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ORIGINAL RESEARCH PAPER

Invasive flora within urban railway areas: a case study from Lublin (Poland) and Lviv (Ukraine)

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Abstract

Heterogeneous and disturbed habitats within railway areas create an ideal environment for establishment of invasive plant species. In this study, we compared the invasive species composition and abundance within railway areas of two cities, Lublin, SE Poland and Lviv, W Ukraine. In total, 70 invasive species were recorded. The invasive species list was similar for the two cities, with the most invasive species occurring at both (81.4%), 8.5% occurring only in Lublin and 10% only in Lviv. The proportion of invasive species in the total flora was almost 1.5-fold higher at Lviv compared to Lublin. Invasive species have originated mainly from continental America (45.7%), followed by Asia and Eurasia. The participation of invasive plants derived from Asia and Eurasia at Lviv is higher than at Lublin. The invasive flora includes a wide range of taxonomic groups, with a predominance of Asteraceae and Poaceae. The ecological attributes of invasive species on railway areas are: mainly annual therophytes, mostly wind- and insect pollination modes, a predominance of generative reproduction, anthropochorous and anemochorous dispersal and short-term persistent, long-term persistent or transient seed banks.

Keywords

vascular flora; native species; neophytes; invasive species; biological traits

Introduction

Invasions of plant species are considered among global problems which impair biodiversity in man-made and natural and seminatural ecosystems [1]. The great spread of invasive plant species is documented worldwide [2–4] and shows an increasing trend observed in Europe of the proportion of neophytes (alien species brought to Europe post-1500) in the total flora, and a decreasing or stable trend in the number of archaeophytes (alien species brought to Europe pre-1500) [5–7]. The spread of invasive neophytes is believed to be associated with human activity, i.e., urban development, human settlements, private gardening and the introduction of exotic ornamental plants, transportation of people and goods, and the development of industrial areas [8,9]. Transport of plant species by humans is the most important agency, even more effective than natural mechanisms of dispersion [10,11]. It is generally accepted that invasive species richness and their population density both increase with increasing levels of human disturbance [12]. Evidence shows that the greater the number of transport links within an urban area, the greater the impact on increased risk from invasive species, as these usually spread along linear corridors, notably roads and railway lines [13].

Within an urban area, railways represent a special situation providing an exceptionally vulnerable environment for establishment of neophytes and plant invasions [14–16]. In railway areas, both the high level of habitat disturbance and heterogeneity create specific conditions for a distinctive flora and vegetation development [17]. In Europe, the development of railway transport was encouraged by the technological innovations of the Industrial Revolution [18]. In the modern landscape (both urban and rural), railways form networks and promote development of an area and its economy, i.e., the production, distribution, trade and consumption of goods and provisioning services [19]. Railway transport systems with associated structures (e.g., tunnels, bridges) can also encourage biodiversity in an urban environment [20]. These structures create new habitats and provide valuable conditions for the activity of animals and/or the occurrence of diverse plant species [16,21,22]. However, there are also many negative impacts of railway areas on the environment such as habitat loss and fragmentation, destruction of habitat conditions, pollution, creation of barriers to the reproductive and food niches of organisms [23]. Even though a predominance of native species has been reported in railway areas, the proportion of alien species is higher than that in domestic floras [22].

The distribution of species is limited by abiotic factors such as altitude, temperature, soil type, soil nutrients, and moisture [24]. These physical conditions also directly determine the environment for establishment and survival (reproductive success, seedling recruitment, growth) of plant species outside their distributional range [25,26]. In the last decade, many studies have discussed the potential impact of climate change on the risk of plant invasions [27,28].

In this study, we build on earlier work and report an analysis of the flora of intraurban railway areas located in the cities of Lublin and Lviv [29–31]. In particular, we compared the richness and abundance of the invasive alien plants recorded within railway areas. We analyzed data on taxonomy, geographical/historical status, and biological and ecological traits of native, alien, and invasive flora. This information will contribute to the knowledge and understanding of the specificity of both urban and railway floras.

Material and methods

Field survey

The flora developed within railway areas of the two cities separated by approximately 220 km was explored between 2014–2016 (Fig. 1). Lublin (51°19′ – 51°10′ N and 23°36′ – 23°14′ E, 170–220 m a.s.l.) is sited on the Lublin-Lviv Upland, Poland. Within the city, a number of valleys, loess gorges, and flat areas are present [32]. Lviv (49°50′ N latitude and 24°00′ E longitude, 320–382 m a.s.l., Ukraine) is located at the intersection of four physiographic regions – the Davydov Plateau, Lviv Plateau, Ukrainian Roztocze, and ridged Pobuzhya [33]. Lublin has an area of ~147 km^2 with approximately 349 000 inhabitants, and Lviv 182 km^2 with approximately 730 270 inhabitants. Long-term climatic conditions differ slightly between the cities; the annual average air temperatures recorded for Lublin and Lviv are 8.0 and 8.9°C, and the precipitation 537.9 and 748 mm, respectively. The railway tracks in both cities have been developed since the midnineteenth century.

Data collection

The flora occurring on railway areas in both cities was recorded between May and September. Floristic data were collected during walks along 90 random transects approximately 300 m long and 2–3 m wide. The relative frequency (the number of times a species was present in transects expressed as a percentage) and the abundance (mean cover) were calculated for all species. Frequency data for the invasive species outside the railway areas in Lublin were available from Rysiak [34], and for Lviv from Mamchur and Chuba [35]. The composition of the floras was analyzed taking into consideration plant family, geographical status, species origin [3,36,37], and biological traits: life-span,

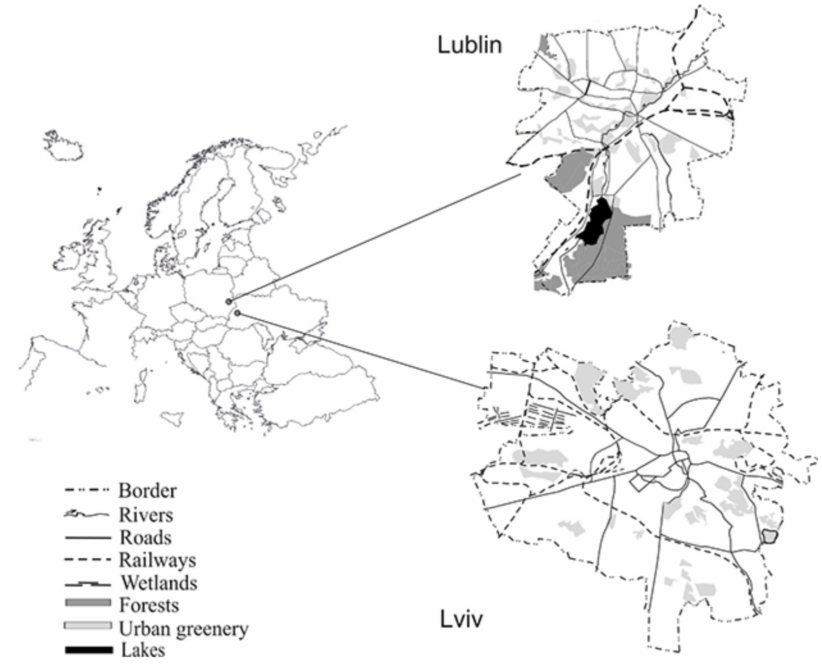

Fig. 1 The railway networks within research area of Lublin (Poland) and Lviv (Ukraine).

Raunkiær life form, pollination agent, type of reproduction, seed dispersal, nature of seed bank (BiolFlor and Traitbase) [38,39]. Native, alien, and invasive status were established for Lublin according to Tokarska-Guzik et al. [3], and for Lviv according to Protopopova et al. [40,41]. The taxonomy and plant nomenclature follow those by Mirek et al. [42].

Results

In total, 509 vascular plant species were recorded on the railway areas (Lublin, 447 and Lviv 371 species; Tab. 1). Native species predominated; 293 (65.5% of the flora) in Lublin and 230 (61.9% of total flora) in Lviv. Alien species constituted 34.4% of the railway flora in Lublin and 36.8% in Lviv. In total, 70 invasive species were recorded. For Lublin, the invasive species comprised 39 (8.7%) of the recorded railway flora. In Lviv, 57 invasive species (15.4%) of the railway flora were noted.

Tab. 1 The richness of native, alien, and invasive plant species found on railway areas within Lublin (Poland) and Lviv (Ukraine).

	Native species	Alien species	Invasive species
Number of species	336	173	70
Number of species per transect (mean ± *SD*)	62.7 ±18.5	23.73 ±6.5	14.1 ±4.4
Mean cover per transect (%) (min–max)	65.5 (51.3–80.5)	20.15 (10.7–35.2)	6.7 (3.7–28.9)

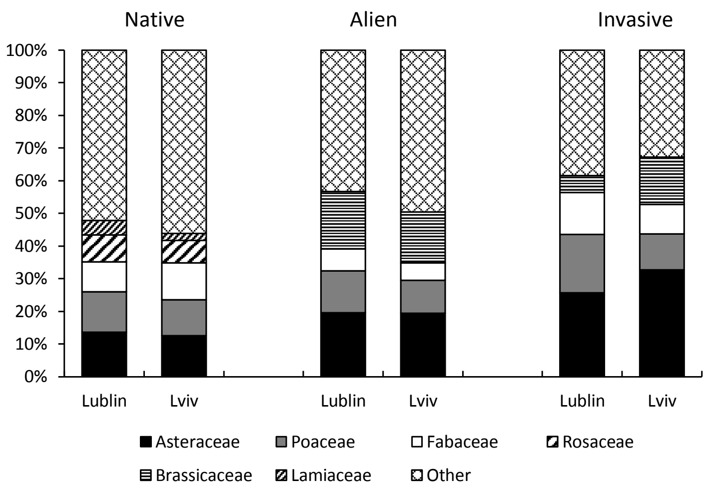

Fig. 2 The taxonomic structure of native, alien and invasive plant species noted in railway flora of Lublin (Poland) and Lviv (Ukraine).

The species in the entire data set belonged to 64 families. Alien flora was represented by 36 families and 117 genera and the invasive flora by 27 families. For both cities, the families with the largest number of invasive species were the Asteraceae (19 species, 27.1% of invasive species), Brassicaceae (10 species, 14.3% of invasive species), Poaceae (eight species, 11.4% of invasive species), and Fabaceae (five species, 7.1% of invasive species; Fig. 2). A total of 21 families (77.7%) were represented by only one invasive species.

Amongst the invasive species, 58 were recorded both within railway areas in Lublin and Lviv. Several invasive species, i.e., *Bromus carinatus* Hook. & Arn., *Cannabis ruderalis* L., *Clematis vitalba* L., *Eragrostis albensis* H. Scholz, and *Vicia grandiflora* Scop. (Fig. 3a) were recorded only in Lublin (Tab. 2). *Atriplex nitens* Schrank (invasive in the Ukraine, noninvasive in Poland) was also noted exclusively in Lublin. In contrast, *Ambrosia*

Fig. 3 Invasive species noted on railway areas: *Vicia grandiflora* Scop. (**a**), *Ambrosia artemisiifolia* L. (**b**), *Helianthus tuberosus* L. (**c**), *Impatiens parviflora* DC. (**d**), *Geranium sibiricum* L. (**e**), *Rumex confertus* Willd. (**f**), *Amaranthus albus* L. (**g**), *Erigeron annuus* (L.) Pers. (**h**).

Tab. 2 The list of invasive species, their relative frequency in all transects (%), and relative abundance (%) in railway areas in Lublin (Poland) and in Lviv (Ukraine) and outside of railway areas.

	Lublin (n = 45)		Lviv (n = 45)		Occurrence in railway areas zones				Frequency outside railway areas
Species	RF	RA	RF	RA	RT	RS	CY	EM	Lublin/Lviv
Acer negundo L.	36.7	6.1	40.0	6.1		x		x	6/6
Amaranthus albus L.*	13.3	2.5	23.3	3.5	x				1/1
Amaranthus blitoides S. Watson*	6.7	1.3	20.0	2.5	x				1/1
Amaranthus retroflexus L.	43.3	7.5	50.0	7.6	x	x	x	x	6/5
Ambrosia artemisiifolia L.		-	83.3	9.5	x	x	x	x	0/3
Amorpha fruticosa L.*			10.0	5.5				x	1/1
Artemisia absinthium L.*	36.7	8.3	33.3	8.3		x		x	3/3
Aster novi-belgii L.**	16.7	7.7	10.0	7.8		x		x	2/2
Aster ×salignus Willd.	20.0	8.6	13.3	8.6		x		x	3/2
Atriplex nitens Schrank*	23.3	8.8	-	-		x		x	5/3
Avena fatua L.	16.7	5.0	6.7	2.5	x	x			4/1
Ballota nigra L.*	43.3	5.7	26.7	5.7	x	x		x	6/5
Bromus carinatus Hook. & Arn.**	23.3	6.7	-	-		x		x	4/3
Bromus tectorum L.*	56.7	15.0	23.3	10.7	x	x	x	x	4/3
Bunias orientalis L.	40.0	9.8	40.0	7.8		x		x	4/3
Cannabis ruderalis L.*	6.7	2.5	-	-				x	3/1
Capsella bursa-pastoris (L.) Medik.	76.7	5.3	70.0	5.3	x	x	x	x	6/6
Cardaria draba (L.) Desv.*	13.3	9.8	20.0	7.8		x	x	x	3/3
Carduus acanthoides L.*	16.7	2.5	23.3	4.3		x		x	4/3
Centaurea diffusa Lam.*	10.0	5.0	26.7	2.5	x				3/2
Chamomilla suaveolens (Pursh) Rydb.*	20.0	6.4	20.0	6.4			x	x	6/5
Clematis vitalba L.**	6.7	5.3	-	-				x	2/1
Conyza canadensis (L.) Cronquist	63.3	9.3	66.7	10.7	x	x	x	x	6/6
Descurania sophia (L.)Webb ex Prantl*	13.3	3.5	20.0	2.5	x	x	x	x	4/4
Diplotaxis muralis (L.) DC.**	20.0	5.5	13.3	5.7	x	x	x	x	5/4
Echinochloa crus-galii (L.) P. Beauv.	23.3	5.7	26.7	5.7		x	x	x	6/6
Echinocystis lobata (F. Michx.) Torr. & A. Gray Gray	43.3	10.3	10.0	5.3		x		x	6/4
Elaeagnus angustifolia L.	-	-	10.0	2.5				x	2/3
Epilobium ciliatum Raf.	10.0	7.5	26.7	3.5	x	x			3/3
Eragrostis albensis H. Scholz**	10.0	5.0	-	-	x		x		3/0
Erigeron annuus (L.) Pers.	80.0	9.9	60.0	8.8	x	x	x	x	6/6

Tab. 2 Continued

Species	Lublin (*n* = 45) RF	Lublin (*n* = 45) RA	Lviv (*n* = 45) RF	Lviv (*n* = 45) RA	Occurrence in railway areas zones RT	RS	CY	EM	Frequency outside railway areas Lublin/Lviv
Fraxinus pennsylvanica Marshall	-	-	6.7	2.5				x	0/2
Galinsoga ciliata (Raf.) S. F. Blake	33.3	6.4	33.3	6.4	x	x	x	x	6/6
Galinsoga parviflora Cav.	33.3	5.0	26.7	5.0	x	x	x	x	6/6
Geranium sibiricum L.*	13.3	9.5	36.7	6.5	x	x			1/3
Helianthus tuberosus L.	33.3	9.7	10.0	9.7				x	4/3
Heracleum sosnowskyi Manden.	-	-	26.7	5.3		x		x	1/4
Hordeum murinum L.	23.3	8.9	40.0	7.1	x		x		4/3
Impatiens parviflora DC.	60.0	5.8	33.3	5.8	x	x			4/5
Iva xantiifolia Nutt.*	16.7	7.2	33.3	9.4				x	2/2
Juglans regia L.**	16.7	5.0	26.7	5.0				x	2/3
Juncus tenuis Willd.**	26.7	6.4	13.3	3.6		x	x		2/1
Lepidium densiflorum Schrad.*	33.3	1.5	16.7	5.3	x	x	x	x	3/3
Lepidium ruderale L.*	60.0	2.6	46.7	2.5	x	x	x	x	6/4
Lupinus polyphyllus Lindl.	23.3	7.2	6.7	14.4				x	3/2
Lycium barbarum Aiton	10.0	10.7	16.7	8.3				x	3/2
Malva neglecta Wallr.*	-	-	16.7	3.7			x	x	3/3
Matricaria maritima L. ssp. *inodora* (L.) Dostal*	80.0	2.6	86.7	5.0	x	x	x	x	6/5
Oxalis fontana Bunge	46.7	8.3	16.7	9.4	x	x			4/2
Papaver rhoeas L.*	53.3	6.3	13.3	3.6	x	x			6/6
Parthenocissus inserta (A. Kern.) Fritsch	23.3	10.0	13.3	7.1		x		x	4/4
Portulaca oleracea L. ssp. *oleracea**	20.0	8.5	46.7	5.3	x		x		3/3
Quercus rubra L.	23.3	3.6	3.3	2.6				x	3/3
Reynoutria japonica Houtt.	10.0	10.5	16.7	10.7				x	3/4
Rhus typhina L.	6.7	9.4	13.3	8.3				x	2/2
Robinia pseudoacacia L.	20.0	5.0	3.3	2.6				x	4/5
Rosa rugosa Thunb.**	43.3	9.4	16.7	9.4		x		x	3/3
Rumex confertus Willd.**	43.3	6.7	20.0	7.3		x	x	x	3/3
Senecio vulgaris L.*	40.0	3.7	30.0	3.6	x	x			6/6
Setaria pumila (Poir) Roem & Schult.	56.7	8.3	43.3	8.3	x	x	x	x	6/5
Setaria viridis (L.) P. Beauv.	63.3	8.3	43.3	8.3	x	x	x	x	6/5
Sinapis arvensis L.*	13.3	2.5	20.0	2.5			x	x	4/3
Sisymbrium loeselii L.*	46.7	8.3	10.0	6.3	x	x	x	x	6/5

Tab. 2 Continued

Species	Lublin (*n* = 45)		Lviv (*n* = 45)		Occurrence in railway areas zones				Frequency outside railway areas
	RF	RA	RF	RA	RT	RS	CY	EM	Lublin/Lviv
Sisymbrium wolgense M. Bieb. ex E. Fourn.*	6.7	2.5	13.3	2.5		x			1/0
Solidago canadensis L.	20.0	7.4	40.0	10.7				x	4/5
Solidago gigantea Aiton	73.3	9.8	20.0	9.8				x	5/5
Sonchus asper (L.) Hill*	23.3	8.3	13.3	2.5				x	4/4
Sonchus oleraceus L.*	40.0	2.5	16.7	2.5				x	6/5
Vicia grandiflora Scop.**	16.7	5.2	-	-	x	x		x	1/0
Vicia villosa Roth*	20.0	5.7	16.7	5.3					4/3

Species: ** – invasive only in Poland; * – invasive only in Ukraine; RF – relative frequency; RA – relative abundance. Occurrence in railway areas: x – present; RT – railway tracts; RS – railway siding; CY – cargo yards; EM – embankments. Frequency outside of railway areas: 1 – sporadic species; 2 – rare; 3 – dispersed; 4 – frequent; 5 – very frequent; 6 – common. The frequency outside the railway areas have been given for Lublin according to Rysiak [34] and for Lviv according to Mamchur and Chuba [35].

artemisiifolia L. (Fig. 3b), *Amorpha fruticosa* L., *Fraxinus pennsylvanica* Marshall, *Heracleum sosnowskyi* Manden., *Elaeagnus angustifolia* L., and *Malva neglecta* Wallr. were found exclusively in Lviv.

The frequency of occurrence and abundance of invasive species are shown in Tab. 2. In Lublin, the most abundant populations of invasive plants were of *Acer negundo* L., *Echinocystis lobata* (F. Michx.) Torr. & A. Gray, *Helianthus tuberosus* L. (Fig. 3c), *Impatiens parviflora* DC. (Fig. 3d), *Reynoutria japonica* Houtt., *Rosa rugosa* Thunb., and *Solidago gigantea* Aiton. In Lviv, the most numerous populations recorded were of *Ambrosia artemisiifolia* L., *Geranium sibiricum* L. (Fig. 3e), *Iva xanthiifolia* Nutt., *Solidago canadensis* L., and *Rumex confertus* Willd. (Fig. 3f). In Lublin, a particularly high frequency was found for *Acer negundo* L., *Bunias orientalis* L., *Echinocystis lobata* (F. Michx.) Torr. & A. Gray, *Helianthus tuberosus* L., *Impatiens parviflora* DC., *Oxalis fontana* Bunge, *R. rugosa* Thunb. For Lviv, *Amaranthus albus* L. (Fig. 3g), *A. artemisiifolia* L., *H. sosnowskyi* Manden., *Hordeum murinum* L., *Geranium sibiricum* L., *Portulaca oleracea* L. ssp. *oleracea* were regularly recorded. *Amaranthus retroflexus* L., *B. orientalis* L., *Conyza canadensis* (L.) Cronquist, *Erigeron annuus* (L.) Pers. (Fig. 3h), *Lepidium ruderale* L., and *Setaria viridis* (L.) P. Beauv. were the most frequently noted in both cities.

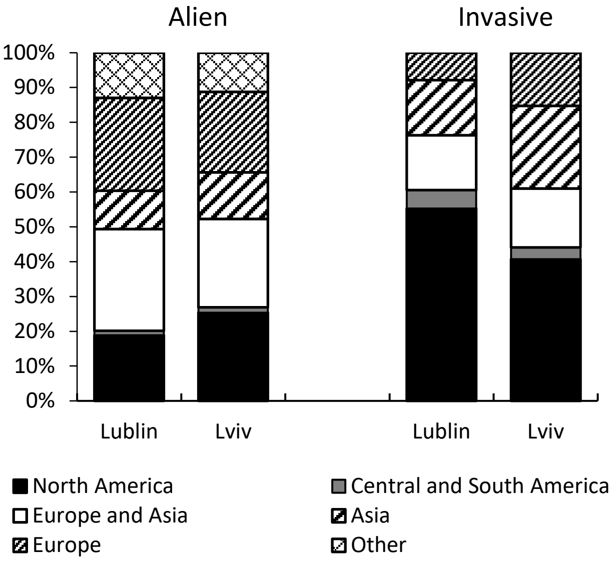

Fig. 4 The geographical origin of alien and invasive plant species noted in railway flora of Lublin (Poland) and Lviv (Ukraine).

The majority of invasive species are native to continental America, including North America (53.8% in Lublin and 42.1% in Lviv), Central and South America (5.1% in Lublin and 3.5% in Lviv; Fig. 4). Those native to the Americas are followed by species native to Asia (Lublin 15.3%, Lviv 24.5%), Eurasia (Lublin 1%, Lviv 17.5%), and Europe (Lublin 7.6%, Lviv 15.7%).

The ecological traits of the native, alien and invasive species are compared in Fig. 5. The flora was quite diverse in terms of life history with perennials predominating amongst the native species. Annual plants dominated the alien species (in Lublin annuals constituted 64.03% of the alien flora and in Lviv 51.24%) and invasive species (in Lublin annuals represented 41.0% of the invasive flora and in Lviv 49.1%).

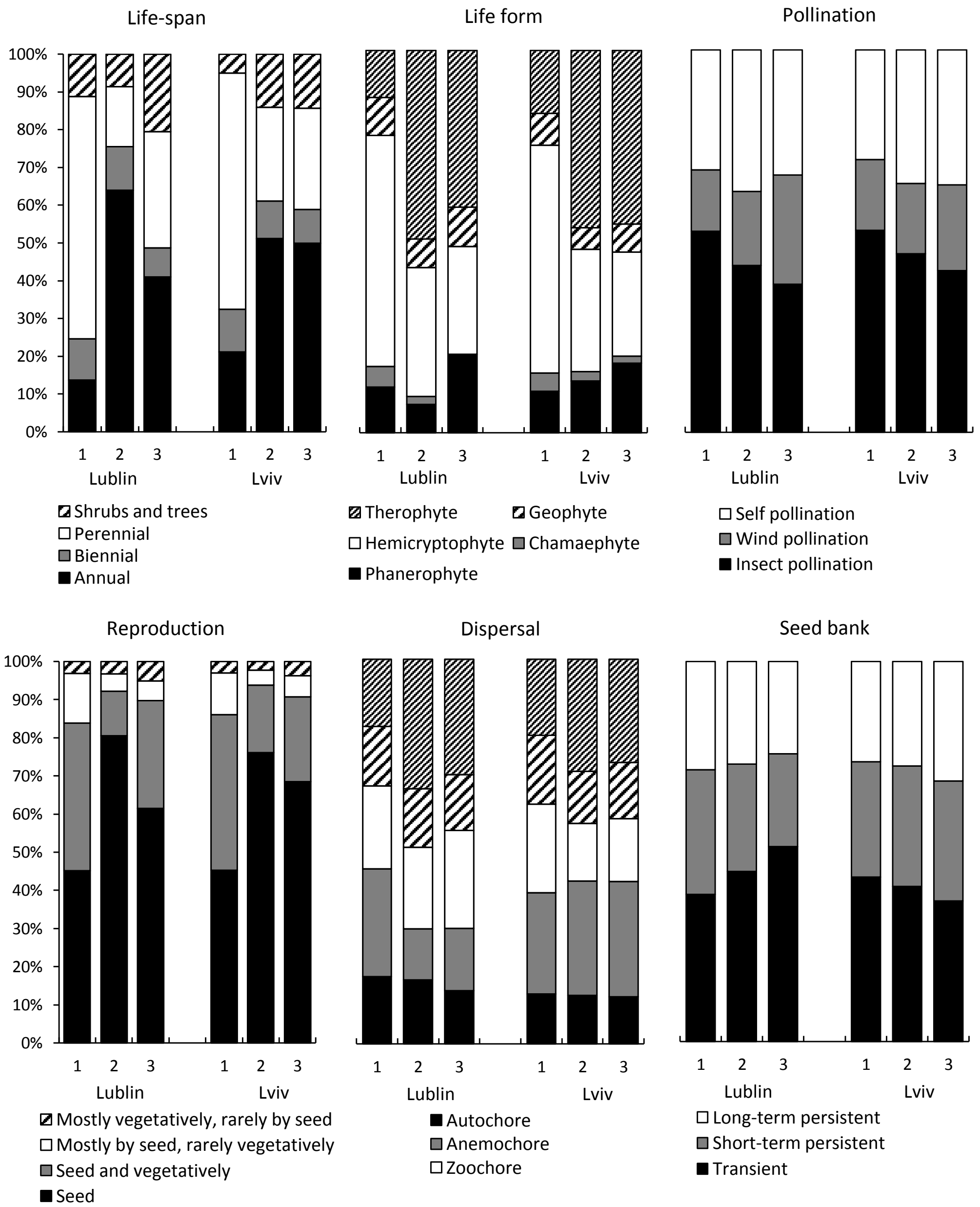

Fig. 5 The functional structure of native (1), alien (2), and invasive species (3) established for railway flora in Lublin (Poland) and Lviv (Ukraine).

With regard to life form spectrum, hemicryptophytes constituted a majority of plants amongst the native species at Lublin and Lviv (60.4% and 59.5%, respectively). In both cities, therophytes were the most numerous amongst alien (Lublin 47.4%, Lviv 43.3%) of total species and amongst the invasive plant species (Lublin 41.0% and Lviv 45.4%). The railway flora of Lublin and Lviv is represented by a large number of phanerophytes, which represent 11.9% and 10.9% of alien species, respectively. For the invasive species, the proportion of phanerophytes is even larger (20.5% in Lublin and 18.2% in Lviv).

The native flora of railway areas was mostly insect-pollinated. An increase of self-pollinated species was recorded for the alien species compared to the native species (alien/native in Lublin 54.5/43.3%, in Lviv 59.5/34.3%). An increase of wind-pollinated species in the invasive species was noted compared to the native species (invasive/native in Lublin 35.9/22.2%, in Lviv 29.1/22.2%), and compared to alien species (invasive/alien in Lublin 35.9/23.1%, in Lviv 29.1/23.1). With regard to the mode of reproduction, generative reproduction by seeds predominated both for the alien (79.7%) and invasive (69.1%) species. Sexual reproduction only by seeds was characteristic for 29.1% of native species. Anemochorous species (28.1%) predominated amongst the native species. Anthropochorous and anemochorous dispersal are prominent in both the alien and invasive species. A similar number of species have short-term persistent, transient, and long-term persistent seed banks for the native, alien, and invasive groups.

Discussion

The intraurban railway flora of Lublin and Lviv is considered to be species-rich [29]. In the present survey, native plant species predominated in railway areas of both cities. A high representation of the native species in the railway flora has been reported in a previous study in Poland, where the ratio of native:alien species was established close to 2:1 [43,44] or 3:1 [45]; in Russia (Middle Urals) it was very similar, 64% to 36% [46], and in "other countries", 68.9% to 17.2% [47].

The proportion of alien species noted within railway areas of Lublin and Lviv was similar (34.4% vs. 36.8%, respectively). Alien species account for 30% in the flora of Poland [3], and in the Ukraine, 14% of total species [40]. The species of alien origin in urban floras, on average, comprise 28% of all species [48]. A higher proportion of alien species in a railway flora compared to native and urban floras indicates that railway habitats within urban areas can act as a source of alien or invasive species, which can penetrate to other habitats. This opinion is in accordance with statements made by other workers, e.g., Lambdon et al. [2], Stajerova et al. [9].

The proportion of invasive species was almost 1.5-fold higher at Lviv compared to Lublin. Presumably, a disparity in the gradient of transport intensity (higher at Lviv than at Lublin) or intercity inhabitant disparities (population – 2.3 persons per 1 km^2 in Lublin and 4.0 persons per 1 km^2 in Lviv) could explain the considerable discrepancy in the invasive flora between railway systems in the two cities studied. As documented for Europe [26], human transport intensity and a high population size can tend to eliminate native species via extreme human disturbance. Moreover, human mobility in urban areas is suggested to be a primary predictor of invasion intensity [9]. Human activity can create ideal habitat conditions for invasive species within railway areas, where disturbance events occur frequently. Such disturbance events are considered to be a major factor for colonization by invasive species [7].

Invasive species differed slightly in their geographical origin between both cities. The proportion that have come from diverse regions is likely an indication of trading routes, intentional and unintentional introductions of alien species coming from America, Europe, and Asia [3,40,41]. We have documented a shift towards the increase of the species originating from Asia in the Lviv flora, which was previously mentioned by Myroszniszenko [49].

In our study, species from the Asteraceae family predominated in the list of invasive plants. This is in accordance with earlier reports from Germany [50], southeast Slovakia [51], and Central Italy [52]. The Poaceae constituted the second most abundant family of invasive species. Similar findings have been reported by Brandes [53] and Anačkov [54]. The biological characteristics of plants may explain the taxonomic pattern in the flora. The members of Asteraceae and Poaceae are habitat-generalists and possess biological traits which enhance dispersal and establishment, i.e., self- or wind pollination, numerous seed production, efficient seed dispersal, and secretion of allelopathic chemicals [55].

Perennials dominated the life-form categories amongst the native species, whereas alien and invasive species were mainly therophytes. A similar spectrum of life forms was found for the railway flora in the north part of Poland [56] and in southeastern Poland [43]. In contrast, Altay et al. [57] indicated an inverse relationship and reported that therophytes are the largest group amongst the native species on railways in Turkey. This disparity in the proportion of life forms of a native flora between regions is presumably related to climatic and/or environmental conditions. As reported by Raven [58], plants with short life cycles predominate in warm and dry climates. Conversely, plants with storage organs and efficient strategies of resource allocation (perennials and hemicryptophytes) are most common in areas with a colder climate.

The dominance of therophytes in the invasive plants seems to be a response to disturbance of habitats on railway areas and is an adaptation to a rapid exploitation of temporarily favorable conditions such as soil moisture. The short seed-to-seed life cycles of therophytes allow them rapid growth, high reproductive allocation, a persistent seed bank, and rapid seed germination [24]. These strategies seem to make invasive therophytes strong competitors in railway habitats.

Several species noted in our study have been indicated in plant databases as dangerous invasives, e.g., *Ambrosia artemisiifolia* L., *Echinocystis lobata* (F. Michx.) Torr. & A. Gray, *Robinia pseudoacacia* L., and *Rosa rugosa* Thunb., are among 100 of the worst in the world (according to the DAISIE database) [59]. Other destructive species are *F. pennsylvanica* Marshall, *A. negundo* L., *B. orientalis* L., *H. sosnowskyi* Manden., *S. gigantea* Aiton, and *S. canadensis* L. (according to DAISIE, EPPO, or NOBANIS) [59–61]. These species initially compete with native species, covering large areas and overgrowing native vegetation [62]. For example, *A. negundo* L., frequently noted both in Lublin and Lviv and reported to colonize diverse habitats (man-made and natural), is particularly harmful for forest ecosystems [63]. Likewise, *F. pennsylvanica* Marshall has the potential to devastate and permanently change the composition of forest communities [64]. In our study, *F. pennsylvanica* Marshall was noted exclusively in Lviv. This species is reported to be the most rapidly spreading tree species in Central Europe over the last 20 years [65]. The increasing occurrence of devastating floods in the Transcarpathian region and in the Danube basin (Western Ukraine, Zakarpatska Oblast, Slovakia, Hungary, Poland, and Romania) is creating environments for further rapid spread of *F. pennsylvanica* Marshall [66]. Therefore, *F. pennsylvanica* Marshall can be expected to soon arrive in SE Poland. Aggressive in Europe, a perennial plant, *B. orientalis* L. forms dense monotypic stands in man-made habitats and invades meadows, thermophilous swards and pastures [67,68]. This species is a plant with a showy floral display and attractive nectar and pollen reward [69], and has the potential to alter plant–pollinator interactions. Negative effects of invasive species on the pollination and reproductive success of native plant species have been reported [70].

In addition to competition with native species and negative ecological effects, other types of destructive effects from invasive species can also occur. For example, *A. artemisiifolia* L., native to North America, is a harmful allergenic species. Its pollen induces asthma twice as often compared to other pollen types [71]. In our study, this species was recorded exclusively in Lviv. It is in accordance with other reports showing that in Europe, *A. artemisiifolia* L. is mainly distributed in warmer south regions [28]. However, due to climate change and mean air temperature increase, the occurrence of *A. artemisiifolia* L. is expected to extend further north [72]. Another species hazardous to health is *H. sosnowskyi* Manden. It is dangerous for humans and animals due to the toxicity of fumarocumarins to skin [73]. Invasive species along railway tracks can also pose a risk in terms of transport safety. The high-stemmed perennials *Solidago* sp., *R. japonica*, or climbers such as *C. vitalba* L. can reduce the visibility of traffic signs and switches, and thus may contribute to traffic accidents. Invasive species along railway tracks are also reported to cause wheel slipping [47]. It highlights the need for the control of such plants along transport tracks.

In conclusion, intraurban railway areas create favorable habitats for the establishment of invasive plant species, and can serve as dispersal corridors for the further spread of species to surrounding areas both in Poland and the Ukraine. Future attention should be focused towards the limitation and/or eradication of invasive species from railway areas.

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Flora inwazyjna terenów kolejowych w obrębie miast – Lublina (Polska) i Lwowa (Ukraina)

Streszczenie

Zróżnicowane i zaburzone siedliska w obrębie terenów kolejowych tworzą środowisko do zadomowienia obcych gatunków roślin. W pracy porównano skład oraz bogactwo gatunkowe gatunków inwazyjnych notowanych w obrębie terenów kolejowych Lublina (południowo-wschodnia Polska) oraz Lwowa (zachodnia Ukraina). Zanotowano 70 gatunków inwazyjnych. Skład gatunkowy flory inwazyjnej był w obu miastach podobny; 81.4% gatunków inwazyjnych notowano w obu miastach, 8.5% tylko w Lublinie, a 10% tylko we Lwowie. Udział gatunków inwazyjnych we florze Lwowa był wyższy w porównaniu z florą Lublina. Gatunki inwazyjne pochodziły głównie z Ameryki (45.7% gatunków), Azji i Eurazji. Udział gatunków inwazyjnych przybyłych z Azji i Eurazji był wyższy we Lwowie niż w Lublinie. Gatunki należące do rodziny Asteraceae i Poaceae dominowały wśród gatunków inwazyjnych. Analiza cech ekologicznych gatunków inwazyjnych zasiedlających tereny kolejowe wykazała, że są to głównie rośliny jednoroczne, wiatro- lub owadopylne, rozmnażające się generatywnie, o nasionach rozsiewających się antropochorycznie lub anemochorycznie, tworzące krótkotrwały lub długotrwały bank nasion.