

Research Article

New alien vascular plants of Slovakia: records from 2008–2021

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Abstract

Monitoring the occurrence of new alien species among native flora is the first prerequisite for preventing their later invasive spread. During the last decade, we recorded data regarding 25 alien taxa new to Slovakia including 21 casual and 4 locally naturalised species, with ornamental plants predominating significantly. The locally naturalised species *Cenchrus flaccidus*, *Cotoneaster zabelii*, *Doronicum pardalianches* and *Panicum virgatum* are able to spread to native habitats and thus represent the greatest risk to native plant species in Slovakia.

Key words: adventive taxa, biodiversity, Central Europe, introduction, invasion status, neophyte, origin

Introduction

Alien plants represent one of the most serious threats to world plant diversity (Hulme 2007; Keller et al. 2011). Altogether, approximately 6000 alien taxa have been recorded in Europe (Lambdon et al. 2008), with ecological and economic impacts being documented for 1094 and 1347 species, respectively (Vilà et al. 2010). It has been established that half of alien neophytes arrived in Europe after 1899. An average of approximately 6.2 new species capable of naturalization arrive in Europe each year (Lambdon et al. 2008). Therefore, it is important to closely monitor and record the escape and spread of new alien species.

The world distribution of alien plants is relatively heterogeneous. The coasts of North America, Northwestern Europe, South Africa, South Eastern Australia, New Zealand, and India are considered hot spots of naturalised alien plants, while some other regions, such as South America or Northern Asia, are relatively less impacted by alien species (Pyšek et al. 2017). The diversity of alien plants in Europe exhibits a west-east gradient

with a decreasing trend towards the east. Due to its position, Slovakia belongs to countries that are moderately influenced by the presence of alien plants (Pyšek et al. 2009). However, our understanding of alien species diversity and future invasion risks might be enhanced by the dark diversity concept (Ronk et al. 2017), as we can assume that the number of species will be increasing in the near future (Pyšek et al. 2011).

Slovakia is a Central European country with mountainous regions in the north and flat terrain in the south (Vaškovský and Vaškovská 1981). The geomorphological, geological and climatic diversity of the country is also reflected in the richness of its flora: 3337 native taxa (species and subspecies, including hybrids and microspecies) were reported by Marhold et al. (2007), with 916 (21.5%) taxa categorised as alien and 33 species being of uncertain native/alien residence status (Medvecká et al. 2012). Historical and geographical factors, such as a location at the crossroads of the continent, many natural or human-created migration routes and the long-lasting human influence on the landscape, have led to the enrichment of Slovak flora by alien species. The survey of Slovak alien flora by Medvecká et al. (2012) noted 282 archaeophytes and 634 neophytes (6.6% and 14.9% of the total number of taxa, respectively). The massive development of trade and services after the fall of the Iron Curtain, together with the rise in living standards, caused this enrichment process to intensify considerably. For example, Májeková et al. (2021a) summarised information on 51 published alien taxa new to the Slovak flora, all recorded after 2012, and dozens more are mentioned in a paper by Ferus et al. (2020). A similar intensity of introductions of neophytes into the territory in the future and their further spread into ruderal, seminatural, and natural environments is expected (Májeková et al. 2021a). Therefore, the aim of our study was i) to supplement and update the knowledge of alien flora by incorporating new unpublished data accumulated in the last decade and ii) to analyse these taxa in terms of their family affiliation, invasion status, origin and the possibility of their threatening the diversity of the Slovak flora in the future.

Materials and methods

Floristic data were obtained from 2008 to 2021. Plant names are according to the Euro+Med Check List (<http://ww2.bgbm.org/EuroPlusMed/query.asp>). The taxa *Hylotelephium* 'Herbstfreude', *Panicum virgatum*, *Populus ×canadensis*, *Prunus incisa*, and *Salvia hispanica* are missing in the above database; therefore, we list them in accordance with Plants of the World Online (POWO 2022).

The sites of the findings are published in this order: the phytogeographical unit according to Futák (1980), the nearest settlement, a brief description of the habitat and population of the taxon, altitude, the mapping grid of Central European Basic Area (CEBA) described by Niklfeld (1971) (grid of

quadrants of 5×3 arc minutes corresponding to approximately 5.5×5.9 km), the locations of the findings by the geographical coordinates in the WGS-84 system, date and data on the collector/s. The method of finding documentation is given in parentheses. The abbreviation “not.” means that the taxon was evidenced neither by a herbarium specimen nor a photograph. Dot maps of the taxa with the highest number of sites are presented. The maps were designed using Corel Draw according to the grid mapping method described by Niklfeld (1971).

Phytosociological relevés documenting the habitat with the presence of selected species were sampled by Zürich-Montpellier’s approach using a modified Braun-Blanquet nine-degree scale (Barkman et al. 1964). The nomenclature of syntaxa follows Jarolímek and Šibík (2008). The acronyms of herbarium collections where vouchers sampled during field research are deposited, are given according to Thiers (2021).

Invasion status was evaluated in two categories: locally naturalised and casual. A locally naturalised alien is a taxon that reproduces and forms stable populations only in a small area, e.g., in a park habitat, and that does not spread from these primary spontaneous populations to the surrounding countryside (Májeková et al. 2021b). The term “casual alien” follows the definition of Richardson et al. (2000).

Results and discussion

Floristic research over the last decade (or 14 years) has generated data on 25 alien taxa new to Slovakia, including 21 casual and 4 locally naturalised species (Table 1, see also Supplementary material Table S1 for geo-referenced records of newly recorded species). Short descriptions of taxa and localities are listed below in alphabetical order.

Achillea filipendulina Lam. (Compositae)

Locality: Podunajská nížina Lowland, Bratislava-Staré Mesto, Hodžovo námestie square, crevices in the pavement and crevices on the edge of the road, around pots with ornamental plants (incl. *A. filipendulina*), approximately 15–30 juveniles to adult flowering plants escaped from cultivation; 156 m a.s.l., 7868d, 48°08'53"N; 17°06'26"E; 27 May 2020, 27 June 2020, 27 June 2021; P. Meredá Jr. (SAV, photo).

A species of Southwest and Central Asia occurs in the area from Turkish Anatolia through the Caucasus, Iran, and Afghanistan to Tajikistan and Kyrgyzstan (Liu et al. 2020). As an escape and alien, it has been found in Belgium, the Czech Republic, France, Germany, Great Britain, Italy, Poland, Spain, Ukraine, and the USA (Reynolds 2002; Sell and Murrell 2006; Verloove 2008, 2021a; Pyšek et al. 2012; Soriano 2014; Tison and Foucault 2014; Aymerich 2019; Bochumer Botanische Verein 2022). Although Kew (POWO 2022) mentions *A. filipendulina* as occurring in

Table 1. A list of newly recorded alien species in Slovakia from 2008–2021. Explanations: Habitat type: H – human-made, S – seminatural, N – natural. Life form: He – Hemicryptophyte, Hy – Hydrophyte, Ch – Chamaephyte, Ph – Phanerophyte, Th – Therophyte.

Taxon	Family	Invasion status	Phytogeographical region	Habitat type	Number of sites found	Life-form	Origin
<i>Achillea filipendulina</i>	Compositae	casual	Pannonicum	H	1	He	Asia
<i>Anemone hupehensis</i>	Ranunculaceae	casual	Pannonicum	H	1	He	Asia
<i>Baldellia ranunculoides</i>	Alismataceae	casual	Pannonicum	H	1	Hy	Atlantic and Mediterranean Europe, W Asia
<i>Calocedrus decurrens</i>	Cupressaceae	casual	Pannonicum	S	1	Ph	North America
<i>Cenchrus flaccidus</i>	Poaceae	locally naturalized	Pannonicum	H+N	2	He	Asia
<i>Centranthus ruber</i>	Valerianaceae	casual	Pannonicum	H	1	He	Mediterranean region
<i>Cotoneaster zabelii</i>	Rosaceae	locally naturalized	Pannonicum + Carpaticum	H+N	3	Ch	Asia
<i>Darmera peltata</i>	Saxifragaceae	casual	Carpaticum	H	1	He	North America
<i>Doronicum pardalianches</i>	Compositae	locally naturalized	Carpaticum	N	1	He	Europe
<i>Geranium macrorrhizum</i>	Geraniaceae	casual	Pannonicum	H	1	He	Europe
<i>Helleborus foetidus</i>	Ranunculaceae	casual	Carpaticum	H	1	He	Europe, N Africa
<i>Hylotelephium</i> 'Herbstfreude'	Crassulaceae	casual	Pannonicum + Carpaticum	H	3	He	Garden hybrid
<i>Jacobaea maritima</i> subsp. <i>maritima</i>	Compositae	casual	Pannonicum	H	2	He	W and central Mediterranean
<i>Kniphofia</i> × <i>praecox</i>	Xanthorrhoeaceae	casual	Pannonicum	S	1	He	Garden hybrid
<i>Ligularia dentata</i>	Compositae	casual	Carpaticum	N	1	He	SE Asia
<i>Panicum virgatum</i>	Poaceae	locally naturalized	Pannonicum	H	3	He	North America
<i>Perilla frutescens</i>	Lamiaceae	casual	Pannonicum	H	1	Th	Central and E Asia
<i>Prunus incisa</i>	Rosaceae	casual	Carpaticum	N	1	Ph	Japan
<i>Psilurus incurvus</i>	Poaceae	casual	Carpaticum	H	1	Th	N Africa, Europe, W and Central Asia
<i>Rodgersia podophylla</i>	Saxifragaceae	casual	Carpaticum	N	1	He	Central and SE Asia
<i>Salvia hispanica</i>	Lamiaceae	casual	Pannonicum	S	1	Th	Central America
<i>Soleirolia soleirolii</i>	Urticaceae	casual	Pannonicum	H	1	Ch	western Mediterranean islands
<i>Tetragonia tetragonoides</i>	Tetragoniaceae	casual	Pannonicum + Carpaticum	H	3	Th	the Far East, parts of Australia, New Zealand and some Pacific Islands
<i>Vincetoxicum rossicum</i>	Apocynaceae	casual	Pannonicum	S	2	He	European part of Russia and Ukraine
<i>Viola jooi</i>	Violaceae	casual	Pannonicum + Carpaticum	H	2	He	E and SE Europe

Poland, Romania and Ukraine, those data are not correct. There has been no confirmation that this species occurs in the wild in Poland. In the new checklist for Poland (Mirek et al. 2020), *A. filipendulina* is listed as a cultivated species. As far as Romania is concerned, the species probably appeared at an experimental site in Bacău in eastern Romania (Fălticeanu et al. 2008) but does not occur in the wild. In Ukraine (Mosyakin and Fedoronchuk 1999), it is resolved as uncertain in records from Transcarpathia (as introduced) and Crimea (as a native species). Any escape from cultivation is usually ephemeral, and these occurrences are rare but have recently increased (Verloove 2021a). According to Soriano (2014), the plant usually occurs near human settlements. However, the species has recently spread near roads and canal banks, on rough ground, by railway tracks and even on old walls in Belgium (Verloove 2021a). In Slovakia, it appeared for the first time in 2020 (Figure 1e). Because it is ornamental and planted in gardens or parks, we can expect its escape in other localities as well.

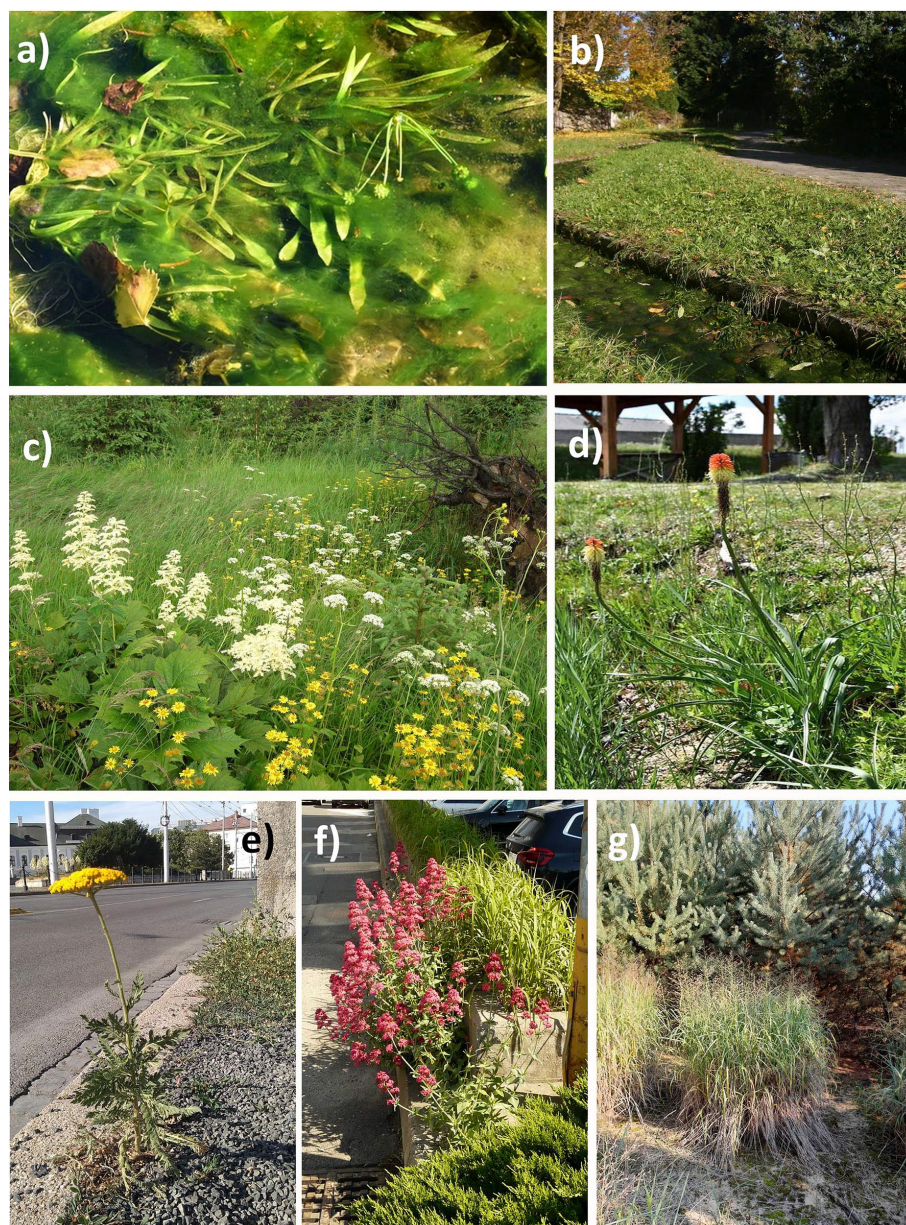


Figure 1. New alien species found in Slovakia: a) *Baldellia ranunculoides* (L.) Parl. plant (photo M. Dudáš), b) habitat of *Baldellia ranunculoides* (L.) Parl., small canal in the Botanical garden of Pavol Jozef Šafárik University, Košice (photo M. Dudáš), c) *Doronicum pardalianches* L. (yellow flowering plants) and *Rodgersia podophylla* A. Grey (white flowering plant on the left) at the railway station Pekná vyhládka between the villages Starý Smokovec and Horný Smokovec, Vysoké Tatry Mts (photo D. R. Letz), d) *Kniphofia xpraecox* Baker near a small pond in the southwestern margin of Ol'dza village (photo R. Hrivnák), e) *Achillea filipendulina* Lam. in crevices on the edge of the road in Hodžovo námestie square, Bratislava (photo P. Mered'a Jr.), f) *Centranthus ruber* (L.) DC. in crevices in the concrete at the foot of the pots and weedy pots, Rigeleho Street, Bratislava (photo P. Mered'a Jr.), g) *Panicum virgatum* L. tussock in abandoned sand pit near Borský Mikuláš (photo P. Eliáš Jr.).

***Anemone hupehensis* (Lemoine) Lemoine (Ranunculaceae)**

Locality: Košická kotlina Basin, Košice-Sever, Slovenského ulica Street, in a concrete slot on the edge of a path at the base of the wall in front of house No. 22; two adult plants with 3 flowering stems and one juvenile plant; 217 m a.s.l., 7293c, 48°44'08.46"N; 21°14'28.63"E; 12 August 2021; M. Dudáš (KO 36157).

Anemone hupehensis is a species native to Asia. It has been introduced as an ornamental plant and has sporadically escaped from cultivation (Wang et al. 2001). In Europe, it is considered an adventive species, particularly in Denmark, France, Germany and Sweden (Raab-Straube et al. 2014+). At the locality in Slovakia, the plants were repeatedly mowed. The origin of diaspores at this site was the front garden.

***Baldellia ranunculoides* (L.) Parl. (Alismataceae)**

Locality: Košická kotlina Basin, Košice, Botanical garden of Pavol Jozef Šafárik University, small canal between lakes with flowing water; 227 m a.s.l., 7293c, 48°44'03.35"N; 21°14'14.15"E; 8 October 2021; R. Hrivnák, R. Gregorek and M. Dudáš (SAV, KO 36400).

Baldellia ranunculoides is a taxonomically problematic aquatic plant with two/three taxa identified at the subspecies level (Kozłowski et al. 2008; Kozłowski and Matthies 2009). The species is native to an Atlantic and west Mediterranean European distribution range (Kozłowski et al. 2008; Kozłowski and Matthies 2009). Hussner (2012) presented the species as an alien aquatic plant of Europe, with a nonnative distribution in Portugal; however, these data are mistaken because the species is native here (Uotila 2009; Talavera et al. 2010). *B. ranunculoides* is also known as a nonnative species in North America (https://explorer.natureserve.org/Taxon/ELEMENT_GLOBAL.2.150083/Baldellia_ranunculoides) and New Zealand (Champion and Clayton 2000).

Our new Slovak locality of *Baldellia ranunculoides* was recorded in a small canal with flowing water, an alkaline water reaction (pH 8.8) and a relatively high conductivity (1095 µS/cm). Fewer than 20 plants, both sterile and fertile individuals, were distributed in several places in the canal in 2021; sterile plants were recorded in 2020 for the first time (Figure 1a, b). The source population for dissemination of the plants was planted in the Botanical garden 5 years ago in a lower small artificial pond, which is connected with an upper pond by a canal network with circulating water in a closed system. Seeds are distributed in the canal network by hydrochory.

***Calocedrus decurrens* (Torr.) Florin (Cupressaceae)**

Locality: Devínska Kobyla Hills, Bratislava-Karlova Ves, Ilkovičova Street, on the edge of a deciduous grove 135 m south of the building of the Faculty of Electrical Engineering and Informatics, Comenius University, 1 sterile ca. 1 m tall individual; 176 m a.s.l., 7868a, 48°09'02"N; 17°04'24"E; 8 April 2021, 1 April 2022; P. Meredá Jr. (SAV, photo).

Evergreen large tree native to North America and cultivated as an ornamental in Europe (Benčať 1982; Thieret 1993). It is mentioned in the List of Species Alien in Europe and to Europe (Anonymous 2009), but data on its escape from culture are missing (Roy et al. 2020), although Galasso

et al. (2019) recorded it as casual in Italy, as did Király and Takács (2020) in Hungary. In Slovakia, Ferus et al. (2020) mentioned dozens of seedlings of the species spreading in the area of the Arboretum Mlyňany (SW Slovakia) in 2018; however, they do not provide any data on their survival. Therefore, our data were likely the first clear evidence of an escape of *C. decurrens* from cultivation in Central Europe. We considered the occurrence in Slovakia to be temporary.

***Cenchrus flaccidus* (Griseb.) Morrone (Poaceae)**

Locality 1: Podunajská nížina Lowland, Imeľ, sandy dunes approximately 1.5 km SE from the village, dozens of fertile individuals in an illegal landfill for garden waste; 112 m a.s.l., 8174b, 47°53'46.9"N; 18°09'49.1"E; 22 September 2016; P. Eliáš Jr. (NI and relevé 1); 28 October 2021; P. Eliáš Jr. (NI, photo).

Locality 2: Devínska Kobyla Hills, Bratislava-Karlova Ves, Dúbravská cesta Street, campus of the Slovak Academy of Sciences, Institute of Botany, ornamental flower bed at the wall of the building at the entrance to the institute, several fertile individuals scattered in an ornamental flowerbed 5–25 m from the cultivated mother bunch in the adjacent lawn; self-seeded individuals found even in the dry lawn around the cultivated mother bunch; 195 m a.s.l., 7868a, 48°10'22"N; 17°03'59"E; 12 September 2017; G. Király (herb. Király); 27 September 2020 and 9 October 2020; P. Meredá Jr. (SAV, photo).

Cenchrus flaccidus (syn. *Pennisetum flaccidum* Griseb.) is a perennial plant with tough spreading rhizomes native to Afghanistan, Bhutan, NW India, Kashmir, Nepal, Pakistan, Tajikistan, and Iran. It occupies hillsides, field margins, and roadsides, especially on dry sandy soils (Chen and Phillips 2006). In Europe, the species is often planted as an ornamental grass, and the first data on its spontaneous spread did not begin to appear until the new millennium in Belgium (Verloove 2006), Germany (Valdés and Scholz 2009) and Poland (Szczesniak 2011). The species is frost and drought resistant and easily spreads clonally; therefore, future invasive behaviour is likely in Poland (Szczesniak 2011). This was also confirmed by our data from the locality near the village of Imeľ, where the area inhabited by this species has tripled in 5 years. As *C. flaccidus* survives for a relatively long time in localities in Slovakia (Figure 2) and is spreading, we proposed to include it among the group of locally naturalised neophytes in Slovakia. The stand at Imeľ originally belonging to the vegetation of the *Festucion vaginatae* alliance is characterised by the following relevé:

Relevé 1. E₁ 95%, 16 m², elev. –, exp. –.

E₁: ***Cenchrus flaccidus* 5**, *Gypsophila paniculata* +, *Robinia pseudoacacia* juv. +, *Lactuca serriola* r.

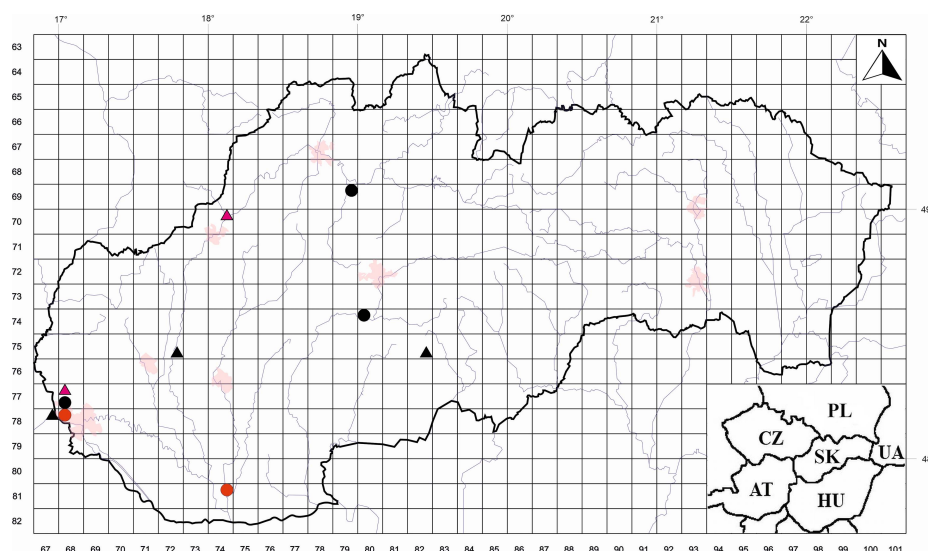


Figure 2. Distribution of the newly recorded alien taxa in Slovakia: black circles – *Hylotelephium* ‘Herbstfreude’, red circles – *Cenchrus flaccidus*, red triangles – *Viola jooi*, black triangles – *Tetragonia tetragonoides* (for details see Supplementary material Table S1).

Centranthus ruber (L.) DC. (Valerianaceae)

Locality: Podunajská nížina Lowland, Bratislava-Staré Mesto, Rigeleho Street, crevices at the side of the road, crevices in the concrete at the foot of the pots and weedy pots at the Hotel Devín, in a section of approximately 30 m, approximately 15 juvenile to adult flowering individuals; 139 m a.s.l., 7868d, 48°08'24"N; 17°06'23"E; 23 April 2021, 11 May 2021, 26 May 2021; P. Mereda Jr. (SAV, photo).

The species is native to the Mediterranean region, where it grows on rocky places and walls (Tutin et al. 1976; Holub and Kirschner 1997). This xerothermophilous, undemanding, frost-resistant perennial is a very popular ornamental plant with red, rose and (rarely) white flowers. It is cultivated in many countries and is often naturalised. It is sold in pots as juveniles in several varieties and is able to spread itself through seeds. In the Czech Republic and Hungary, the species is evaluated as a casual neophyte with the first occurrence in the wild in 1800 in Czechia (Balogh et al. 2004; Pyšek et al. 2012; Király and Király 2018). Spontaneous occurrences within Europe are also known from Austria, Germany, Great Britain, and the Netherlands (Denters 1998; Essl and Rabitsch 2002; Hill et al. 2002; Tofts 2004; Shimwell 2009; Brandes 2014; Smettan 2016; Hohla 2018), while in Great Britain, it is naturalised and invasive in some places (Stace and Crawley 2015). Typical habitats in the secondary area are walls, fortifications, crevices, rocks, and cliffs, similar to its natural habitats (Swierkosz 2012; Brandes 2020). Lambdon et al. (2008) included *C. ruber* among the 150 most widespread alien plant species in Europe. The species is also adventive in Argentina (Delucchi 2013) and naturalised with invasive potential in South Africa (Holmes et al. 2018).

The occurrence in Bratislava probably comes from ornamental plantings (Figure 1f), but in 2021, no cultivated individuals were present at the locality. Based on Google Street View images, the flowering spontaneous individuals were already present at the locality in June 2019, but even then, there were no cultivated individuals. The species must have been cultivated there in 2018 or earlier, with spontaneous individuals appearing later. The species is cultivated in several places in the city centre; therefore, other allochthonous occurrences can be expected in Bratislava in the future.

***Cotoneaster zabelii* C. K. Schneid. (Rosaceae)**

Locality 1: Malé Karpaty Mts, Bratislava-Nové Mesto, Kramársky les Forest, in a young light oak stand north of the area of the National Institute of Heart and Vascular Diseases; approximately 20 mature individuals scattered in the forest; approximately 265 m a.s.l., 7868b, 48°10'17.65"N; 17°05'10.77"E; 14 November 2020, 9 May 2021, 5 June 2021, 8 October 2021; D. R. Letz (SAV, photo).

Locality 2: Devínska Kobyla Hills, Bratislava-Devín, Hadia cesta Street, in an edge of oak forest, approximately 5 mature individuals; approximately 193 m a.s.l., 7867b, 48°10'46.2"N; 16°59'07.00"E; 10 September 2020; P. Eliáš Jr. (NI).

Locality 3: Malé Karpaty Mts, Bratislava-Staré Mesto, Na Kalvárii Street, in the hedge of *Ligustrum ovalifolium* at the edge of the parish courtyard, 1 low, approximately 5 years old individual; approximately 230 m a.s.l., 7868b, 48°09'28.31"N; 17°06'00.04"E; 10 September 2021, 9 April 2022; D. R. Letz (photo).

A shrub up to 3 m tall, with leaves tomentose on the underside, native to central China, grows in calcareous mountain regions, shaded slopes, river valleys, and thickets (Lingdi and Brach 2003). It is occasionally planted as an ornamental plant in Europe. The species is naturalised in the British Isles (Stace 2019) and is also listed as alien in Germany (John and Frank 2008), Czechia (Danihelka et al. 2012, Pladias database) and Hungary (Somlyay and Sennikov 2012), but it has not yet been included in the Euro+Med PlantBase (Sennikov 2009). According to Dickoré and Kasperek (2010), *C. zabelii* might have the potential to naturalise in the drier and warmer parts of Central Europe. In Slovakia, the spreading around city of Bratislava was found (Figure 3). The population found in Bratislava-Nové Mesto consists of approximately 20 individuals of different ages, including flowering and fruiting individuals. Populations in Devín village and Bratislava-Staré Mesto are smaller, but here all individuals produced fruits. However, there is an unsolved and sometimes controversial taxonomic problem associated with the separation of the similar species *C. fangianus* T.T. Yu, which is rarely straightforward, and identification keys in standard floras are often conflicting (Verloove 2022a). The taxonomic affiliation of the plants identified as *C. zabelii* is therefore not fully resolved here.

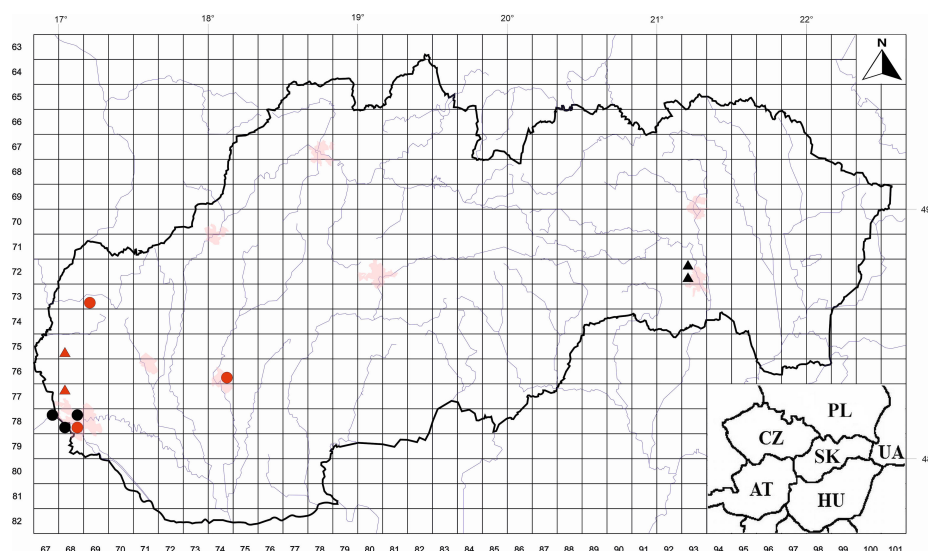


Figure 3. Distribution of the newly recorded alien taxa in Slovakia: black circles – *Cotoneaster zabelii*, red circles – *Panicum virgatum*, red triangles – *Jacobea maritima* subsp. *maritima*, black triangles – *Vincetoxicum rossicum* (for details see Supplementary material Table S1).

***Darmera peltata* (Benth.) Voss (Saxifragaceae)**

Locality: Turčianska kotlina Basin, Martin-Košúty, small lake, near the brook Jordán, approximately 5 juvenile to adult sterile individuals; 386 m a.s.l., 6979b, 49°05'16.3"N; 18°56'24.6"E; 14 September 2021; K. Hegedúšová (photo).

The species is a slowly spreading rhizomatous perennial native to mountain woodland stream sides in the western part of North America (mostly California, Oregon, Utah) (Fortson Wells and Elvander 2009). In Europe, it is most often cultivated in botanical gardens as an ornamental species. *Darmera peltata* was introduced into cultivation in Britain in 1873 and is known to occur in the wild by approximately 1920. According to Reynolds (2002), it may be spreading in some suitable areas along rivers, streams or lakes. It has also been recorded as an escape and alien in Belgium, the Czech Republic, France, Great Britain and Ireland (Král et al. 2004; Pyšek et al. 2012; Verloove 2021b; POWO 2022).

This was the first observation of spreading *D. peltata* that has been made in Slovakia, where it probably escaped from a garden. The mother plant was large, with a height of approximately 80–100 cm. It is very vital, and during two years of observation, it spread along the shore of the lake to four other places approximately 20 m away from the mother plant, displacing the original riparian vegetation. Because the locality is very close to the stream, we expect further spreading of the plant.

***Doronicum pardalianches* L. (Compositae)**

Locality: Vysoké Tatry Mts, between the villages Starý Smokovec and Horný Smokovec, at the railway station Pekná vyhládka, overgrown area after uprooting of spruce trees under the railway, approximately 200 flowering individuals; 962 m a.s.l., 6887c, 49°08'22.25"N; 20°14'04.10"E; 18 June 2011, 23 June 2013, 24 July 2014, 17 August 2016; D. R. Letz (SAV, photo).

This rhizomatous perennial is native to Western Europe, where it was originally distributed from Spain east to Italy, Switzerland and Germany; it also occurs as a naturalised alien in the British Isles, Belgium, Denmark and Sweden (Greuter 2006+). It is considered a probably nonnative species in Austria, naturalised especially in the eastern part of the Leitha Mts (Fischer et al. 2008). In Czechia, it is a casual neophyte, although persisting longer in some places (Kaplan 2019), while in Hungary, it is considered rare casual (Balogh et al. 2004). In both native and secondary distribution areas, it mainly inhabits woods, moist forest openings, ravines and disturbed places and secondarily parks. It is cultivated as an ornamental and medicinal plant and occasionally escapes. The population discovered in the foothills of the Vysoké Tatry Mts has persisted in the place for more than a decade and is gradually increasing thanks to its spread by underground runners. This species, very rarely cultivated in Slovakia, was brought here most likely in garden waste; this could correspond to the finding of other escaped species in the same locality (see *Ligularia dentata* and *Rodgersia podophylla*). The garden waste or soil containing some plant material (living rhizomes, seeds) could have been deposited in places disrupted after the wind disaster on November 19th, 2004, which caused a massive uprooting of spruce trees in this locality, where these species found suitable conditions for their further spontaneous growth. *D. pardalianches* has proven to be the most vigorous among them, with strong potential to persist there for a longer period and with a presumed possibility of further dispersal (Figure 1c).

***Geranium macrorrhizum* L. (Geraniaceae)**

Locality: Devínska Kobyla Hills, Bratislava-Karlova Ves, Slávičie údolie cemetery, dozens of sterile individuals escaped from planting; 205 m a.s.l., 7868a, 48°09'21"N; 17°03'59"E; 16 September 2020; R. Hrivnák, J. Májeková, T. Čejka (SAV); 28 February 2022; J. Májeková (photo).

The species is native to southern Europe and grows on rocky and stony slopes and in bushes and forests, mostly on limestone. It is often grown as an ornamental or medicinal perennial in gardens and parks as a groundcover, propagated by seeds and rhizomes (Slavík 1997). The plant is commonly available for sale in pots as juveniles in different varieties. The species occasionally also occurs spontaneously, e.g., in Austria (Hohla 2006, 2018; Reich et al. 2019; Sauberer et al. 2020), Germany (Smettan 2016; Wünsche et al. 2019), Finland (Lampinen et al. 2015) and Turkey (Öner et al. 2010). In the Czech Republic (Pyšek et al. 2012) and Great Britain (Stace and Crawley 2015), the species is considered a naturalised neophyte, and in Hungary, it is considered a rare casual neophyte (Balogh et al. 2004; Dudáš et al. 2020). *Geranium macrorrhizum* was cultivated in several places in the studied cemetery in Bratislava and spontaneously spread within abandoned graves but rarely grew in paths among the graves.

***Helleborus foetidus* L. (Ranunculaceae)**

Locality: Malé Karpaty Mts, Bratislava-Staré Mesto, between the streets Hlboká cesta and Na Kalvárii No. 2, sparse spontaneous young forest stand of *Acer platanoides* on the slope below the embankment with a small parking space next to the Lourdes grotto area; 222 m a.s.l., 7868b, 48°09'25.98"N; 17°05'59.93"E; 17 October 2017 (2 individuals); D. R. Letz (not.); 3 February 2022 (6 individuals); D. R. Letz (SAV, photo).

This perennial with an overwintering leafy stem has a native range in western Europe and northwestern Africa from Morocco and the Iberian Peninsula east to Italy, Switzerland and Germany (Raab-Straube et al. 2014+), while in the British Isles, it is considered only “possibly native” (Stace 2019). In Denmark and Sweden, it is reported as a naturalised alien; in Slovenia, it has also been recorded as alien; and in the Czech Republic and Hungary, it is recorded as casually escaping (Balogh et al. 2004; Pyšek et al. 2012). In Austria, it is locally naturalised in the Wiener Wald Mts (Fischer et al. 2008). In its native range, it mainly grows in wood and scrub on calcareous soils. It is cultivated as an ornamental perennial flowering in early spring and previously as a medicinal plant. In Slovakia, *H. purpurascens* is the only native species of the genus, a typical element of the eastern Carpathian flora occurring in the eastern part of the country only. The species of the Alps *H. niger* is cultivated quite often and has already been found to have escaped in Slovakia, unlike *H. foetidus*, which is cultivated very rarely there. The finding reported here is an escape of plants cultivated in nearby gardens caused by seed dispersal or from garden waste containing living plants. Near the found micropopulation one older, a larger clump was also found on an overgrown slope of the Lourdes grotto area (a former quarry). It is not clear whether this was planted here or whether it also grew there as an escape. It is possible that this particular clump was the source of the seeds from which the younger plants grew not far from this older individual. Initially, only 2 individuals were found, and after 5 years, 6 individuals had appeared. Over time, the micropopulation has shown a tendency to increase in abundance.

***Hylotelephium* ‘Herbstfreude’ [*H. spectabile* (Boreau) H. Ohba × *H. telephium* (L.) H. Ohba] (Crassulaceae)**

Locality 1: Zvolenská kotlina Basin, between the towns Zvolen and Sliač, an overgrown small illegal dump of construction and garden waste at a field road; 1 adult flowering plant; 290 m a.s.l., 7480a, 48°35'56.33"N; 19°07'04.05"E; 30 September 2012, 1 September 2016; D. R. Letz (photo).

Locality 2: Záhorská nížina Lowland, Bratislava-Devínska Nová Ves, city part of Bory, northerly of the Metro store, ground dump; 4 flowering tussocks; 155 m a.s.l., 7768c, 48°12'50"N; 17°00'52"E; 24 November 2020; P. Meredá Jr. (SAV, photo).

Locality 3: Turčianska kotlina Basin, Martin-Košúty, behind the residential area, under the abandoned old cemetery “Atilov hrob”; flowering plants in several places, probably extended from a nearby gardening settlement; 388 m a.s.l., 6979b, 49°05′16.4″N; 18°56′32.0″E; 28 September 2021; K. Hegedúšová (not.).

Approximately 33 species of the genus *Hylotelephium* are native to temperate areas of Eurasia and North America (Fu et al. 2001). *Hylotelephium* ‘Herbstfreude’ (also known as “Autumn Joy”) has a garden (hybrid) origin appearing in Europe in 1955 (Stephenson 2009). The taxon is a drought-tolerant, clump-forming herbaceous perennial. Although it is one of the most frequently grown members of the genus with a wide distribution in parks and gardens, it is not mentioned in many countries (e.g., Germany – cf. Jäger et al. 2007) and is often confused with one of the parent species (*H. telephium* or *H. spectabile*). Correctly distinguished, it has been reported to have grown and escaped in the British Isles (Stace 2019). The species is planted across Serbia as an ornamental and medicinal plant (Stojanović et al. 2014). In contrast to its parent species, this hybrid is sterile, as its flowers have no male parts (i.e., no stamens or anthers), and it can escape only from thrown rhizomes (International Crassulaceae Network 2022). In Slovakia, it mostly grows on dumps of garden waste, and its further spreading by rhizomes is probable (Figure 2). Occurrence can be expected in other locations of Slovakia near the gardens where it is planted.

***Jacobaea maritima* (L.) Pelsner et Meijden subsp. *maritima* (Compositae)**

Locality 1: Záhorská nížina Lowland, Malacky, the Starý cintorín cemetery; ca. 3 juvenile (this year's) individuals escaped from cultivation; 159 m a.s.l., 7568c, 48°26′32″N; 17°00′48″E; 10 May 2021; J. Májeková (SAV).

Locality 2: Záhorská nížina Lowland, Stupava, Hlavná ulica Street, opposite the castle, crevices in the pavement and the crevice between the pavement and the concrete flower pot with planted individuals; 8 juvenile (this year's) individuals with the height 5–15 cm; 181 m a.s.l., 7768a, 48°16′25″N; 17°01′54″E; 9 July 2021, 16 December 2021, 20 February 2022; P. Meredá Jr. (SAV, photo).

Jacobaea maritima [syn. *Cineraria maritima* (L.) L., *Senecio cineraria* DC., *S. bicolour* subsp. *cineraria* (DC.) Chater, *S. maritimus* (L.) Rchb., nom. illeg.] is a perennial species native to western and central Mediterranean regions, where it inhabits coastal cliffs and rocks or walls, e.g., of old fortifications (Brandes 1992, 2020; Peruzzi et al. 2006). It is often cultivated as an ornamental plant for its silvery habitus and yellow inflorescences in many countries and occasionally escapes from cultivation. In the British Isles, it has been cultivated and naturalised for decades (Dunn 1905; Perring and Walters 1962). Spontaneous occurrence has also been seen in Belgium (Verloove 2001), while in Greece and Hungary, it is considered a

casual neophyte (Balogh et al. 2004; Arianoutsou et al. 2010). The species belongs to a complicated taxonomic complex of 8 closely related taxa treated as species or subspecies (Peruzzi et al. 2006; Passalacqua et al. 2008). Therefore, some of the abovementioned published data from the past may also relate to other taxa of *J. maritima* agg.

Our findings are the first known records of spontaneous occurrence of the taxon in Slovakia (Figure 3), but as the species is commonly commercially available as seeds or young plants, cases of escaping can be expected to increase, especially in warm parts of the country. In Central European conditions, *J. maritima* plants sometimes do not survive the winter even when cultivated and have to be sown again every year, so we do not expect its massive introduction to the natural or seminatural habitats in Slovakia.

***Kniphofia ×praecox* Baker (Xanthorrhoeaceae)**

Locality: Podunajská nížina Lowland, Oldza, small pond in the southwestern margin of the village; several flowering and sterile individuals; 113 m a.s.l., 7970b, 48°05'09.73"N; 17°25'04.46"E; 23 June 2020; R. Hrivnák (photo).

Kniphofia taxa are native to Africa and occur as alien plants in North America, Central and South America, Western and North-Western Europe and Turkey, Australia, New Zealand, and occasionally in Asia (China) and some islands in the Atlantic, Indian and Pacific oceans (<https://www.gbif.org/species/5305033>). In Europe, several taxa (e.g., *K. ulvaria*) as well as hybrids of mixed or uncertain parentage are frequently planted as ornamental plants. We determined our plants to be *K. ×praecox* according to Jäger et al. (2007). This taxon was reported in Europe as alien in Belgium and the British Isles (Stace 2019; Verloove 2022b). Fewer than 10 individuals (flowering as well as sterile) grew on the gravel bank of the small urban pond (Figure 1d), and their origin is not clear.

***Ligularia dentata* (A. Gray) Hara (Compositae)**

Locality: Vysoké Tatry Mts, between the villages Starý Smokovec and Horný Smokovec, at the railway station named Pekná vyhládka, overgrown area after uprooting of spruce trees under the railway; single individual; 962 m a.s.l., 6887c, 49°08'22.25"N; 20°14'00.11"E; 23 June 2013, 17 August 2016; D. R. Letz (not.).

Ligularia dentata is a perennial herb. It occurs naturally in China, Japan, Myanmar and Vietnam (Liu and Illarionova 2011). A secondary occurrence has been found in North America, as well as in several European countries (Belgium, England, Germany, and Sweden), as a result of escapes from ornamental plantations (Stace 2019; Verloove 2021c).

The origin of *L. dentata* at the Slovak locality may be associated with the windstorm of November 19th 2004 (see *Doronicum pardalianches*), which disrupted the original spruce forest (suitable places were opened for attachment) and at the same time likely brought diaspores from the surroundings to the site.

***Panicum virgatum* L. (Poaceae)**

Locality 1: Záhorská nížina Lowland, Borský Mikuláš, abandoned sand pit W of the village; approximately 30 mature individuals; 200 m a.s.l., 7369c, 48°37'41.5"N; 17°11'18.9"E; 16 October 2013; P. Eliáš Jr., D. Dítě, Z. Dítě (NI, photo); 23 September 2021, P. Eliáš Jr. (NI, photo, relevé 2).

Locality 2: Podunajská nížina Lowland, Nitra, garden waste deposit in old barrack area; 2 tussocks; 190 m a.s.l., 7674d, 48°19'23.1"N; 18°06'11.5"E; 20 July 2017; L. Ďurišová (NI).

Locality 3: Podunajská nížina Lowland, Bratislava-Staré Mesto, Palackého ulica Street, cracks at the foot of the wall in front of the primary school; several flowering individuals; 140 m a.s.l., 7868d, 48°08'30.6"N; 17°06'41"E; 31 August 2021; J. Májeková (SAV, photo).

Panicum virgatum is a perennial bunchgrass native to North America, where it occurs naturally up to 55°N latitude from Saskatchewan to Nova Scotia, Canada, south over most of the United States east of the Rocky Mountains and further south into Mexico (Freckmann and Lelong 2003; Vogel 2004; Triplett et al. 2012). It is a dominant species of the tallgrass prairie, woodland, and riparian areas (Uchytíl 1993). The species is cultivated as an energy crop in North America (Parrish et al. 2012) and is increasingly planted as an ornamental plant in Europe (Verloove 2021d). Escaping from cultivation is rarely reported in Europe, but data from Austria, Belgium, England, Germany, Switzerland, the Czech Republic, Hungary, and Russia have recently been published (Verloove 2006; Hohla 2011; Chytrý and Danihelka 2015; Csiky et al. 2018; Gilli et al. 2020). Since 2013, three sites have been recorded in Slovakia (Figure 3), all related to the escape of the species from cultivation and via disposal of horticultural waste. At the site near Borský Mikuláš (Figure 1g), the species has survived in the *Koelerion arenariae* vegetation for almost 10 years (see relevé 2), so we propose to include it among the locally naturalised alien species of the Slovak flora.

Relevé 2. E₁ 40%, E₀ 60%, 16 m², elev. 10°, exp. SSW.

E₁: ***Panicum virgatum* 3**, *Calamagrostis epigejos* 1, *Erigeron canadensis* +, *Plantago arenaria* +, *Rumex acetosella* +, *Viola tricolor* +, *Festuca psammophila* subsp. *dominii* r.

***Perilla frutescens* (L.) Britton (Lamiaceae)**

Locality: Podunajská nížina Lowland, Nitra, ruderal vegetation in the city park Sihot; several flowering plants; 141 m a.s.l., 7674c, 48°18'51.15"N; 18°04'45.63"E; 13 July 2016; L. Bakay (not., relevé 3).

Perilla frutescens (syn. *Ocimum frutescens* L., *Perilla ocimoides* L.) is distributed in the Himalayan region of India and Nepal and the northern part of Southeast Asia, China, Korea, Japan and Taiwan. The centre of diversity of the species is midstream and downstream of the Changjiang

(Yangtze) River (Nitta et al. 2003). It is also a common annual weed of the eastern United States but is considered a commercial crop in Asia (Brenner 1993). In the US, *P. frutescens* grows along roadsides, ditches, forest margins, and hillsides. It spreads to natural areas, especially disturbed areas. It can disrupt native ecosystems by outcompeting native plants. It is ordinarily avoided by cattle and has been implicated in cattle poisoning. Beefsteak plants are most toxic if cut and dried for hay late in the summer, during seed production (Swearingen and Barger 2016).

At the locality in Nitra, we found plants in the city park next to the gardens of the Faculty of Horticulture and Landscape Engineering. The flowerbeds of the garden contained several plants of *P. frutescens* var. *crispa* f. *discolor*, which spontaneously spread into the nearby park. The stand of class *Artemisietea vulgaris* is characterised by the following phytosociological relevé:

Relevé 3. E₁ 30%, 9 m², elev. –, exp. –.

E₁: *Stellaria media* 2b, *Acer platanoides* juv. 1, *Urtica dioica* +, ***Perilla frutescens*** +.

***Prunus incisa* Thunb. (Rosaceae)**

Locality: Nízke Tatry Mts, Svit, SE from the village, xerophyllous pine forest; single mature individual (cultivar was not identified); 720 m a.s.l., 6987a, 49°03'10.42"N; 20°13'09.80"E; 10 May 2016; L. Bakay (not., relevé 4).

Prunus incisa [syn. *Cerasus incisa* (Thunb.) Mill.] is endemic to southern Japan (Kato and Ebihara 2011). It is widely distributed as an ornamental plant with several cultivars ('February pink', 'Kojo-no-mai', 'Mikinori', 'Moerheimii', 'Omoinoyama', 'Oshidori', 'Praecox', 'The bride' and 'Yamadei' etc.) (Fitschen 2007). The species is reported as alien in the British Isles (Fitter and Peat 1994); however, data on its escape from cultivation are lacking in continental Europe (Kurtto 2009).

We contended that the origin of *P. incisa* in this Slovak locality is associated with the planting of ornamental trees in the nearby park, probably via seed transfer by birds (endozoochory). In this park, we found one adult plant of *Prunus incisa* "Kojo-no-mai". The character of the vegetation of the class *Vaccinio-Piceetea* is given in the following relevé:

Relevé 4. E₃ 85%, E₂ 15%, E₁ 10%, 20 m², elev. –, exp. –.

E₃: *Pinus sylvestris* 4, *Picea abies* 2b, *Sorbus aucuparia* +.

E₂: *Cotoneaster melanocarpus* agg. 2a, *Lonicera xylosteum* 2a, *Vaccinium myrtillus* 1, ***Prunus incisa*** +.

E₁: *Brachypodium pinnatum* 1, *Luzula luzuloides* 1, *Carlina acaulis* +.

***Psilurus incurvus* (Gouan) Schinz & Thell. (Poaceae)**

Locality: Vtáčnik Mts, Prievidza, the main railway station, firm gravel embankment between the rails; two fertile clumps; 264 m a.s.l., 7277b,

48°46'33"N; 18°37'04"E; 21 May 2021; leg. and det. I. Svitková, rev. P. Meredá Jr. (SAV).

This ephemeral annual grass was classified into the monotypic genus *Psilurus* Trin. but is currently included in the genus *Festuca* [as *Festuca incurva* (Gouan) Gutermann] (Torrecilla et al. 2004; Pignatti et al. 2017). The species is native to Mediterranean Europe (including Crimea), Northern Africa and Western and Central Asia (POWO 2022). In some areas of its native range, the species is considered near-threatened (e.g., Argenti et al. 2016). It was introduced to northern Italy (Engelmaier and Wilhelm 2018) and southern Australia, where it has naturalised (<https://id.biodiversity.org.au/tree/51684092/51291444>). As a casual species, it occurs in Great Britain and Germany (Valdés and Scholz 2009). The closest native localities to Slovakia are in Slovenia (Jogan 1997). Except for Germany, the species has not been previously found elsewhere in Central Europe.

In natural habitats, *Psilurus incurvus* thrives in open dry grasslands on sandy to stony and shallow soils. It forms erect to curved culms growing up to 40 cm with filiform leaf blades and several slender spikes with inconspicuous remote spikelets (Watson et al. 1992). In the Slovak locality, two fertile clumps were found between train rails growing on a firm gravel embankment. The origin of these individuals is unknown. Since the species is not of economic importance or grown as an ornamental plant, the most likely reason for its occurrence is unintentional, human-aided dispersal. Due to the geographical position of the locality (Central Slovakia) and the fact that there are no other records in surrounding countries, we assume that the species might be already more common but overlooked because of its inconspicuous habitus.

***Rodgersia podophylla* A. Gray (Saxifragaceae)**

Locality: Vysoké Tatry Mts, between the villages Starý Smokovec and Horný Smokovec, at the railway station Pecná vyhládka, overgrown area after uprooting of spruce trees under the railway; several fertile plants; 962 m a.s.l., 6887c, 49°08'22.25"N; 20°14'04.10"E; 23 June 2013, 17 August 2016; D. R. Letz (not.).

Rodgersia podophylla (syn. *R. japonica* A. Gray ex Regel) is a member of the small genus native to Central and SE Asia. The species occupies forests, forest margins, scrub, meadows and rock clefts in China, Korea and Japan (Jintang and Cullen 2001). In Europe, it is relatively often cultivated and escaping and has been reported in Scandinavia (Karlsson 1997), Ireland (Reynolds 2002), the Czech Republic (Faiferlík 2004; Lustyk and Doležal 2019), Germany (Fuchs et al. 2008), the British Isles (Stace 2019), and Belgium (Verloove 2021e).

In Slovakia, approximately 10 individuals were found at the above locality (Figure 1c). As in the case of *Doronicum pardalianches* and *Ligularia*

dentata, the occurrence of *R. podophylla* is probably related to serious changes in vegetation after the windstorm in 2004. This species has been recorded in the area for almost 10 years.

***Salvia hispanica* L. (Lamiaceae)**

Locality: Ipeľsko-rimavská brázda Region, Želiezovce, left bank of the Hron River; several sterile plants; 130 m a.s.l., 7978a, 48°02'51.3"N; 18°40'14.1"E; 6 October 2016; P. Eliáš Jr. and G. Király (NI, relevé 5).

The species originates from Central America and is increasingly cultivated in Central Europe as an oil seed crop ("chia"), seeds are used for the food and pharmaceutical industry, and as a component of commercial birdseed or fodder (Cahill 2003). It is reported as a casual weed from several European countries, and their overview is given by Maslo and Šarić (2020). It occupies mainly ruderal habitats (e.g., along railways, waste places, Hohla 2016; Verloove 2021f; Bochumer Botanische Verein 2022) as well as river banks (Kaplan et al. 2018).

Salvia hispanica was found on the bank of the Hron River not far from the gardens. Therefore, the introduction of *S. hispanica* at the locality is probably connected to its occasional cultivation as part of birdseed mixes.

Relevé 5. E₁ 15%, 16 m², elev. –, exp. –.

E₁: *Persicaria lapathifolia* 2a, *Melilotus albus* 1, *Populus ×canadensis* juv. 1, *Agrostis stolonifera* +, *Amaranthus retroflexus* +, *Artemisia vulgaris* +, *Carex hirta* +, *Echinochloa crus-galli* +, *Lycopersicon esculentum* +, ***Salvia hispanica*** +, *Tripleurospermum inodorum* +, *Xanthium orientale* subsp. *italicum* +, *Robinia pseudoacacia* juv. r.

***Soleirolia soleirolii* (Req.) Dandy (Urticaceae)**

Locality: Podunajská nížina Lowland, Dunajská Lužná-Nové Košariská, Námestie sv. Martina Square, in a concrete crevice along the foot of an old ground floor house next to the Chapel of St. Martin, with northeastern exposition, but protected by the opposite wall of the Pizzeria San Marco at a distance of approximately 3 m from the house; approximately 5 connected clumps along 3 m length of the crevice; 130 m a.s.l., 7969b, 48°05'08.49"N; 17°15'25.49"E; 23 October 2018; D. R. Letz (SAV, photo).

A small creeping to carpet-like herbaceous chamaephyte, member of a monotypic genus endemic to the western Mediterranean islands (Corsica, the Balearic Islands, Mallorca, Sardinia, Tuscan Archipelago). A phytogeographically interesting occurrence of this species was discovered in nearby Algeria (Hamel and Boulemtafes 2017). In Corsica, for example, it grows on damp rocks and old walls, on the margins of springs and streams, and on siliceous and carbonate bedrock (Jeanmonod and Gamisans 2013). It has quickly spread worldwide indoors as a very popular ornamental houseplant but has also started to escape outdoors in sheltered

places or become unintentionally introduced in other countries. It is already naturalised in the Iberian Peninsula, Canary Islands, Madeira, Azores, British Isles, and the Netherlands and is also found as an alien in Belgium, Denmark, Germany, and Italy (Uotila 2011; Galasso et al. 2019) and once in Austria in Vienna (Walter et al. 2002). Its secondary habitats include shady, humid ruderal biotopes such as cracks of concrete, bricks, pavements and foot of walls, etc., always in places with a more stable microclimate, protected from sunstroke and drying or freezing wind. Despite the relative rarity of the species, it is—especially in recent decades—increasing and becoming locally naturalised in western Europe, e.g., in Belgium in many of the larger cities in Flanders, in Brussels, and in much smaller cities and villages. The naturalization of *S. soleirolii* in Belgium is a recent event, and the same trend is visible in neighbouring countries (Verloove 2022c).

The discovered locality in Dunajská Lužná is one of the warmest regions of Slovakia; therefore, thanks to the suitable and well-protected microbiotope, *S. soleirolii* is well established there and continues to persist. It can be assumed that the plant was introduced there as a casual alien in planting material together with other ornamental plants planted alongside the house. In addition to growing from seeds, it can easily be attached vegetatively from fragments of its fragile stem. Our record from Slovakia represents a unique finding in the eastern part of Central Europe and indicates that this species can also be expected in this area in the near future.

***Tetragonia tetragonoides* (Pall.) Kuntze (Tetragoniaceae)**

Locality 1: Devínska Kobyla Hills, Bratislava-Devín, in a currant plantation above the village; number of individuals is not known; September 1936; K. Ptačovský (SAV, revised by P. Eliáš Jr. in 2014).

Locality 2: Javorie Mts, Ábelová, a small field near house No. 110; several flowering individuals; 602 m a.s.l., 7582d, 48°24'31.15"N; 19°25'57.99"E; 12 August 2017; R. Hrivnák (not.).

The species is native to the Far East, Australia, New Zealand and several Pacific Islands. It has been introduced worldwide as an edible garden plant (Grubben and Denton 2004) and has potential medicinal applications (Okuyama and Yamazaki 1983). In Europe, it is regarded mostly as a casual alien, but in some countries of the Mediterranean region (Portugal, France, Italy) and in Great Britain, it is naturalised (Stace and Crawley 2015; Raab-Straube 2018; Galasso et al. 2021).

A curious finding of *Tetragonia tetragonoides* from Slovakia is dated to 2014, during revision of herbarium material deposited in the Herbarium of the Institute of Botany, Slovak Academy of Sciences in Bratislava (SAV). Ptačovský collected it as a weed (“gone wild”) in a currant plantation above the village of Devín (SW Slovakia, currently a city district of Bratislava) in

1936 and determined it to be *Spinacia oleracea* subsp. *spinosa* Moench. The species was also found in the mid-eighties in Rázusova Street in Hlohovec (SW Slovakia); it grew on the edge of the sidewalk, where it had escaped from a nearby garden (Feráková 2017 in verb). Recently, it was found in the locality of Ábelová (Figure 2). One year after planting (2016), as well as every subsequent year, new *T. tetragonoides* individuals appeared regularly without planting, regularly flowered, and fructified.

***Vincetoxicum rossicum* (Kleopow) Barbar. (Apocynaceae)**

Locality 1: Košická kotlina Basin, Košice-Sever, Botanical Garden of Pavol Jozef Šafárik University, edge of the forest path near the “Panská lúčka” meadow; several dozens of individuals; 261 m a.s.l., 7293c, 48°44′09.44″N; 21°14′08.20″E; 6 June 2008; P. Mártonfi; 2n=22, 7 July 2008, analysed by L. Mártonfiová (not.).

Locality 2: Košická kotlina Basin, Košice-Sever, Botanical Garden of Pavol Jozef Šafárik University, edge of forest park near the orchid greenhouse; 230 m a.s.l., 7293c, 48°44′07.93″N; 21°14′14.46″E; 29 June 2021; M. Dudáš and F. Spanyol (KO 36142).

Vincetoxicum rossicum is a twining perennial herb with its origin in southern parts of the European parts of Russia and Ukraine (Fedorov 1978). The species is currently expanding its range, threatening primarily natural and seminatural forested habitats in Northern America (DiTommaso et al. 2005; Kricsfalussy and Miller 2008).

In the Botanical Garden, it was first observed in 2008 on the edge of the cultivated forest area, and it was assumed that this may be an escape of plants from a nearby area where various representatives have grown years ago as an example of a plant system (Figure 3). However, there is no direct evidence that *Vincetoxicum rossicum* was grown in the area. A part of the survey was also a karyological study, and the number of chromosomes for this species was confirmed, namely, $2n = 22$ (first reported by Moore 1959). At present, it grows inconspicuously on the edge of the forest park. The observed number of plants has increased every year since 2019.

***Viola jooi* Janka (Violaceae)**

Locality 1: Záhorská nížina Lowland, Stupava, Zemanská Street, paving slots in front of the gate to the house; approximately 20 sterile to fertile individuals; 177 m a.s.l., 7768a, 48°16′20″N; 17°01′46″E; 1 June 2021; P. Meredá Jr. (SAV, photo).

Locality 2: Strážovské vrchy Mts, Dubnica nad Váhom, Palárikova Street, crossroad with Kvášovecká Street, front garden of the house, crevices between the asphalt pavement and the wall of the house, approximately 5 sterile or fertile individuals, other spontaneously self-seeded sterile and fertile individuals also in other places in the ornamental

bed in the vicinity of cultivated individuals; 244 m a.s.l., 7074b, 48°57'12"N; 18°09'57"E; 1 June 2013; P. Meredá Jr. (photo).

Viola jooi is an endemic species with a restricted distribution range in Eastern and Southern Carpathians and in the Balkan Peninsula in Romania, Serbia and Ukraine (Niketić et al. 2015). It grows in vegetation of low-altitude calcareous screes, colline to alpine rock grasslands, outcrops and screes as well as dry grasslands on gypsum bedrock (Roleček and Dřevojan 2019). It is reported as a casual alien in Hungary (Balogh et al. 2004). The findings reported here are an escape of plants cultivated in nearby gardens caused most probably by seed dispersal by ants (Figure 2).

Evaluation of the findings and possible impact on native flora diversity

Altogether, nearly 80 new alien plants were recorded during the last decade in Slovakia, including 53 taxa reported by some authors (Májeková et al. 2021a; Meredá 2021) and 25 taxa mentioned in our study. The number of alien plants in Slovakia has increased by 8% since the publication of the last checklist (Medvecká et al. 2012). Ferus et al. (2020) mention another 67 taxa (species, subspecies and hybrids), which are not mentioned in Medvecká et al. (2012) or Májeková et al. (2021a) and thus may also represent aliens new to Slovakia. However, Ferus et al. (l. c.) do not distinguish according to life stages because they use the term “seedling” to refer to all developmental stages, including adult plants as well as vegetatively reproduced individuals. It is also not clear which “seedlings” actually survived the winter so that their escape from the culture could be considered real.

In terms of introduction, ornamental plants predominated significantly in our records (88%). Mother plants of only two species (*Salvia hispanica*, *Tetragonia tetragonoides*) were most likely grown for food/feed purposes, and one species (*Psilurus incurvus*) is of unknown origin. Garden flora is an important source of alien species (Dehnen-Schmutz et al. 2007; Hulme et al. 2018); indeed, several studies have confirmed that ornamental plants of foreign origin could account for up to 70–90% of the range grown in garden urban areas (Smith et al. 2006; Acar et al. 2007; Pergl et al. 2016). Therefore, the highest number of escaping taxa alien to Europe as a whole was of ornamental origin (Arianoutsou et al. 2021), and this also holds in Slovakia, where ornamental species represented 55.9% of alien flora (Medvecká et al. 2012).

According to Medvecká et al. (2012), the richest alien floras are recorded in the Pannonicum region (southern Slovakia); similarly, 56% of alien plants found in our study were recorded in Pannonicum, 28% in Carpathicum and 16% in both Carpathicum and Pannonicum regions. From the taxonomical classification point of view, taxa of the family Compositae (*Achillea filipendulina*, *Doronicum pardalianches*, *Jacobaea maritima* subsp. *maritima*, *Ligularia dentata*) predominated in the results, followed

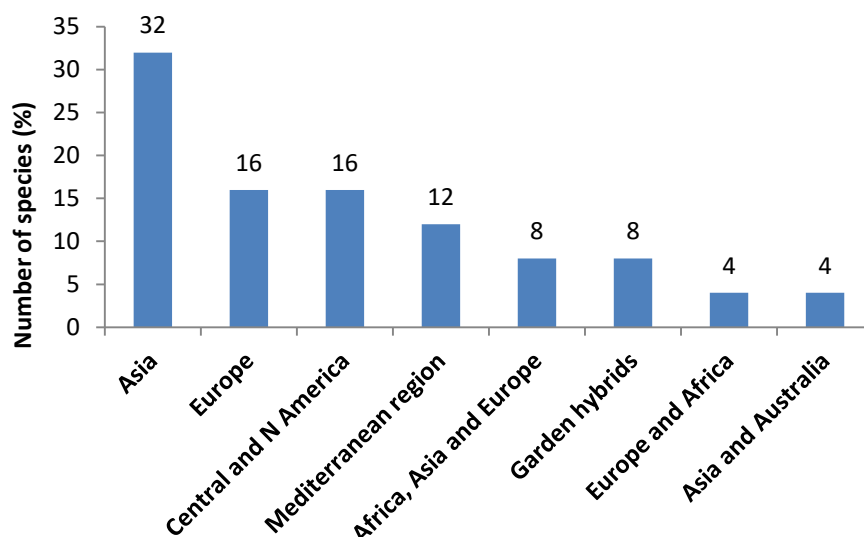


Figure 4. The phytogeographical origin of newly recorded alien taxa to Slovakia (in %).

by Poaceae (represented by 3 species), and Lamiaceae, Ranunculaceae Rosaceae and Saxifragaceae are represented by two species per family (Table 1). It seems that the species from the Compositae and Poaceae families are among the most successful invasive species on regional (Pyšek et al. 2002; Rabitsch and Essl 2006; Medvecká et al. 2012) as well as pan-European (Arianoutsou et al. 2021) and global levels (Pyšek et al. 2017).

In our study, most of the species originated from Asia (32%), Europe (16%) and Central and North America (16%, Figure 4). On the pan-European level as well as in Slovakia, other parts of the continent are the main donor area of aliens, followed by the species native to Asia and North America (Pyšek et al. 2009; Medvecká et al. 2012). This is explained by the better preadaptation of aliens originating in other parts of Europe to a wider range of European habitats but also by the longer residence time of aliens with European native range compared to alien species from other parts of the world (Pyšek et al. 2009). In addition, habitat type is also important for the survival of nonnative species. Kalusová et al. (2017) found that species occurring in both human-made habitats and seminatural or natural habitats in Europe have the highest probability of naturalization in other parts of the world. The alien species recorded in our study occupied mostly man-made habitats (15 taxa, 60%) but also spread into natural (4 taxa, 16%) and seminatural (4 taxa, 16%) habitats (Figure 5).

The greatest risk is posed by naturalised alien species in terms of threats to local biodiversity. Medvecká et al. (2012) pointed out that 39.1% of alien species recorded in Slovakia are naturalised but not invasive and 3.3% are invasive. We found four locally naturalised species during field research: *Cenchrus flaccidus*, *Cotoneaster zabelii*, *Doronicum pardalianches*, and *Panicum virgatum* (Table 1). All these species are capable of vegetative reproduction using underground outcrops, have been recorded in several

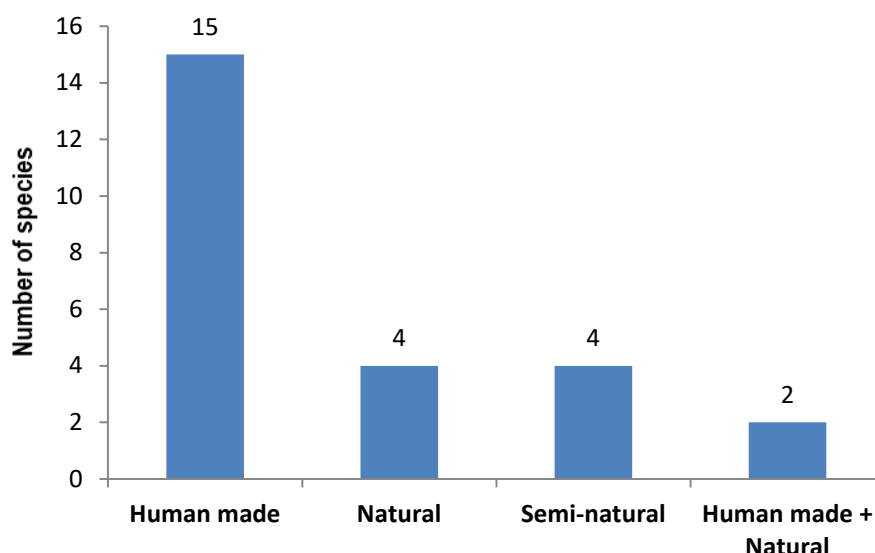


Figure 5. Distribution of the newly recorded taxa with respect to the type of habitat in which they were found in Slovakia.

localities (except *D. pardalianches*), and have spread to native habitats and thus represent the greatest risk for native plant species in Slovakia. The localities of these species will need to be further monitored, and if necessary, their spreading local populations should be eradicated.

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Authors' contribution

RH – research conceptualization, sample design and methodology, investigation and data collection, original draft; PE Jr. – sample design and methodology, investigation and data collection, original draft, editing, data analysis and interpretation, funding provision; JM – investigation and data collection, original draft, editing, funding provision; KH, MD, LB – investigation and data collection, original draft; IS – investigation and data collection, original draft, review; DRL – investigation and data collection, original draft, ethics approval; PM Jr. – investigation and data collection, original draft, review, funding provision; TČ, DD, ZD, LĎ, RG, GK, LM, PM, FS – investigation and data collection.

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Supplementary material

The following supplementary material is available for this article:

Table S1. Geo-referenced records of newly recorded alien species.

This material is available as part of online article from:

http://www.reabic.net/journals/bir/2023/Supplements/BIR_2023_Elias_et_al_SupplementaryMaterial.xlsx