Preslia 97: 659–675, 2025
doi: 10.23855/preslia.2025.659

Preslia

Nurseries and garden centres act as hubs of alien plant invasions: a case study from Hungary

Judit Sonkoly[1,2,*], Attila Molnár V.[3,4], Péter Török[2,5,6], Kristóf Süveges[7] & Attila Takács[3,4]

[1]Department of Ecology, University of Debrecen, Egyetem tér 1, H-4032 Debrecen, Hungary; [2]HUN-REN–UD Functional and Restoration Ecology Research Group, Egyetem tér 1, H-4032 Debrecen, Hungary; [3]Department of Botany, University of Debrecen, Egyetem tér 1, H-4032 Debrecen, Hungary; [4]HUN-REN–UD Conservation Biology Research Group, Egyetem tér 1, H-4032 Debrecen, Hungary; [5]Polish Academy of Sciences, Botanical Garden – Center for Biological Diversity Conservation in Powsin, PL-02973 Warszawa, Poland; [6]Balaton Limnological Research Institute, HUN-REN, Klebelsberg Kuno út 3, H-8237 Tihany, Hungary; [7]Lendület Seed Ecology Research Group, Institute of Ecology and Botany, ELKH Centre for Ecological Research, Alkotmány út 2-4, H-2163 Vácrátót, Hungary
*corresponding author: judit.sonkoly@gmail.com

Abstract: The growing global horticultural trade has a key role in the introduction of alien plant species into new areas, partly because it also entails the unintentional dispersal of many contaminant species over large distances. However, apart from sporadic reports of such contaminant species, this phenomenon is largely understudied. In order to study this, a systematic field survey of garden centres in Hungary was carried out to assess their role in unintentionally introducing invasive alien species. Twelve garden centres were surveyed in spring, summer and autumn and all individuals of alien species recorded. In addition to the pots and containers of plants for sale, all indoor and outdoor areas, such as flowerbeds, bare and covered surfaces, cracks in the pavement, lawns and other vegetated areas were surveyed. A total of 93,788 individuals of 67 alien species were recorded, seven of which were recorded for the first time in this country. Despite their small area, the studied garden centres hosted a large percentage of the local alien flora, indicating that they strongly accumulate alien species. There were large populations of many alien species, suggesting that garden centres can act as invasion hubs. Trait differences between the alien species in the garden centres and the regional alien flora indicate that the species most successful at colonizing garden centres are both good dispersers and possess an effective resource-acquisitive strategy. Thus, populations of alien plants in garden centres may be the source of local invasions. Moreover, individuals and seeds in the containers of ornamental plants are likely to be transported to distant areas by customers. Despite the limited spatial extent of this survey, the findings indicate that the horticultural trade may act not only as a source of plant introductions, but can also potentially influence the subsequent stages of the invasion process. Thus, there is a need for further studies on the role of species contaminating horticultural stock in alien plant invasions.

Keywords: alien species, horticulture, human-mediated dispersal, nursery industry, plant invasion

Received: 5 Nov 2024; Revised: 2 Jun 2025; Accepted: 3 Oct 2025; Published: 11 Dec 2025

Introduction

Invasive alien species are one of the major drivers of environmental change worldwide (Díaz et al. 2019). As summarized in the review of Pyšek et al. (2020), invasive species can have a multitude of adverse effects, such as reducing biodiversity, disrupting food webs, altering habitat structure, and ultimately altering ecosystem functions and services (Ehrenfeld 2010, Vilà et al. 2011). In addition, invasive species can also be detrimental to human health and economy (Early et al. 2016, Haubrock et al. 2021). Global changes, including climate change and anthropogenic habitat conversion, as well as the rising rates of international trade and transport, are major drivers in the spread of invasive species (Bradley et al. 2010, Pyšek et al. 2020, Hulme et al. 2023), and climate change is expected to further increase the number and effect of plant invasions globally (Early et al. 2016, Dullinger et al. 2017). Hence, it is important to obtain a better understanding of the spread of invasive species.

Long-distance dispersal events play a crucial role in many large-scale ecological processes (Nathan 2006, Paulose & Hallatschek 2020), such as gene flow between distant populations (Clobert et al. 2012) and range shifts associated with changing landscapes and climates (Clark et al. 1999). Biological invasions are also more likely to be driven by long-distance dispersal events than local dispersal (Kot et al. 1996, Nathan 2006). As long-distance dispersal is very difficult to study, our understanding of it is still severely limited (Levin et al. 2003, Jordano 2017), which also prevents a full understanding of the processes underlying the spread of invasive species. Human activity has historically been a considerable factor in the dispersal of species, both accidentally and on purpose (Hulme 2009, Bullock et al. 2018). Moreover, due to the quickly rising rates of global trade and human mobility in the last century, humans have presumably become the major dispersal vector (Hodkinson & Thompson 1997). Humans can now also be considered as the main long-distance dispersal vector (Higgins et al. 2003, Taylor et al. 2012), suggesting that the increasing levels of globalization and human activity has led to more chances for long-distance spread.

Likely associated with the increased chances of long-distance dispersal, all evidence indicates that the rate of invasive species introductions at many locations is also increasing (Lockwood et al. 2005, Hulme 2009) and the spread of invasive species is widely considered to be mainly driven by international trade and transport, both in terrestrial and in aquatic ecosystems (Jenkins 1996, Perrings et al. 2005, Essl et al. 2015). Studies have demonstrated a clear link between the monetary value of imports and the number of invasive species in a country (Vilà & Pujadas 2001, Westphal et al. 2008, Dalmazzone & Giaccaria 2014), and the rate of invasive species accumulation in different species groups in the United States is well described by a model based on the cumulative value of imports (Levine & D'Antonio 2003).

Horticulture has always been one of the most significant human activities responsible for introducing invasive species into new areas (Kenis et al. 2007, van Kleunen et al. 2018), but the growing global horticultural trade (van Kleunen et al. 2018) is increasing the rate at which they are being introduced into new areas (Bradley et al. 2012, Liebhold et al. 2012). Ornamental species are widely known as the main source of introduced alien plants, many of which are capable of becoming naturalized and subsequently invasive in their introduced range (Pergl et al. 2016, Hulme et al. 2018). However, the global horticultural trade is also responsible for the unintentional dispersal of many contaminant species (Hodkinson & Thompson 1997, Montagnani et al. 2022, Sonkoly et al. 2022).

Nurseries and garden centres (hereafter garden centres for simplicity) have been repeatedly shown to provide habitat for a wide range of plant species (e.g. Hoste et al. 2009, Gallego & Lumbreras 2013, Takács et al. 2020, Rigó et al. 2023), plant pathogens (Bienapfl & Balci 2014, Jung et al. 2016), molluscs (Bergey et al. 2014, Páll-Gergely et al. 2020) and planarians (Lazányi et al. 2024). Alien species found in the diverse anthropogenic microhabitats inside the garden centres can arrive there via various pathways. They can come from nearby populations, but also from much more distant locations via long-distance dispersal, for example, they may be dispersed on the clothing and footwear of the staff or the customers (Ansong & Pickering 2016, Lukács et al. 2024) or attached to vehicles (von der Lippe & Kowarik 2007, Taylor et al. 2012). Moreover, in addition to pathogens (e.g. De Groote et al. 2006, Bienapfl & Balci 2014), horticultural substrates are frequently contaminated with seeds and other plant propagules (Conn et al. 2008, Dyer et al. 2017, Sonkoly et al. 2022). Therefore, importing plants in containers is likely to disperse species over large distances and potentially introduce new alien species into garden centres, which can act as sites for multiplication and acclimatization for many of them.

To develop evidence-based and effective strategies for the prevention of further plant invasions, more research is needed on the role of the horticultural trade in the unintentional spread of alien plant species (van Kleunen et al. 2018). Although there are reports of noteworthy occurrences of alien plant species in garden centres (e.g. Gallego & Lumbreras 2013, Takács et al. 2020, Molnár V. et al. 2024, Dudáš et al. 2025), their occurrence has hardly been studied systematically (but see Hoste et al. 2009). Codes of conduct for the horticultural industry regarding invasive species also exist (e.g. Baskin 2002, Brundu et al. 2011), but these typically focus on the deliberately introduced ornamental plants rather than on the accidental introductions of contaminant species. To bridge this knowledge gap, we conducted systematic field surveys in order to assess which alien plant species occur in garden centres and what is their abundance. We hypothesized that (i) the number of alien species in garden centres is positively correlated with their size, (ii) relative to their size, garden centres host a disproportionately large proportion of the local alien flora, and (iii) alien species inhabiting garden centres differ from the regional alien flora in their ecological and dispersal traits.

Materials and methods

In 2019, three surveys (spring, summer and autumn, separated by 2–3 month intervals) of 12 ornamental plant retailers were carried out in and near the city of Debrecen, Hungary (Fig. 1). These included both nurseries and garden centres of different sizes from small, family-owned businesses to large franchises (ranging from ~1,200 m^2 to ~12,000 m^2 in area, see Table 1). Owners and/or managers were informed and gave their consent for the surveys. Repeated surveys in each season during the vegetation period ensured the finding of species with different phenologies. The whole area of each garden centre including both outdoor and indoor areas (buildings and greenhouses) was surveyed, which included examining the pots and containers of ornamentals for sale, as well as flowerbeds, bare soil or covered soil surfaces (with agrotextile or gravel), cracks in the pavement and

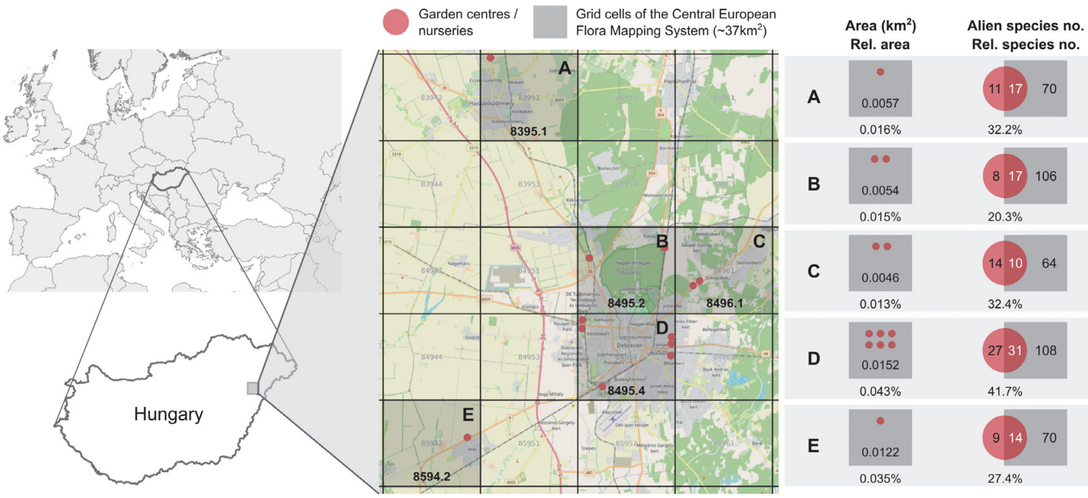

Fig. 1. Species numbers in the garden centres studied, located in and around the city of Debrecen, Hungary. The panel on the right (left column) shows the number of garden centres in each quarter-grid cell of the Central European Flora Mapping System (Niklfeld 1971), their total area and relative area compared to the total area of the grid cell. The right column shows the number of alien plant species recorded in the garden centres (separately for newly recorded species and those that have been known from the given grid cell), the number of alien plant species found in the respective grid cell according to the Vascular plants of Hungary online database (Bartha et al. 2021+) and not in the garden centres, and the percentage of grid-cell's alien species recorded in garden centres.

fugues, lawns and other vegetated areas. All spontaneously occurring individuals of all alien species were recorded, therefore excluding planted individuals and the plants offered for sale. Ornamental plant species (e.g. *Buddleja davidii*, *Pilea microphylla*, *Soleirolia soleirolii*) were also recorded if they occurred spontaneously (as a contaminant) in pots of other species or outside the pots. For species that spread clonally or form mats and in the case of extremely abundant species, the number of individuals was estimated. The native versus alien status of species in Hungary was assessed using the checklist of Csiky et al. (2023); neophytes and archaeophytes were both treated as aliens (see Supplementary Table S1). We treated *Oxybasis glauca* (whose native or alien status in Hungary is debated) as an alien species and therefore included it in the analyses. To compare the percentage of species in each invasion status category (casual, naturalized, invasive, and transformer) between the species documented in the garden centres and the regional alien flora, we considered the invasion status of the species according to Csiky et al. (2023). To compare the percentages in the two species lists, we used Pearson's chi-square test with a simulated P-value (via Monte Carlo simulation) because some cell counts were very low.

The area of the garden centres was measured using Google Earth. The correlation between the area of each garden centre and the number of species and individuals they host was tested using Spearman's rank correlations. The studied garden centres were scattered in five quarter grid cells (hereafter grid cells for simplicity) of the Central European Flora Mapping System (Niklfeld 1971, see Fig. 1). The list of alien species recorded in garden centres located in each grid cell was compared with the list of documented alien species in the same grid cell, based on Bartha et al. (2021+). To test whether garden centres host a disproportionately large percentage of the local alien flora relative to their size, two metrics were calculated: (i) the percentage of each grid cell's area occupied by the garden centre(s), and (ii) the percentage of the documented alien species in each grid cell (including newly recorded species in the surveys) that were recorded in the garden centre(s) in that grid cell. The two metrics were compared using Wilcoxon rank sum test.

When comparing traits and ecological indicator values (EIVs) of the species found in the garden centres with the traits and EIVs of the total regional alien flora, we considered the alien checklist of Csiky et al. (2023) and obtained data from the Pannonian Database of Plant Traits (PADAPT; Sonkoly et al. 2023). We considered those traits which may influence the species' ability to colonize garden centres and for which data was available for the majority of the species. Based on these criteria, thousand-seed mass (TSM, g), plant height (cm), leaf area (LA, mm^2), specific leaf area (SLA, mm^2/mg), leaf dry matter content (LDMC, mg/g) and leaf dry weight (LDW, mg) were selected. As EIVs, we used the Borhidi-type indicator values (Borhidi 1995) for soil moisture (W_B), light intensity (L_B) and nutrient supply (N_B), which are based on the indicator values of Ellenberg et al. (1992) and also adapted to the Pannonian Ecoregion. For the species recorded in the garden centres, traits and ecological indicator values were also mainly obtained from the regional database PADAPT (Sonkoly et al. 2023), with missing trait values filled in wherever possible, either by new measurements carried out for the purpose of this analysis or data in the LEDA Traitbase (Kleyer et al. 2008). Traits and EIVs of the two species groups (i.e. recorded aliens vs. the regional alien flora) were compared using Wilcoxon rank sum tests. All statistical analyses were conducted in an R environment (version 4.3.2, R Core Team 2023). Nomenclature follows the Euro+Med PlantBase (2006+).

Results

A total of 93,788 individuals of 67 introduced species were recorded (Table 2, Fig. S1), seven of which are new records for Hungary: *Acalypha brachystachya*, *Fumaria capreolata*, *Gnaphalium pensylvanicum*, *Hylotelephium sieboldii*, *Oldenlandia corymbosa*, *Soleirolia soleirolii* and *Urtica pilulifera*. The majority of the species are neophytes (85%), and only 12% are archaeophytes (the status of 3% of the species was uncertain, see Supplementary Table S1). Most of the species are naturalized in Hungary (32 species), 15 are casual aliens (including the newly recorded species), 14 are invasive, and six of them are considered transformer species in Hungary (Table 1). The proportion of species in each invasion status category differed significantly between the species documented in the garden centres and the species of the regional alien flora (chi-square test, $\chi^2 = 26.798$, $P < 0.0001$), with a higher proportion of invasive and transformer species in the garden centres.

The five most abundant species were *Sagina procumbens*, *Oxalis corniculata*, *Cardamine occulta*, *Oxybasis glauca* and *Euphorbia maculata*, each with more than 10 thousand individuals. On the other hand, 13 species (19%) were each represented by a single individual (Table 2). On average, each species occurred in four of the 12 garden centres. Twenty-eight species (42%) were found in a single one, while six species (*Erigeron annuus*, *Erigeron canadensis*, *Euphorbia maculata*, *Oxalis corniculata*, *Oxalis dillenii* and *Sagina procumbens*) occurred in all the garden centres (Table 2).

Table 1. The location and approximate area of the garden centres studied, together with the number of species and number of individuals documented in them.

Code	Settlement and street name	Coordinates (N, E)	Outdoor area (m^2)	Greenhouse area (m^2)	No. of species	No. of individuals
1	Debrecen, Díszfaiskola street	47.583, 21.592	2,100	–	18	7,928
2	Debrecen, Hét vezér street	47.525, 21.660	1,600	–	29	7,974
3	Debrecen, Vértesi street	47.508, 21.603	2,700	160	29	10,223
4	Debrecen, Kócsag street	47.542, 21.584	1,600	–	31	8,084
5	Hajdúböszörmény, Külső Dorogi street	47.697, 21.507	5,700	1,800	28	5,756
6	Debrecen-Apafa, Route 4	47.587, 21.656	3,300	–	19	5,301
7	Debrecen, Balmazújvárosi street	47.544, 21.586	7,000	1,200	33	8,085
8	Ebes, Route 4	47.478, 21.487	12,000	6,400	12	24,877
9	Debrecen, Budai Nagy Antal street	47.533, 21.660	1,200	700	11	4,168
10	Debrecen, Budai Nagy Antal street	47.532, 21.660	1,500	400	16	1,440
11	Debrecen, Külső Sámsoni street	47.566, 21.682	1,400	1,400	16	2,448
12	Debrecen, Külső Sámsoni street	47.566, 21.683	3,200	–	17	7,504

Table 2. List of the spontaneously occurring invasive alien species in the garden centres studied with the number of recorded individuals and the number of garden centres where they were found. Invasion status in Europe and in Hungary are given according to Kalusová et al. (2024) and Csiky et al. (2023), respectively: nat – naturalized; inv – invasive; trans – transformer; n.l. – not listed in the given source. * species of Union concern (European Commission 2025), ^ species new to alien flora of Hungary. Note that some species are not listed in Csiky et al. (2023) but have been recorded in the country since then.

Species	Total number of individuals	Individuals inside containers	Individuals not in containers	Number of garden centres	Invasion status in Europe	Invasion status in Hungary
Acalypha brachystachya^	17	15	2	2	n.l.	n.l.
Acer negundo	1	1	0	1	inv	nat
Acer saccharinum	200	200	0	1	nat	nat
*Ailanthus altissima**	4	1	3	4	inv	trans
Amaranthus blitum	94	51	43	10	inv	nat
Amaranthus deflexus	37	9	28	7	inv	nat
Amaranthus powellii	186	2	184	3	inv	nat
Amaranthus retroflexus	412	26	386	7	inv	nat
Ambrosia artemisiifolia	827	91	736	8	inv	nat
Artemisia annua	1	0	1	1	inv	inv
*Asclepias syriaca**	1	0	1	1	inv	trans
Buddleja davidii	10	0	10	1	inv	nat
Cardamine occulta	11,395	7,642	3,753	11	nat	n.l.
Chenopodiastrum hybridum	3	0	3	2	nat	nat
Chenopodiastrum murale	8	5	3	1	nat	nat
Chenopodium album	95	21	74	7	nat	nat
Chenopodium betaceum	33	13	20	6	casual	nat
Chenopodium ficifolium	165	164	1	4	nat	nat
Claytonia perfoliata	1	1	0	1	nat	casual
Commelina communis	4	0	4	1	inv	nat
Dysphania pumilio	1	1	0	1	inv	nat
Eclipta prostrata	8	3	5	4	inv	n.l.
Elaeagnus angustifolia	1	1	0	1	inv	trans
Epilobium ciliatum	228	147	81	7	inv	nat
Erigeron annuus	4,529	1,498	3,031	12	inv	inv
Erigeron canadensis	1,629	528	1,101	12	inv	inv
Erigeron sumatrensis	52	0	52	2	inv	n.l.

Species	Total number of individuals	Individuals inside containers	Individuals not in containers	Number of garden centres	Invasion status in Europe	Invasion status in Hungary
Euphorbia maculata	10,113	4,352	5,761	12	inv	inv
Euphorbia peplus	758	109	649	8	inv	nat
Euphorbia prostrata	167	11	156	4	inv	nat
Euphorbia serpens	3,550	918	2,632	5	inv	nat
Fumaria capreolata^	1	1	0	1	nat	n.l.
Galinsoga parviflora	726	28	698	8	inv	inv
Galinsoga quadriradiata	73	47	26	5	inv	nat
Geranium dissectum	2	0	2	1	nat	nat
Gleditsia triacanthos	105	0	105	1	inv	nat
Gnaphalium pensylvanicum^	1	1	0	1	inv	n.l.
*Humulus japonicus**	1	0	1	1	inv	inv
Hylotelephium sieboldii^	1	1	0	1	nat	n.l.
Lepidium didymum	2	2	0	1	inv	casual
Microrrhinum minus	21	0	21	1	inv	nat
Oenothera biennis	3	0	3	2	inv	inv
Oldenlandia cf. *corymbosa*^	26	26	0	2	n.l.	n.l.
Oxalis corniculata	15,662	8,614	7,048	12	inv	inv
Oxalis dillenii	6,011	1,789	4,222	12	inv	inv
Oxalis stricta	3,640	2,239	1,401	4	inv	inv
Oxybasis glauca	11,197	4,314	6,883	9	nat	nat
Panicum dichotomiflorum	15	0	15	1	inv	inv
Panicum riparium	44	36	8	2	casual	casual
Parietaria judaica	267	8	259	3	nat	nat
Parthenocissus quinquefolia	3	0	3	1	inv	nat
Phytolacca americana	1	0	1	1	inv	inv
Pilea microphylla	106	79	27	5	casual	n.l.
Polycarpon tetraphyllum	1	1	0	1	nat	nat
Polypogon viridis	11	6	5	1	nat	casual
Populus ×canadensis	2	2	0	1	inv	nat
Potentilla indica	2	2	0	1	inv	inv
Robinia pseudoacacia	12	11	1	2	inv	trans
Sagina procumbens	17,672	4,714	12,958	12	nat	nat
Senecio leucanthemifolius subsp. *vernalis*	6	0	6	1	inv	nat
Soleirolia soleirolii^	5	5	0	1	inv	n.l.
Solidago canadensis	36	9	27	3	inv	trans
Solidago gigantea	207	139	68	4	inv	trans
Ulmus pumila	196	78	118	5	inv	inv
Urtica pilulifera^	1	1	0	1	nat	n.l.
Veronica peregrina	2,787	626	2,161	9	inv	nat
Veronica persica	412	4	408	6	inv	nat

Fifty-two of the 67 species occurred in the containers of ornamental plants. There were 15 species occurring only outside containers and 15 that occurred only in containers (Table 2). The majority of the individuals were found in outdoor areas (69.9%), while a much lower percentage was in greenhouses (30%, Supplementary Table S1), which reflects the areas of the outdoor and greenhouse areas as a percentage of the total area surveyed (Table 1). Regarding the different locations where alien species were found, pots and containers hosted the highest number of individuals (41.1%), followed by pavement (22.1%) and agrotextile (16.4%), while the remaining 20.4% were distributed among all other types of locations (Supplementary Table S1).

Each garden centre hosted an average of 7,816 individuals of 22 alien species. However, they varied considerably, with species numbers ranging from 11 to 33 and the total number of individuals ranging between 1,440 and 24,877 (Table 1). The number of species in a garden centre was not correlated with the area of the garden centre ($P = 0.314$), however, the number of individuals was significantly positively correlated with the area ($R = 0.606$, $P = 0.037$). The number of species and the number of individuals in a garden centre were also not correlated ($P = 0.105$).

The garden centres occurred in five grid cells of the Central European Flora Mapping System (Fig. 1). Although garden centres covered a very small fraction of the grid cells (ranging from 0.013% to 0.043%), they hosted high numbers of alien species. On average, 17.2% (ranging from 13.5% to 22.3%) of the already known alien flora of the grid cells were found in the comparatively tiny area of the garden centres. In addition, eight to 27 species in the garden centres in each grid cell were not previously documented in those grid cells. The garden centres host a disproportionately large proportion of the local alien flora relative to their size (Fig. 1).

When the alien species recorded in garden centres were compared with the regional alien flora in terms of traits and ecological indicator values (EIVs, see Supplementary Table S1), we found that they had significantly lighter seeds, higher specific leaf area (SLA), lower leaf dry matter content (LDMC), and higher EIVs for soil moisture and nutrient supply than the regional alien flora (Table 3).

Table 3. Traits and ecological indicator values (EIVs) of the alien species recorded in garden centres compared with those of the regional alien flora (Wilcoxon rank sum tests). Abbreviations: TSM – thousand-seed mass; LA – leaf area; SLA – specific leaf area; LDMC – leaf dry matter content; LDW – leaf dry mass; W_B, L_B, and N_B – ecological indicator values for soil moisture, light intensity and nutrient supply, respectively (Borhidi 1995).

	Regional alien flora (mean±SE)	Garden centres (mean±SE)	P-value
TSM (g)	30.1±6.1	10.5±4.3	**< 0.0001**
Plant height (cm)	306.1±24.2	434.7±114.1	0.636
LA (mm^2)	3,132±385	2,479±675	0.537
SLA (mm^2/mg)	23.5±0.8	31.0±2.3	**< 0.0001**
LDMC (mg/g)	247.5±5.2	212.9±11.7	**0.015**
LDM (mg)	196.4±28.5	119.8±33.1	0.058
W_B	4.5±0.1	5.1±0.2	**0.005**
L_B	7.4±0.1	7.2±0.2	0.205
N_B	5.4±0.1	6.5±0.3	**0.001**

Discussion

The role of horticultural trade in biological invasions has been mainly considered in the context of ornamental plants escaping cultivation and becoming invasive, and it has been much less considered as a pathway of accidental human-vectored dispersal (Bullock et al. 2018) of contaminant species. This study revealed that, despite their small area, the garden centres contained surprisingly large numbers of alien plant species. Many of these species had large populations, which could facilitate dispersal not just locally in the surrounding landscape, but also more widely, because customers may transport them over long distances in the containers of the ornamental plants. The fact that the majority of the species were found inside the containers of ornamental plants supports our assumption that most accidental alien plant species arrive at the garden centres via shipments of ornamental plants. This is also supported by the presence of species that have not been previously recorded in Hungary.

The seven species recorded in Hungary for the first time fall into three categories: (i) species of Mediterranean origin, which presumably arrived in garden centres due to the increase in sourcing plants from Mediterranean countries, particularly Italy and Spain (Hoste & Verloove 2009): *Fumaria capreolata* and *Urtica pilulifera*; (ii) emerging species of (sub)tropical origin, which are not yet widespread, but have already been introduced to some temperate regions: *Acalypha brachystachya*, *Gnaphalium pensylvanicum*, and *Oldenlandia corymbosa*; (iii) ornamental species, which are probably present in garden centres due to their widespread cultivation: *Hylotelephium sieboldii* and *Soleirolia soleirolii*. Seventeen of the 67 species documented were also found in containers of ornamental plants in Belgium (Hoste et al. 2009), including two of the species new to the Hungarian flora (*F. capreolata* and *G. pensylvanicum*).

The most abundant alien species in garden centres were mostly already quite widespread both in Hungary and in Europe (Kalusová et al. 2024). However, the third most abundant species, *Cardamine occulta*, of which more than 11,000 individuals were recorded, was only included in the alien plant inventory of eight out of 55 European countries and territories up until 2022 (Kalusová et al. 2024) and was also only recently found in Hungary (Takács et al. 2020). This species has quickly spread in Europe in places where its occurrence can be attributed to the horticultural trade (see e.g. Leostrin & Mayorov 2019, Šlenker et al. 2019, Pliszko 2020, Hruševar et al. 2021, Király et al. 2021, Kovács et al. 2023).

Both the number of species and the number of individuals were highly variable across the garden centres studied. We hypothesized that the number of alien species found in a garden centre is positively related to the size of the garden centre, as larger garden centres presumably have a larger incoming stock. A larger incoming stock can be associated with higher propagule pressure (i.e. a larger number of individuals released into the area), which is considered as one of the most important factors determining the success of invasive species (Lockwood et al. 2005, Colautti et al. 2006). In addition, a survey of land snails in plant nurseries revealed that the number of taxa occurring in a nursery was positively related to its area (Bergey et al. 2014). Despite this, there was no relationship between the size of a garden centre and the number of alien plant species it hosts. However, there was a significant positive relationship between the size of a garden centre and the number of alien plant individuals found in it. The highest numbers of alien species were recorded in garden centres that, rather than being the largest in area, were the busiest and offered the greatest diversity of plants for sale in our experience. This observation is in line with the key importance of propagule pressure, but, unfortunately, we have no data to test this assumption.

We also hypothesized that, relative to their size, garden centres host a disproportionately large percentage of the local alien flora. Although the garden centres cover only a very small fraction of the area of the flora mapping grid cells they are located in, they host a high percentage of the recorded alien flora within those grid cells, supporting this hypothesis. This result illustrates that garden centres strongly accumulate alien species and that they can act as invasion hubs for several new invading species (Letnic et al. 2015). Human-vectored dispersal can result in spatially aggregated populations of alien species, which frequently occur in and around anthropogenic habitats (Bullock et al. 2018). These habitats can function as invasion hubs, from which established satellite populations of alien species can spread further into the landscape (Suarez et al. 2001, With 2002). Because eradicating such invasion hubs is a targeted and effective way of reducing the spread of invasive species (Moody & Mack 1988, Florance et al. 2011), their identification is a very important step in controlling this phase of invasion.

The hypothesis that alien species in garden centres differ from the regional alien flora in their traits was partially supported by the results. There was no difference between these two groups of species in terms of plant height and leaf size (expressed in terms of specific leaf area and leaf dry mass). On the other hand, the documented alien species had significantly lower LDMC and higher SLA compared to the regional alien flora, which indicates that they are placed on the leaf economic spectrum towards the fast-growing, resource-acquisitive strategies (Leishman et al. 2007). The fact that the recorded alien species had a lower seed mass is probably due to the presumed better dispersal ability (Guo et al. 2000, Tremlová & Münzbergová 2007) and longer seed persistence (Thompson et al. 1993, Zhao et al. 2011) of small-seeded species. Persistent seeds remain viable in containers throughout the potentially lengthy transportation process from wholesalers to garden centres (and eventually to the customer's gardens). These findings indicate that the species that are most successful at colonizing garden centres are both good dispersers and have a resource-acquisitive strategy (Wright et al. 2004, Pierce et al. 2014), because they need to be able to grow and reproduce quickly. Species with a slow growth rate, high stature or long life cycle also occasionally appear in garden centres, but they are less abundant and unlikely to establish self-sustaining populations within the garden centres. Thus, horticultural trade can play a role in their introduction, but the garden centres themselves play a less important role as invasion hubs for these species (Suarez et al. 2001, Letnic et al. 2015). Regarding ecological indicator values, the alien species in garden centres had significantly higher values for soil moisture and nutrient supply than the regional alien flora, which indicates the effect of fertilizer use and frequent irrigation in nurseries and garden centres.

Fifty-two of the recorded 67 species occurred in the containers of ornamental plants. As the customers regularly transport the containers over great distances, further long-distance dispersal of these species can be expected regularly (Hodkinson & Thompson 1997, Bergey et al. 2014). The 15 species not recorded in containers may have arrived in the garden centres from populations in the neighbouring area by other means of dispersal than as contaminants of horticultural stock. Individuals outside containers are not readily transported to distant areas, but as several species had populations of considerable size even outside the containers (*Cardamine occulta*, *Euphorbia* spp., *Oxalis* spp., *Veronica peregrina* etc.), they can exert sufficient propagule pressure to induce local invasions.

Regarding the genetic effects of accidental long-distance dispersal associated with the horticultural trade, it is likely that these long-distance dispersal events commonly lead to low genetic diversity in the introduced populations due to strong founder effects (Setsuko et al. 2020, Wu et al. 2023). On the other hand, long-distance dispersal by humans often transports many propagules or individuals of a species at a time (Bullock et al. 2018). If propagules arriving at a site are from different areas and the genetic makeup of the species in its native range is spatially structured, the genetic diversity of such introduced populations may be higher than that in any of the native source populations (Lockwood et al. 2005, Smith et al. 2020), which can minimize Allee effects and founder effects (Wu et al. 2023). This supports the notion that the international horticultural trade not only has a key role in new species introductions, but also increases the chance of successful invasions due to the recurring introductions of alien plants into local outlets of the global horticultural trade (Dehnen-Schmutz et al. 2007), which increase the chances of novel genetic combinations and evolutionary shifts (Kolbe et al. 2004, Lockwood et al. 2005, Šlenker et al. 2018).

It is frequently suggested that managing and controlling invasive species is easiest and most cost-effective in the early stages of the invasion process (e.g. Rout et al. 2011, Simberloff et al. 2013, Chapman et al. 2016). Specifically, eradicating recently established satellite populations (Moody & Mack 1988, Florance et al. 2011) or reducing the probability of long-distance dispersal events that create such populations (Buckley et al. 2005, Shea et al. 2010) can be especially effective in controlling the spread of invasive species. Our results indicate that eradicating new populations of alien species in garden centres would be easier and more cost-effective than focusing the control measures on older and bigger populations. Therefore, early detection and eradication of satellite populations in garden centres should be a priority in invasive species management. In the meantime, there is a need to raise public awareness, thus both the managers and employees of plant nurseries and garden centres, as well as the customers should be educated and informed about the potential adverse consequences of new plant species introduced as contaminants in the containers of plants.

It has to be noted that our assessment of the role of garden centres as invasion hubs is somewhat limited due to the lack of reliable information on which species arrived at the garden centres by long-distance dispersal via the horticultural trade and which came from existing populations in the neighbouring areas. However, it does not refute the fact that even the species originally entering the garden centres from the neighbouring populations can be further dispersed by customers transporting the containers to distant areas. Furthermore, this survey was of a relatively small area; thus, the limited spatial extent of the study makes it difficult to draw general conclusions. Due to these limitations and the complexity of this phenomenon, many questions remain unanswered. For example, the propagule content of the containers of ornamental plants has been rarely studied (but see Cross & Skroch 1992, Conn et al. 2008). Assessing the different pathways by which propagules can reach these containers could also provide information about the step of the horticultural trade at which interventions could be the most effective.

Conclusions

This study is one of the few assessments of the accidental dispersal of plants as contaminants of plants offered for sale by the horticultural trade. The garden centres surveyed hosted large populations of alien species, therefore they may serve as invasion hubs. Propagule pressure of the populations in garden centres can be sufficient to result in local invasions. In addition, individuals occurring in containers and their seed bank are regularly transported to distant areas by customers, where they may establish new invasion hubs. Thus, the horticultural trade may not only be a pathway of alien plant introductions, but also important in the subsequent stages of the invasion process. Due to the diverse range of species and the large number of propagules arriving with increasing inflow of horticultural stock, it is highly likely that at least some of them will be naturalized and ultimately become invasive in their new range. Although more attention has been paid to other introduction pathways such as deliberate introductions for ornamental purposes, this study indicates that plant species dispersed as contaminants of horticultural stock need to be better considered in invasion biology in order to reduce the threat they may present.

Supplementary materials

Fig. S1. Photographs of some of the recorded alien species and their habitats in the garden centres studied.
Table S1. Numbers of individuals of each species in different specific locations in garden centres and data on the traits of the species used in the analyses.

Supplementary materials are available at https://www.preslia.cz.

Acknowledgements

We are grateful to Edina Tóth-Szabó and Balázs Hubicska for their help in carrying out the surveys, and to Andrea McIntosh-Buday for her help with some trait measurements. The authors are thankful for the support of the National Research, Development and Innovation Office (PD 137747, KKP144068; K132573; MEC N 24 148930) and to the Bolyai János Scholarship of the Hungarian Academy of Sciences (BO/00587/23/8) during manuscript preparation.

References

Ansong M. & Pickering C. (2016) The effects of seed traits and fabric type on the retention of seed on different types of clothing. – Basic and Applied Ecology 17: 516–526.

Bartha D., Bán M., Schmidt D. & Tiborcz V. (2021+) Magyarország edényes növényfajainak online adatbázisa [Vascular Plants of Hungary Online Database]. – Soproni Egyetem Erdőmérnöki Kar, Sopron. URL: http://floraatlasz.uni-sopron.hu.

Baskin Y. (2002) The greening of horticulture: new codes of conduct aim to curb plant invasions. – BioScience 52: 464–471.

Bergey E. A., Figueroa L. L., Mather C. M., Martin R. J., Ray E. J., Kurien J. T., Westrop D. R. & Suriyawong P. (2014) Trading in snails: plant nurseries as transport hubs for non-native species. – Biological Invasions 16: 1441–1451.

Bienapfl J. C. & Balci Y. (2014) Movement of *Phytophthora* spp. in Maryland's nursery trade. – Plant Disease 98: 134–144.

Borhidi A. (1995) Social behaviour types, the naturalness and relative ecological indicator values of the higher plants in the Hungarian Flora. – Acta Botanica Hungarica 39: 97–181.

Bradley B. A., Blumenthal D. M., Early R., Grosholz E. D., Lawler J. J., Miller L. P., Sorte C. J. B., D'Antonio C. M., Diez J. M., Dukes J. S., Ibanez I. & Olden J. D. (2012) Global change, global trade, and the next wave of plant invasions. – Frontiers in Ecology and the Environment 10: 20–28.

Bradley B. A., Blumenthal D. M., Wilcove D. S. & Ziska L. H. (2010) Predicting plant invasions in an era of global change. – Trends in Ecology & Evolution 25: 310–318.

Brundu G., Brunel S. & Heywood V. (2011) The European code of conduct on horticulture and invasive alien plants. – In: Rindos E. (ed.), Plant invasions: policies, politics, and practices, p. 32–36, Proceedings of the 2010 Weeds Across Borders Conference, 1–4 June 2010, National Conservation Training Center, Shepherdstown, West Virginia, Montana State University, Center for Invasive Plant Management, Bozeman.

Buckley Y. M., Brockerhoff E., Langer L., Ledgard N., North H. & Rees M. (2005) Slowing down a pine invasion despite uncertainty in demography and dispersal. – Journal of Applied Ecology 42: 1020–1030.

Bullock J. M., Bonte D., Pufal G., da Silva Carvalho C., Chapman D. S., García C., García D., Matthysen E. & Delgado M. M. (2018) Human-mediated dispersal and the rewiring of spatial networks. – Trends in Ecology & Evolution 33: 958–970.

Chapman D. S., Makra L., Albertini R., Bonini M., Paldy A., Rodinkova V., Šikoparija B., Weryszko-Chmielewska E. & Bullock J. M. (2016) Modelling the introduction and spread of non-native species: international trade and climate change drive ragweed invasion. – Global Change Biology 22: 3067–3079.

Clark J. S., Silman M., Kern R., Macklin E. & HilleRisLambers J. (1999) Seed dispersal near and far: patterns across temperate and tropical forests. – Ecology 80: 1475–1494.

Clobert J., Baguette M., Benton M. J., Bullock J. M. & Ducatez S. (2012) Dispersal ecology and evolution. – Oxford University Press, Oxford.

Colautti R. I., Grigorovich I. A. & MacIsaac H. J. (2006) Propagule pressure: a null model for biological invasions. – Biological Invasion 8: 1023–1037.

Conn J. S., Stockdale C. A. & Morgan J. C. (2008) Characterizing pathways of invasive plant spread to Alaska: I. Propagules from container-grown ornamentals. – Invasive Plant Science and Management 1: 331–336.

Cross G. B. & Skroch W. A. (1992) Quantification of weed seed contamination and weed development in container nurseries. – Journal of Environmental Horticulture 10: 159–161.

Csiky J., Balogh L., Dancza I., Gyulai F., Jakab G., Király G., Lehoczky É., Mesterházy A., Pósa P. & Wirth T. (2023) Checklist of alien vascular plants of Hungary and their invasion biological characteristics. – Acta Botanica Hungarica 65: 53–72.

Dalmazzone S. & Giaccaria S. (2014) Economic drivers of biological invasions: a worldwide, bio-geographic analysis. – Ecological Economics 105: 154–165.

De Groote M. A., Pace N. R., Fulton K. & Falkinham III J. O. (2006) Relationships between *Mycobacterium* isolates from patients with pulmonary mycobacterial infection and potting soils. – Applied and Environmental Microbiology 72: 7602–7606.

Dehnen-Schmutz K., Touza J., Perrings C. & Williamson M. (2007) A century of the ornamental plant trade and its impact on invasion success. – Diversity and Distributions 13: 527–534.

Díaz S., Settele J., Brondízio E. S., Ngo H. T., Agard J., Arneth A., Balvanera P., Brauman K. A., Butchart S. H. M., Chan K. M. A., Garibaldi L. A., Ichii K., Liu J., Subramanian S. M., Midgley G. F., Miloslavich P., Molnár Z., Obura D., Pfaff A., Polasky S., Purvis A., Razzaque J., Reyers B., Chowdhury R. R., Shin Y.-J., Visseren-Hamakers I., Willis K. J. & Zayas C. N. (2019) Pervasive human-driven decline of life on Earth points to the need for transformative change. – Science 366: eaax3100.

Dudáš M., Bauer N., Eliáš P. Jr., Király A., Király G., Kis Sz., Molnár V. A. & Týr Š. (2025) New floristic records from Central Europe 15 (reports 222–231). – Thaiszia – Journal of Botany 35: 028–041.

Dullinger I., Wessely J., Bossdorf O., Dawson W., Essl F., Gattringer A., Klonner G., Kreft H., Kuttner M., Moser D., Pergl J., Pyšek P., Thuiller W., van Kleunen M., Weigelt P., Winter M. & Dullinger S. (2017) Climate change will increase the naturalization risk from garden plants in Europe. – Global Ecology and Biogeography 26: 43–53.

Dyer A. R., Cochran J. E., Phillips J. M., Layne K. I., Berry M. E. & Kule A. K. (2017) Bagged commercial soils are an avenue for regional dispersal of weedy plant species. – American Midland Naturalist 178: 275–283.

Early R., Bradley B. A., Dukes J. S., Lawler J. J., Olden J. D., Blumenthal D. M., Gonzalez P., Grosholz E. D., Ibañez I., Miller L. P., Sorte C. J. & Tatem A. J. (2016) Global threats from invasive alien species in the twenty-first century and national response capacities. – Nature Communications 7: 12485.

Ehrenfeld J. G. (2010) Ecosystem consequences of biological invasions. – Annual Review of Ecology, Evolution, and Systematics 41: 59–80.

Ellenberg H., Weber H. E., Düll R., Wirth V., Werner W. & Paulißen D. (1992) Zeigerwerte von Pflanzen in Mitteleuropa. – Scripta Geobotanica 18: 1–258.

Essl F., Bacher S., Blackburn T. M., Booy O., Brundu G., Brunel S., Cardoso A.-C., Eschen R., Gallardo B., Galil B., García-Berthou E., Genovesi P., Groom Q., Harrower C., Hulme P. E., Katsanevakis S., Kenis M., Kühn I., Kumschick S., Martinou A. F., Nentwig W., O'Flynn C., Pagad S., Pergl J., Pyšek P., Rabitsch W., Richardson D. M., Roques A., Roy H. E., Scalera R., Schindler S., Seebens H., Vanderhoeven S., Vilà M., Wilson J. R. U., Zenetos A. & Jeschke J. M. (2015) Crossing frontiers in tackling pathways of biological invasions. – BioScience 65: 769–782.

Euro+Med (2006+) [continuously updated] Euro+Med PlantBase: the information resource for Euro-Mediterranean plant diversity. – URL: https://europlusmed.org.

European Commission (2025) Commission Implementing Regulation (EU) 2025/1422 of 17 July 2025 amending Implementing Regulation (EU) 2016/1141 to update the list of invasive alien species of Union concern. – Official Journal of the European Union. URL: https://eur-lex.europa.eu/eli/reg_impl/2025/1422/oj

Florance D., Webb J. K., Dempster T., Kearney M. R., Worthing A. & Letnic M. (2011) Excluding access to invasion hubs can contain the spread of an invasive vertebrate. – Proceedings of the Royal Society B: Biological Sciences 278: 2900–2908.

Gallego P. P. F. & Lumbreras E. L. (2013) *Muntingia calabura* L. (*Muntingiaceae*), nueva especie exótica para la flora europea, introducida a través de sustratos de cultivo hortícola [*Muntingia calabura* L. (*Muntingiaceae*), new exotic species in European flora, introduced through horticulture]. – Bouteloua 15: 88–92.

Guo Q., Brown J. H., Valone T. J. & Kachman S. D. (2000) Constraints of seed size on plant distribution and abundance. – Ecology 81: 2149–2155.

Haubrock P. J., Turbelin A. J., Cuthbert R. N., Novoa A., Taylor N. G., Angulo E., Ballesteros-Mejia L., Bodey T. W., Capinha C., Diagne C., Essl F., Golivets M., Kirichenko N., Kourantidou M., Leroy B., Renault D., Verbrugge L. & Courchamp F. (2021) Economic costs of invasive alien species across Europe. – NeoBiota 67: 153–190.

Higgins S. I., Nathan R. & Cain M. L. (2003) Are long-distance dispersal events in plants usually caused by nonstandard means of dispersal? – Ecology 84: 1945–1956.

Hodkinson D. J. & Thompson K. (1997) Plant dispersal: the role of man. – Journal of Applied Ecology 34: 1484–1496.

Hoste I. & Verloove F. (2009) Mediterranean container plants and their stowaways: a potential source of invasive plant species. – Science Facing Aliens 11: 39–44.

Hoste I., Verloove F., Nagels C., Andriessen L. & Lambinon J. (2009) De adventievenflora van in België ingevoerde mediterrane containerplanten [The adventive flora of Mediterranean container plants imported into Belgium]. – Dumortiera 97: 1–16.

Hruševar D., Mesaroš J., Vladović D., Vucić A., Belamarić I., Surać L. & Mitić B. (2021) *Cardamine occulta* Hornem. – a new concealed alien plant in the flora of Croatia. – Natura Croatica: Periodicum Musei Historiae Naturalis Croatici 30: 207–215.

Hulme P. E. (2009) Trade, transport and trouble: managing invasive species pathways in an era of globalization. – Journal of Applied Ecology 46: 10–18.

Hulme P. E., Brundu G., Carboni M., Dehnen-Schmutz K., Dullinger S., Early R. & Verbrugge L. N. (2018) Integrating invasive species policies across ornamental horticulture supply chains to prevent plant invasions. – Journal of Applied Ecology 55: 92–98.

Hulme P. E., Ikeda T., Vandvik V., Blanchard R., Camacho-Cervantes M., Herrera I., Koyama A., Morales C. L., Munishi L. K., Pallewatta P. K. T. N. S., Per E., Pergl J., Ricciardi A. & Xavier R. O. (2023) Chapter 3: Drivers affecting biological invasions. – In: Roy H. E., Pauchard A., Stoett P. & Renard Truong T. (eds), Thematic Assessment Report on Invasive Alien Species and their Control of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, p. 266–388, IPBES secretariat, Bonn. URL: https://doi.org/10.5281/zenodo.7430727.

Jenkins P. T. (1996) Free trade and exotic species introductions. – Conservation Biology 10: 300–302.

Jordano P. (2017) What is long-distance dispersal? And a taxonomy of dispersal events. – Journal of Ecology 105: 75–84.

Jung T., Orlikowski L., Henricot B., Abad-Campos P., Aday A. G., Aguín Casal O., Bakonyi J., Cacciola S. O., Cech T., Chavarriaga D., Cravador A. & Wenneker M. (2016) Widespread *Phytophthora* infestations in European nurseries put forest, semi-natural and horticultural ecosystems at high risk of *Phytophthora* diseases. – Forest Pathology 46: 134–163.

Kalusová V., Čeplová N., Danihelka J., Večeřa M., Pyšek P., Albert A., Anastasiu P., Biurrun I., Boch S., Cottaz C., Essl F., Kuzemko A., Maslo S., Mifsud S., Protopopova V. V., Shevera M., Sîrbu C., Svenning J. C., Welk E. & Axmanová I. (2024) Alien plants of Europe: an overview of national and regional inventories. – Preslia 96: 149–182.

Kenis M., Rabitsch W., Auger-Rozenberg M. A. & Roques A. (2007) How can alien species inventories and interception data help us prevent insect invasions? – Bulletin of Entomological Research 97: 489–502.

Király G., Hohla M. & Nikolić T. (2021) Novelties in the vascular flora of Croatia. – Natura Croatica: Periodicum Musei Historiae Naturalis Croatici 30: 173–189.

Kleyer M., Bekker R. M., Knevel I. C., Bakker J. P., Thompson K., Sonnenschein M., Poschlod P., Van Groenendael J. M., Klimeš L., Klimešová J., Klotz S., Rusch G. M., Hermy M., Adriaens D., Boedeltje G., Bossuyt B., Dannemann A., Endels P., Götzenberger L., Hodgson J. G., Jackel A.-K., Kühn I., Kunzmann D., Ozinga W. A., Römermann C., Stadler M., Schlegelmilch J., Steendam H. J., Tackenberg O., Wilmann B., Cornelissen J. H. C., Eriksson O., Garnier E. & Peco B. (2008) The LEDA Traitbase: a database of life-history traits of the Northwest European flora. – Journal of Ecology 96: 1266–1274.

Kolbe J. J., Glor R. E., Rodríguez Schettino L., Lara A. C., Larson A. & Losos J. B. (2004) Genetic variation increases during biological invasion by a Cuban lizard. – Nature 431: 177–181.

Kot M., Lewis M. A. & van den Driessche P. (1996) Dispersal data and the spread of invading organisms. – Ecology 77: 2027–2042.
Kovács D., Málnási-Csizmadia G., Somlyai M., Táborská J. & Tálas L. M. (2023) Data on spreading cultivated species in Hungarian botanical gardens. – Kitaibelia 28: 62–78.
Lazányi E., Boll P. K., Páll-Gergely B., Simon J., Szeder K. H., Turóci A. & Katona G. (2024) First records of alien land planarians (Platyhelminthes: *Geoplanidae*) in Hungary. – Zootaxa 5403: 592–596.
Leishman M. R., Haslehurst T., Ares A. & Baruch Z. (2007) Leaf trait relationships of native and invasive plants: community-and global-scale comparisons. – New Phytologist 176: 635–643.
Leostrin A. V. & Mayorov S. R. (2019) Current state and distribution of alien weedy *Cardamine occulta* Hornem. (*Brassicaceae*) in European Russia. – Russian Journal of Biological Invasions 10: 236–245.
Letnic M., Webb J. K., Jessop T. S. & Dempster T. (2015) Restricting access to invasion hubs enables sustained control of an invasive vertebrate. – Journal of Applied Ecology 52: 341–347.
Levin S. A., Muller-Landau H. C., Nathan R. & Chave J. (2003) The ecology and evolution of seed dispersal: a theoretical perspective. – Annual Review of Ecology, Evolution, and Systematics 34: 575–604.
Levine J. M. & D'Antonio C. M. (2003) Forecasting biological invasions with increasing international trade. – Conservation Biology 17: 322–326.
Liebhold A. M., Brockerhoff E. G., Garrett L. J., Parke J. L. & Britton K. O. (2012) Live plant imports: the major pathway for forest insect and pathogen invasions of the US. – Frontiers in Ecology and the Environment 10: 135–143.
Lockwood J. L., Cassey P. & Blackburn T. (2005) The role of propagule pressure in explaining species invasions. – Trends in Ecology & Evolution 20: 223–228.
Lukács K., Tóth Á., Kiss R., Deák B., Rádai Z., Tóth K., Kelemen A., Bátori Z., Hábenczyus A. A., Tölgyesi C., Miglécz T., Godó L. & Valkó O. (2024) The ecological footprint of outdoor activities: factors affecting human-vectored seed dispersal on clothing. – Science of the Total Environment 906: 167675.
Molnár V. A., Kis S., Molnár C., Bak H., Fekete R., Kozma-Bognár T., Sonkoly J., Süveges K. & Takács A. (2024) Adatok idegenhonos növényfajok ismeretéhez Magyarországon [Data on alien vascular plant species in Hungary] I. (1–6). – Kitaibelia 29: 65–80.
Montagnani C., Gentili R., Brundu G., Caronni S. & Citterio S. (2022) Accidental introduction and spread of top invasive alien plants in the European Union through human-mediated agricultural pathways: what should we expect? – Agronomy 12: 423.
Moody M. E. & Mack R. N. (1988) Controlling the spread of plant invasions: the importance of nascent foci. – Journal of Applied Ecology 25: 1009–1021.
Nathan R. (2006) Long-distance dispersal of plants. – Science 313: 786–788.
Niklfeld H. (1971) Bericht über die Kartierung der Flora Mitteleuropas. – Taxon 20: 545–571
Páll-Gergely B., Fehér Z. & Čejka T. (2020) New records of the Mediterranean land snail *Massylaea vermiculata* (O. F. Müller, 1774) in Hungary and Slovakia. – Folia Malacologica 28: 337–341.
Paulose J. & Hallatschek O. (2020) The impact of long-range dispersal on gene surfing. – Proceedings of the National Academy of Sciences of the United States of America 117: 7584–7593.
Pergl J., Sádlo J., Petřík P., Danihelka J., Chrtek J. Jr., Hejda M., Moravcová L., Perglová I., Štajerová K. & Pyšek P. (2016) Dark side of the fence: ornamental plants as a source of wild-growing flora in the Czech Republic. – Preslia 88: 163–184.
Perrings C., Dehnen-Schmutz K., Touza J. & Williamson M. (2005) How to manage biological invasions under globalization. – Trends in Ecology & Evolution 20: 212–215.
Pierce S., Bottinelli A., Bassani I., Ceriani R. M. & Cerabolini B. E. (2014) How well do seed production traits correlate with leaf traits, whole-plant traits and plant ecological strategies? – Plant Ecology 215: 1351–1359.
Pliszko A. (2020) First record of Asian *Cardamine occulta* Hornem. (*Brassicaceae*) in Poland. – BioInvasions Records 9: 655–659.
Pyšek P., Hulme P. E., Simberloff D., Bacher S., Blackburn T. M., Carlton J. T., Dawson W., Essl F., Foxcroft L. C., Genovesi P., Jeschke J. M., Kühn I., Liebhold A. M., Mandrak N. E., Meyerson L. A., Pauchard A., Pergl J., Roy H. E., Seebens H., van Kleunen M., Vilà M., Wingfield M. J. & Richardson D. M. (2020) Scientists' warning on invasive alien species. – Biological Reviews 95: 1511–1534.
R Core Team (2023) R: A language and environment for statistical computing. – R Foundation for Statistical Computing, Vienna. URL: https://www.R-project.org.
Rigó A., Malatinszky Á. & Barina Z. (2023) Inventory of the urban flora of Budapest (Hungary) highlighting new and noteworthy floristic records. – Biodiversity Data Journal 11: e110450.
Rout T. M., Moore J. L., Possingham H. P. & McCarthy M. A. (2011) Allocating biosecurity resources between preventing, detecting, and eradicating island invasions. – Ecological Economics 71: 54–62.

Setsuko S., Sugai K., Tamaki I., Takayama K., Kato H. & Yoshimaru H. (2020) Genetic diversity, structure, and demography of *Pandanus boninensis* (*Pandanaceae*) with sea drifted seeds, endemic to the Ogasawara Islands of Japan: comparison between young and old islands. – Molecular Ecology 29: 1050–1068.

Shea K., Jongejans E., Skarpaas O., Kelly D. & Sheppard A. W. (2010) Optimal management strategies to control local population growth or population spread may not be the same. – Ecological Applications 20: 1148–1161.

Simberloff D., Martin J. L., Genovesi P., Maris V., Wardle D. A., Aronson J., Courchamp F., Galil B., García-Berthou E., Pascal M., Pyšek P., Sousa R., Tabacchi E. & Vilà M. (2013) Impacts of biological invasions: what's what and the way forward. – Trends in Ecology & Evolution 28: 58–66.

Šlenker M., Zozomová-Lihová J., Mandáková T., Kudoh H., Zhao Y., Soejima A., Yahara T., Skokanová K., Španiel S. & Marhold K. (2018) Morphology and genome size of the widespread weed *Cardamine occulta*: how it differs from cleistogamic *C. kokaiensis* and other closely related taxa in Europe and Asia. – Botanical Journal of the Linnean Society 187: 456–482.

Šlenker M., Zozomová-Lihová J. & Marhold K. (2019) *Cardamine occulta*: inconspicuous neophyte in Slovakia. – Bulletin Slovenskej botanickej spoločnosti 41: 13–23.

Smith A. L., Hodkinson T. R., Villellas J., Catford J. A., Csergő A. M., Blomberg S. P., Crone E. E., Ehrlén J., Garcia M. B., Laine A.-L., Roach D. A., Salguero-Gómez R., Wardle G. M., Childs D. Z., Elderd B. D., Finn A., Munné-Bosch S., Baudraz M. E. A., Bódis J., Brearley F. Q., Bucharova A., Caruso C. M., Duncan R. P., Dwyer J. M., Gooden B., Groenteman R., Hamre L. N., Helm A., Kelly R., Laanisto L., Lonati M., Moore J. L., Morales M., Olsen S. L., Pärtel M., Petry W. K., Ramula S., Rasmussen P. U., Enri S. R., Roeder A., Roscher C., Saastamoinen M., Tack A. J. M., Töpper J. P., Vose G. E., Wandrag E. M., Wingler A. & Buckley Y. M. (2020) Global gene flow releases invasive plants from environmental constraints on genetic diversity. – Proceedings of the National Academy of Sciences of the United States of America 117: 4218–4227.

Sonkoly J., Takács A., Molnár A. & Török P. (2022) Trade of commercial potting substrates: a largely overlooked means of the long-distance dispersal of plants. – Science of Total Environment 825: 154093.

Sonkoly J., Tóth E., Balogh N., Balogh L., Bartha D., Csendesné Bata K., Bátori Z., Békefi N., Botta-Dukát Z., Bölöni J., Csecserits A., Csiky J., Csontos P., Dancza I., Deák B., Dobolyi Z. K., E-Vojtkó A., Gyulai F., Hábenczyus A. A., Henn T., Horváth F., Höhn M., Jakab G., Kelemen A., Király G., Kis S., Kovacsics-Vári G., Kun A., Lehoczky É., Lengyel A., Lhotsky B., Löki V., Lukács B. A., Matus G., McIntosh-Buday A., Mesterházy A., Miglécz T., Molnár V. A., Molnár Z., Morschhauser T., Papp L., Pósa P., Rédei T., Schmidt D., Szmorad F., Takács A., Tamás J., Tiborcz V., Tölgyesi C., Tóth K., Tóthmérész B., Valkó O., Virók V., Wirth T. & Török P. (2023) PADAPT 1.0–the Pannonian dataset of plant traits. – Scientific Data 10: 742.

Suarez A. V., Holway D. A. & Case T. J. (2001) Patterns of spread in biological invasions dominated by long-distance jump dispersal: insights from Argentine ants. – Proceedings of the National Academy of Sciences of the United States of America 98: 1095–1100.

Takács A., Wirth T., Schmotzer A., Gulyás G., Jordán S., Süveges K., Virók V. & Somlyay L. (2020) *Cardamine occulta* Hornem. in Hungary, and other stowaways of the ornamental plant trade. – Kitaibelia 25: 195–214.

Taylor K., Brummer T., Taper M. L., Wing A. & Rew L. J. (2012) Human-mediated long-distance dispersal: an empirical evaluation of seed dispersal by vehicles. – Diversity and Distributions 18: 942–951.

Thompson K. B. S. R., Band S. R. & Hodgson J. G. (1993) Seed size and shape predict persistence in soil. – Functional Ecology 7: 236–241.

Tremlová K. & Münzbergová Z. (2007) Importance of species traits for species distribution in fragmented landscapes. – Ecology 88: 965–977.

van Kleunen M., Essl F., Pergl J., Brundu G., Carboni M., Dullinger S., Early R., González-Moreno P., Groom Q. J., Hulme P. E., Kueffer C., Kühn I., Máguas C., Maurel N., Novoa A., Parepa M., Pyšek P., Seebens H., Tanner R., Touza J., Verbrugge L., Weber E., Dawson W., Kreft H., Weigelt P., Winter M., Klonner G., Talluto M. V. & Dehnen-Schmutz K. (2018) The changing role of ornamental horticulture in plant invasions. – Biological Reviews 93: 1421–1437.

Vilà M., Espinar J. L., Hejda M., Hulme P. E., Jarošík V., Maron J. L., Pergl J., Schaffner U., Sun Y. & Pyšek P. (2011) Ecological impacts of invasive alien plants: a meta-analysis of their effects on species, communities and ecosystems. – Ecology Letters 14: 702–708.

Vilà M. & Pujadas J. (2001) Land-use and socio-economic correlates of plant invasions in European and North African countries. – Biological Conservation 100: 397–401.

von der Lippe M. & Kowarik I. (2007) Long-distance dispersal of plants by vehicles as a driver of plant invasions. – Conservation Biology 21: 986–996.

Westphal M. I., Browne M., MacKinnon K. & Noble I. (2008) The link between international trade and the global distribution of invasive alien species. – Biological Invasions 10: 391–398.
With K. A. (2002) The landscape ecology of invasive spread. – Conservation Biology 16: 1192–1203.
Wright I. J., Reich P. B., Westoby M., Ackerly D. D., Baruch Z., Bongers F., Cavender-Bares J., Chapin T., Cornelissen J. H. C., Diemer M., Flexas J., Garnier E., Groom P. K., Gulias J., Hikosaka K., Lamont B. B., Lee T., Lee W., Lusk C., Midgley J. J., Navas M. L., Niinemets U., Oleksyn J., Osada N., Poorter H., Poot P., Prior L., Pyankov V. I., Roumet C., Thomas S. C., Tjoelker M. G., Veneklaas E. J. & Villar R. (2004) The worldwide leaf economics spectrum. – Nature 428: 821–827.
Wu Z. Y., Milne R. I., Liu J., Nathan R., Corlett R. T. & Li D. Z. (2023) The establishment of plants following long-distance dispersal. – Trends in Ecology & Evolution 38: 289–300.
Zhao L. P., Wu G. L. & Cheng J. M. (2011) Seed mass and shape are related to persistence in a sandy soil in northern China. – Seed Science Research 21: 47–53.

Zahradní centra jako zdroj neúmyslného zavlékání nepůvodních rostlin a lokálních invazí – případová studie z Maďarska

Rostoucí globální zahradnický obchod hraje klíčovou roli při zavlékání nepůvodních druhů rostlin do nových oblastí, mimo jiné proto, že s sebou nese i neúmyslné šíření mnoha druhů na velké vzdálenosti. V Maďarsku jsme provedli systematický terénní průzkum dvanácti zahradních center, zaměřený na posouzení jejich role v neúmyslném zavlékání invazních druhů rostlin. Zaznamenali jsme všechny jedince nepůvodních druhů v květináčích a kontejnerech rostlin určených k prodeji i na všech vnitřních a venkovní plochách, jako jsou záhony, nezakryté i zakryté povrchy, dlažební spáry, trávníky a další plochy s vegetací. Celkem jsme zaznamenali 93 788 jedinců 67 nepůvodních druhů, sedm z nich bylo pro Maďarsko nových. Navzdory malé rozloze hostila studovaná zahradní centra značný podíl místní nepůvodní flóry, u mnoha druhů byly navíc zjištěny početné populace, což ukazuje, že nepůvodní rostliny v zahradních centrech mohou představovat zdroj lokálních invazí. Nepůvodní rostliny a jejich semena v kontejnerech s okrasnými rostlinami jsou navíc pravděpodobně zákazníky transportovány na velké vzdálenosti. Přes omezený rozsah tohoto výzkumu výsledky ukazují, že zahradnický obchod může fungovat nejen jako zdroj introdukcí rostlin, ale potenciálně může ovlivňovat i následné fáze invazního procesu.

How to cite: Sonkoly J., Molnár V. A., Török P., Süveges K. & Takács A. (2025) Nurseries and garden centres act as hubs of alien plant invasions: a case study from Hungary. – Preslia 97: 659–675.

Preslia, a journal of the Czech Botanical Society

https://www.preslia.cz