooch	Ruderal v	A
34	*Phytolacca americana* L.	*Phytolaccaceae*	N Am	cas	a	G	per n-clo h	C	s	Autoch / Endozooch	Ruderal v	A
35	*Potentilla indica* (Jacks.) Th. Wolf (syn. *Duchesnea indica* (Andrews) Focke)	*Rosaceae*	As	nat	a	H	clo h	CSR	vvs	Autoch / Endozooch	Ruderal v	A
36	*Reynoutria japonica* Houtt.	*Polygonaceae*	As	nat	a	G	clo h	C	vvs	Autoch / Hydroch / Anemoch	Ruderal v	A
37	*Rhus typhina* L.	*Anacardiaceae*	N Am	cas	d	P	sh	C	vvs	no dispersal	Ruderal v	A
38	*Robinia pseudoacacia* L.	*Fabaceae*	N Am	inv	a	P	t	C	sv	Autoch	Forest v	N
39	*Rudbeckia laciniata* L.	*Compositae*	N Am	nat	a	H	clo h	C	sv	Autoch	Ruderal v, Flood F&S	A, N
40	*Solidago gigantea* Aiton	*Compositae*	N Am	inv	a	H, G	clo h	C	sv	Anemoch / Autoch	Ruderal v, Grass v, Marsh v	A, SN, N
41	*Sorghum halepense* (L.) Pers.	*Poaceae*	Med	nat	a	G	clo h	C	sv	Autoch	Weed v	A
42	*Symphoricarpos albus* (L.) S. F. Blake	*Caprifoliaceae*	N Am	cas	d	P	sh	C	sv	Autoch / Endozooch	Ruderal v	A
43	*Veronica persica* Poir.	*Plantaginaceae*	W As, Med	inv	a	T	ann h	R	s	Autoch	Weed v, Ruderal v	A

Invasion status

According to the invasion status in the neophyte flora of Bedekovčina, invasive species are represented by 25.6%, naturalised by 48.8% and casual by 25.6%. In the total flora of Bedekovčina, there are 2% invasive species, 4% naturalised and 2% casual.

The greatest risk is posed by invasive neophytes. They establish themselves quickly and usually cover large areas, often displacing native vegetation. Therefore, they have adverse effects on native biodiversity, but some also have adverse effects on human health, and some cause damage to agriculture as weeds. In general, invasive neophytes interfere with the provision of many ecosystem services. In the flora of Bedekovčina these are the following species: *Amaranthus retroflexus* L., *Ambrosia artemisiifolia* L., *Echinocystis lobata* (Michx.) Torr. & A. Gray, *Erigeron annuus* (L.) Desf., *E. canadensis* L., *Galinsoga parviflora* Cav., *G. quadriradiata* Ruiz & Pav., *Oxalis corniculata* L., *Robinia pseudoacacia* L., *Solidago gigantea* Aiton and *Veronica persica* Poir. These species are very common and some of them are dominant in the vegetation where they grow. They need to be monitored and managed.

Naturalised and casual species represent a relatively low risk, although future invasive species could be recruited from them. The composition of casual species in an area is highly variable, and a considerable proportion consists of species that have escaped cultivation.

In other floristic works from Croatia (e.g. Justić *et al.*, 2020, 2021; Milović *et al.*, 2021) only invasive species defined by Boršić *et al.* (2008), Nikolić *et al.* (2014) and in FCD (Nikolić, 2021) were analysed. They were not determined according to their actual invasive status in the study area.

In the flora of the Czech Republic Pyšek *et al.* (2002) list 2% invasive species of the total flora, 9.6% naturalised and 21.6% casual species. In the Bedekovčina flora, the percentage of invasive species is exactly the same, while that of naturalized and casual species is significantly lower as in the Czech Republic. The probable cause of the higher proportion of naturalized and casual species in the Czech Republic is the higher anthropogenic influence. Such comparison with the updated edition of the Catalogue of Alien Plants of the Czech Republic (Pyšek *et al.*, 2012) is not possible, as no percentages are given in relation to the total flora.

It is interesting to note that some commonly recognised invasive species at the European Union level (EU, 2014, 2016, 2019; Boršić *et al.*, 2018) and in Croatia (Boršić *et al.*, 2008; Nikolić *et al.*, 2014) show no invasiveness in the Bedekovčina area, such as *Amorpha fruticosa* L. and *Asclepias syriaca* L. In addition, some invasive species accepted at the country level that occur in northwestern Croatia have not yet been identified in the flora of Bedekovčina, such as *Impatiens glandulifera* Royle.

Introduction mode

It is estimated that 86% of neophytes in the flora of Bedekovčina were accidentally introduced and only 14% delibarately (mostly escaped from cultivation). These data differ significantly from those for alien flora in the whole Europe and in some individual countries. According to Lambdon *et al.* (2008), most species in the alien flora of Europe have been deliberately introduced. The same trend was found by Pyšek *et al.* (2012) for the flora of the Czech Republic, where deliberate introduction was found in

51.4% and accidental in 48.6% of cases. This can be explained by the fact that most alien plants, once deliberately introduced to the European continent, continue to spread spontaneously, i.e. accidentally. This is an important signal for those who shape European policy and control of alien species to increase their activities and prevent further introductions and spreads.

Plant families

The neophyte flora of Bedekovčina is assigned to 26 families. The plant families with the largest number of taxa are: *Compositae* (10 species, 23%), *Fabaceae* (4 species, 9%), *Oxalidaceae* (3 species, 7%), *Poaceae* (3 species, 7%) and *Euphorbiaceae* (2 species, 5%), while all other families are represented by only one species. These data are comparable to other studies with minor variations. In Austria, the families *Asteraceae*, *Poaceae*, *Brassicaceae*, and *Fabaceae* contain the largest number of neophytes (Rabitsch & Essl, 2006). In the Czech Republic, *Asteraceae*, *Poaceae*, *Fabaceae, Rosaceae* and *Brassicaceae* are the most represented among neophytes (Pyšek *et al.*, 2012). Throughout Europe, the families with the greatest number of alien species are: *Asteraceae*, *Poaceae*, *Rosaceae*, *Fabaceae* and *Brassicaceae* (Lambdon *et al.*, 2008). Accordingly, only species from the families *Brassicaceae* and *Rosaceae* are underrepresented in the neophyte flora of Bedekovčina.

Geographical origin

Bedekovčina neophytes are mainly introduced from North America (63%), followed by taxa from Asia (26%) and the Mediterranean region (14%) (Fig. 2). Such a trend can be observed for alien invasive species throughout Croatia (Boršić *et al.*, 2008), for invasive neophytes in neighboring Pannonian Serbia (Anačkov *et al.*, 2013) and for alien flora in Europe (Lambdon *et al.*, 2008). However, it is interesting to note that in the Czech Republic most neophytes originate from the Mediterranean region (34.6%), other parts of Europe (19.4%), Asia (13.1% and then from North America (12.6%) (Pyšek *et al.*, 2012). The same trend was observed in Austria (Rabitsch & Essl, 2006), where most neophytes originated from the Palaearctic region (55%, with 33% from the Mediterranean subregion) and then from North America (20%). It is obvious that the countries of Central Europe have different introduction routes for alien plant species than Croatia, and that the Mediterranean region is the main donor region for their alien flora. In continental Croatia some of the alien species also originate from Mediterranean and sub-Mediterranean regions. Some of these species have their natural range in the

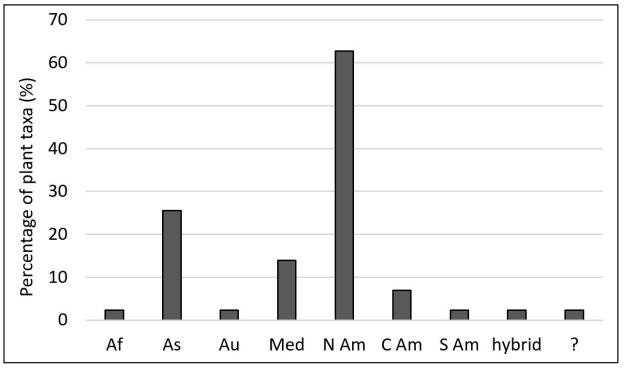

Fig. 2. Representation of neophytes in the flora of Bedekovčina by geographical origin. Abbreviations: Af - Africa, As - Asia, Au - Australia, Med - Mediterranean area, N Am - North America, C Am - Central America, S Am - South America. Some species are represented in several areas.

southern part of Croatia with its Mediterranean climate. Here arises the problem of their classification according to their origin, especially in the categories of neophytes or archaeophytes. In continental Croatia, these species usually invade thermophilic ruderal sites and urban heat islands.

Life and growth forms

In the neophyte flora of Bedekočina, analysis of the life form spectrum (Fig. 3) shows that therophytes dominate with 49%, followed by hemicryptophytes with 28%, phanerophytes with 23%, and geophytes with 12% (Fig. 3); some species were assigned to two life forms. Such a distribution pattern of life forms was also found in other studies (Pyšek *et al.*, 2002; Boršić *et al.*, 2008; Anačkov *et al.*, 2013).

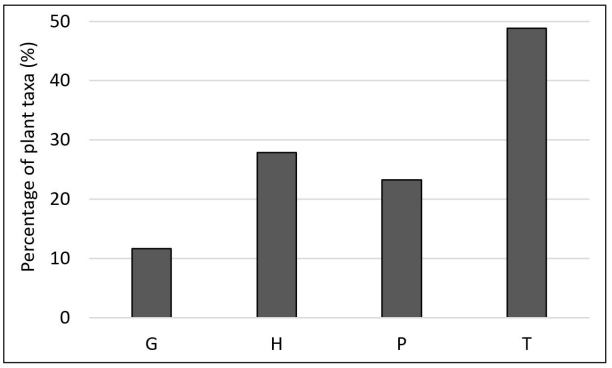

Fig. 3. The proportion of life forms in the neophyte flora of Bedekovčina. Abbreviations: G - geophyte, H - hemicryptophyte, P - phanerophyte, T - therophyte. Some species were assigned to more than one life form.

According to the proportion of growth forms, in Bedekočina area the largest group consists of annual herbs with 47%, followed by clonal herbs with 21%, trees with 12%, perennial non-clonal herbs and shrubs with 9% each, and woody lianas with 2% (Fig. 4). A similar trend is shown by analyses in other countries (Pyšek *et al.*, 2002, 2012; Anačkov *et al.*, 2013), where a slightly different classification was used: annuals are the most common, followed by perennials and then others.

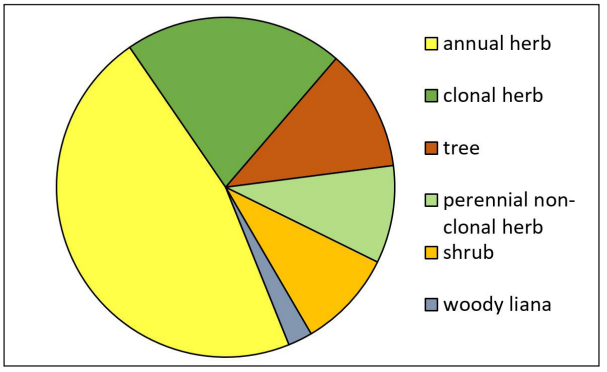

Fig. 4. The proportion of growth forms in the neophyte flora of Bedekovčina.

CSR life strategies

Grime CSR strategies are represented in the neophyte flora of Bedekovčina as follows: most species belong to competitors (42%), followed by a combination of compet-

itors and ruderals (28%), then ruderals (16%), while other combinations are less represented (Tab. 2). Almost the same ratio was found by Pyšek *et al.* (2002) in the neophyte flora of the Czech Republic. However, Vuković *et al.* (2014) analysed the CSR strategies of only invasive species in continental Croatia. The results showed the dominance of the CR strategy (42.2%), followed by competitors (33.3%) and ruderals (8.9%). A closer look at the CSR strategies of invasive species in the flora of Bedekovčina (Tab. 1) shows the same trend. Thus, most invasive plants have a different representation of CSR strategies than the overall neophyte flora. They have both the characteristics of good competitors and adaptation to disturbance. Competition enables the suppression of other species, and ruderality colonization of bare soil patches in habitats with various disturbances.

Tab. 2. Proportion of species with different Grime CSR life strategies in the neophyte flora of Bedekovčina. Abbreviations: C - competitors, R - ruderals, and S - stress tolerators.

Grime life strategy	Number of taxa	%
C	18	42
CR	12	28
CSR	2	5
R	7	16
R/CR	1	2
-	3	7

Reproduction and dispersal

According to the ratio of reproductive types in the Bedekovčina neophyte flora, all species reproduce to some extent by seeds, with 58% of species reproducing only by seeds, 30% by seeds and vegetatively, 9% mainly vegetatively and rarely by seeds, and 2% mostly by seeds and rarely vegetatively. Species that reproduce only by seeds belong mainly to therophytes and annual herbs. The seed dispersal strategy is predominantly autochory, with 53% of species having pure autochory, 19% of species having a combination of anemochory and autochory, etc. (Tab. 3).

Tab. 3. Proportion of different seed dispersal strategies in the neophyte flora of Bedekovčina.

Seed dispersal strategy	Number of taxa	%
Autochory	23	53
Anemochory / Autochory	8	19
Autochory / Endozoochory	6	14
Autochory /Epizoochory	1	2
Autochory / Hydrochory/ Anemochory	1	2
no dispersal	2	5
no data	2	5

Seeds play an important role in the spread of neophytes. A deep insight into the reproductive characteristics of invasive and non-invasive neophytes in the Czech Republic is given by Moravcová *et al.* (2010). They studied various seed traits and con-

cluded that invasive species produce a larger number of seeds, have lighter seeds, the seed shape is rounder than in non-invasive neophytes, and that such seeds have a better ability to disperse by wind. However, analysis of seed dispersal strategies in the Bedekovčina neophyte flora does not provide a clear explanation for the spread of alien species. In addition to autochory and anemochory, it is fairly certain that various anthropogenic activities, such as the transport of people and goods, play an important role in the spread of diaspores. This is often confirmed by the large number of specimens and species of neophytes along transport infrastructure.

Habitats

Neophytes were also analysed in terms of the vegetation groups in which they grow. Most species were found in ruderal (79%) and weed vegetation (30%), and considerably fewer in forest vegetation without (7%) and with (7%) the influence of floodwater, grassland vegetation (7%) and others (Fig. 5). A somewhat coarser analysis of habitat types by intensity of anthropogenic influence shows that most neophytes grow in anthropogenous habitats (91%), few in natural (21%), and very few in semi-natural habitats (7%). In both analyses, the sum of species exceeds 100% because some species were recorded in multiple vegetation groups and habitat types.

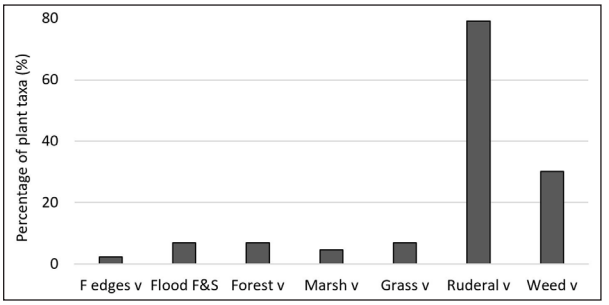

Fig. 5. Representation of the neophyte flora of Bedekovčina by vegetation groups. Some species grow in several different vegetation types and therefore have more than one vegetation group assigned. Abbreviations: F edges v - vegetation of forest edges, Flood F&S - floodplain forests and shrubs, Forest v – forest vegetation without the effects of floods, Marsh v - marsh vegetation, Grass v - wet and mesic grassland vegetation, Ruderal v - ruderal vegetation, Weed v - weed vegetation.

Pyšek *et al.* (2002) state that in the Czech Republic 62.8% of aliens are confined to man-made or anthropogenic habitats, 11.0% to natural or semi-natural habitats, and 26.2% occur in both types. According to Rabitsch & Essl, (2006) more than 90% of neophytes in Austria are confined to anthropogenic or naturally disturbed habitats. Also Anačkov *et al.* (2013) state that alien invasive species mainly occur in anthropogenic and semi-natural habitats.

In order to establish proper management and identify invasive species, it is important to know in which habitats neophytes grow. For this purpose, phytosociological research is very useful as it provides a set of detailed data collected with a method standardized in Europe and worldwide. This is confirmed by the extensive research conducted by Chytrý *et al.* (2005) in the Czech Republic, who used a phytosociological database to determine that most non-native species (archaeophytes and neophytes) grow in weed

and ruderal vegetation. This is consistent with the results of this work, but also with other studies (Rabitsch & Essl, 2006; Lambdon *et al.*, 2008; Anačkov *et al.*, 2013).

The problem is that in Croatia, with respect to many species of neophytes, very little is known about the plant communities in which they grow. I was confronted with this problem during the project development (Stančić, 2007). For most neophytes, there are general data on their occurrence in urban areas and ruderal habitats, but there are relatively few published phytocoenological relevés, i.e., detailed habitat data. There is an urgent need for targeted phytosociological and ecological research and monitoring of plant communities with alien species. Such data can provide useful guidance for selecting best management practices. For example, during the construction of the highway that passes south of Bedekovčina and was opened to traffic in early 2017, the roadsides were left bare after construction, which is very common everywhere. *Ambrosia artemisiifolia* developed very abundantly on these surfaces in the first two years. A simple measure that could be applied is sowing the grass mixture and mowing. Chytrý *et al.* (2005) state that open habitats are mainly invaded by non-native species if they are fertile.

As mentioned above, in the neophyte flora of Bedekovčina, the most species were found in ruderal and weed vegetation, with some species occurring in both vegetation types. These results indicate a significant anthropogenic influence in the study area, i.e. the presence of disturbance, which can be considered the main driver of the spread of neophytes. Disturbance can be defined as the removal and/or damage of vegetation cover, resulting in larger or smaller bare patches of soil suitable for neophyte colonization. In addition to disturbance, the presence of seeds or vegetative propagules is also required. Weed habitats are subject to predictable, frequent, regular, and large-scale disturbance by tillage (Lososová *et al.*, 2006). In contrast, ruderal habitats are exposed to multiple, unpredictable, and irregular disturbances that vary in spatial extent, usually with small patches of different plant communities and different successional stages (Lososová *et al.*, 2006). Ruderal vegetation develops mainly in urban and industrial areas: along transport infrastructure, in places where bare soils are created by construction works, filling with various materials (soil, compost, garbage, construction debris), the uncovering of bare surfaces by relocation of goods, areas treated with herbicides, trampled places, etc. In such areas, the movement of people and goods leads to the dispersal of seeds and vegetative propagules. The great heterogeneity of ruderal vegetation resulted in most neophyte species being detected in this habitat type. However, disturbances occur in both natural and semi-natural habitats and can be caused by human activities and natural phenomena. Natural phenomena that lead to the formation of bare soil surfaces are often found along watercourses where bank erosion occurs and where bare banks are revealed due to falling water levels during the warmer months. Other natural phenomena that cause disturbances include landslides, storms uprooting trees, animals destroying the soil surface (feral pigs, moles), etc. Human activities that most often lead to the disturbance are deforestation, regulation of watercourses, and mowing of meadows.

In the neophyte flora of Bedekovčina, relatively few species were identified in the natural vegetation, but they potentially pose a great threat, because they can displace the natural vegetation. In the forest vegetation without the influence of floods, *Robinia pseudoacacia* and *Ailanthus altissima* (Mill.) Swingle are found. In the floodplain forests and shrubs in the lowlands of the Krapina River *Echinocystis lobata*, *Helianthus tuberosus* L. and *Rudbeckia laciniata* L. are recorded. In the vegetation of forest edges *Impatiens*

balfourii Hook. f. was detected. In the composition of marsh vegetation *Bidens frondosa* L. and *Solidago gigantea* were found, but with low cover values. According to observations, the most common invasive plant species in the natural vegetation are *Robinia pseudoacacia* and *Echinocystis lobata*.

In the semi-natural vegetation of regularly mowed meadows, the following species were found: *Erigeron annuus*, *Solidago gigantea*, and *Medicago* × *varia*. They all have low cover values.

A threat to the native flora and vegetation of Bedekovčina comes mostly from invasive neophytes, which have a large distribution area and high cover values. These are *Solidago gigantea* and *Erigeron annuus*. Both species cover large areas around Bedekovčina. *Erigeron annuus* dominates on abandoned agricultural land in the early stages of succession, i.e. from the second to fourth year after the cessation of cultivation. *Solidago gigantea* covers the largest areas of all recorded neophytes and is the most invasive species. It dominates in the later stages of succession and develops in ruderal habitats along the railroad line, abandoned agricultural land and meadows.

It can be concluded that in the Bedkovčina area, the main introduction pathways of neophytes are roadsides, railroad station and railroad lines, inhabited and industrial areas, the river Krapina and its tributaries, agricultural land with annual crops and abandoned agricultural land.

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SAŽETAK

Neofiti u flori Bedekovčine (sjeverozapadna Hrvatska)

Z. Stančić

Na području Bedekovčine u sjeverozapadnoj Hrvatskoj (Hrvatsko zagorje, Krapinsko-zagorska županija) utvrđene su 43 vrste neofita. To čini 8,5 % od ukupne flore koja broji 507 svojti. Prema stupnju invazivnosti, 11 vrsta (25,6 % neofitske flore odnosno 2 % cjelokupne flore) pokazuje svojstvo invazivnog širenja i te vrste su s aspekta očuvanja bioraznolikosti najopasnije, 21 vrsta neofita je naturalizirana, a 11 vrsta su povremeni neofiti. Kao invazivne prepoznate su sljedeće vrste: *Amaranthus retroflexus* L., *Ambrosia artemisiifolia* L., *Echinocystis lobata* (Michx.) Torr. & A. Gray, *Erigeron annuus* (L.) Desf., *E. canadensis* L., *Galinsoga parviflora* Cav., *G. quadriradiata* Ruiz & Pav., *Oxalis corniculata* L., *Robinia pseudoacacia* L., *Solidago gigantea* Aiton i *Veronica persica* Poir. Status invazivnosti određen je na temelju lokalne abundancije, širenja i postojanosti populacija. Najveći broj neofita zabilježen je na staništima pod intenzivnim antropogenim utjecajem (39 vrsta) odnosno u sastavu ruderalne (34 vrste) i korovne vegetacije (13 vrsta). Na poluprirodnim staništima odnosno u sastavu travnjačke vegetacije zabilježene su samo tri vrste. Najviše su zabrinjavajuće vrste koje rastu u sastavu prirodne vegetacije šuma i šikara (6 vrsta), šumskih rubova (1 vrsta) i močvarne vegetacije (2 vrste). Najveće površine pokrivene su sastojinama zlatošipke (*Solidago gigantea*) koje se razvijaju na ruderalnim površinama, na nekadašnjim zapuštenim poljoprivrednim površinama i livadama u sastavu travnjačke i močvarne vegetacije. Analizom podrijetla neofitskih vrsta, najviše ih potječe iz Sjeverne Amerike (27 vrsta), Azije (11 vrsta) i Mediterana (6 vrsta). Prema procjeni, najviše vrsta je uneseno slučajno (86 %), a manji dio namjerno (14 %) i to su uglavnom vrste odbjegle iz kulture. Prema ostalim analiziranim svojstvima, među neofitima ima najviše terofita (21 vrsta), jednogodišnjih zeljastih biljaka (20 vrsta), biljaka koje prema Grimeovoj teoriji životnih strategija spadaju u kompetitore (18 vrsta), koje se razmnožavaju isključivo sjemenom (25 vrsta) i koje kao oblik rasprostranjivanja sjemena imaju autohoriju (23 vrste).