Environmental & Socio-economic Studies Alien plant invasion in the ruderal vegetation of Ukraine

Article *in* Environmental & Socio-economic Studies · December 2021

DOI: 10.2478/environ-2021-0025

CITATION
1

READS
58

6 authors, including:

Svitlana Iemelianova
M.G.Kholodny Botany Institute
31 PUBLICATIONS **95** CITATIONS
SEE PROFILE

Tetiana Dziuba
M.G. Kholodny Institute of Botany National Academy of Sciences of Ukraine
61 PUBLICATIONS **507** CITATIONS
SEE PROFILE

Myroslav Shevera
M.H. Kholodny Institute of Botany of the National Academy of Sciences of Ukraine
146 PUBLICATIONS **259** CITATIONS
SEE PROFILE

sciendo

Environmental & Socio-economic Studies

DOI: 10.2478/environ-2021-0025

Environ. Socio.-econ. Stud., **2021, 9, 4: 57-70**

Original article

Alien plant invasion in the ruderal vegetation of Ukraine

Dmytro V. Dubyna[1], Svitlana M. Iemelianova[1]*, Tetiana P. Dziuba[1], Pavlo A. Tymoshenko[1], Vira V. Protopopova[2,1], Myroslav V. Shevera[1,2]

[1]Department of Geobotany and Ecology, M.G. Kholodny Institute of Botany, National Academy of Sciences of Ukraine, Kyiv, 2 Tereschenkivska Str., 01004, Ukraine
[2]Ferenc Rákóczi II Transcarpathian Hungarian College of Higher Education, 6 Kossuth sq., Beregove 90200, Transcarpathian Region, Ukraine
*E–mail address (*corresponding author): yemelianova.sv@gmail.com*
ORCID iD: Dmytro V. Dubyna: https://orcid.org/0000-0002-0490-4774; Svitlana M. Iemelianova: https://orcid.org/0000-0001-5885-3186; Tetiana P. Dziuba: https://orcid.org/0000-0001-8621-0890; Pavlo A. Tymoshenko: https://orcid.org/0000-0003-4380-7077; Vira V. Protopopova: http://orcid.org/0000-0002-1492-1084; Myroslav V. Shevera: http://orcid.org/0000-0002-1178-045

ABSTRACT

The article presents the results of an analysis of the alien flora of the ruderal vegetation of Ukraine. A total of 325 alien species which belong to 58 families and 198 genera were identified. The total anthropogenization index of the ruderal phytocoenoses is 19.8%. It was established that the highest level of anthropogenization was found in the phytocoenoses of *Polygono-Poetea annuae*, *Stellarietea mediae* and *Plantaginetea majoris*. The leading families of the non-native fraction of the studied plant communities were *Asteraceae*, *Brassicaceae* and *Poaceae*. It has been revealed that in the biomorphological spectrum of alien plants therophytes prevailed. The ecological analysis has shown the predominance of submesophytes, acidophytes, semieutrophytes, acarbonatophytes and heminitrophytes plants. It was established that according to the arrival time the kenophytes predominate and by the degree of naturalization – the epoecophytes. Comparison of the alien species composition of the ruderal plant communities by means of Jaccard's indices showed the most similarity between the classes *Polygono-Poetea annuae* and *Plantaginetea majoris*, *Robinietea* and *Galio-Urticetea*, *Stellarietea mediae* and *Artemisietea vulgaris*. For the separate classes the indices of archaeophytization, kenophytization, modernization and fluctuation of the flora were calculated. It has been established that there are 23 highly invasive species in the ruderal vegetation of Ukraine and among these *Ambrosia artemisiifolia*, *Anisantha tectorum*, *Grindelia squarrosa*, *Heracleum mantegazzianum*, *H. pubescens* and *Xanthium oreintale ssp. riparium* are transformers.

KEY WORDS: ruderal vegetation, man-made habitats, alien plants, transformers, Ukraine

ARTICLE HISTORY: received 10 June 2021; received in revised form 29 October 2021; accepted 4 November 2021

1. Introduction

The increase of human impacts in recent years has been accompanied by the transformation of the environment, in particular the digression of indigenous plant communities and the formation of ruderal ones (SOUSA, 1984). Such plant communities are natural-anthropogenic phytocomplexes of extrazonal character, the territorial differentiation of which, within a particular territory, depends on a complex of natural and historical factors (CHYTRÝ, 2009, DUBYNA ET AL., 2019).

Ruderal vegetation plays a significant role in the optimization of the environment, especially in urban areas, due to its photosynthetic activity, adsorption of different toxic compounds, fixation of substrates, prevention of erosion processes, etc. (SUKOPP & WERNER, 1983, MUCINA ET AL., 1993, WITTIG, 2002, CHYTRÝ, 2009, GUO ET AL., 2018). At the same time, these phytocoenoses are also a powerful source of diaspores of alien plants, which are recognized as one of the greatest threats for losses of biodiversity worldwide (HOBBS & HUMPHRIES, 1995, LONSDALE, 1999, LEVINE ET AL., 2003, VILÀ ET AL., 2011, PYŠEK ET AL., 2012, RICCIARDI ET AL.,

2013, IUCN Council, 2000). Exactly the ruderal phytocoenoses with their unstable and dynamic structure, mosaic, weak coenotic connections and tolerance of intensified anthropogenic impacts are almost the ideal recipient environment for primary penetrations and adaptations by new alien plants, as well as the source of their further transfer and distribution to the nearest phytocoenotic environment. Compared to the natural plant communities in ruderal coenoses, such processes are much more intensive, which is facilitated by the specifics of the anthropogenic phytocoenoses and the peculiarities of the habitats which they occupy (Chytrý et al., 2005). Thus, as a result of human activity, not only a large number of new man-made habitats, with free or favourable abiotic space, are formed, but also natural ecotopes are transformed due to changes in their soil-hydrological conditions and microclimatic parameters. This greatly facilitates the permeation of the new alien species, with different florogenetic connections, to expand their ecological spectrum and to spread to new areas. As a result, there is a gradual decrease in the stability and self-restoration ability of the natural components of phytodiversity and the loss of aboriginal part its own specific zonal and regional features (Simonová & Lososová, 2008, Medvecká et al., 2010, Šilc, 2010). In this regard, it is important to evaluate the potential dangers of the ruderal plant communities as centers of immigration, naturalization and spread of alien plants.

There have been some studies on the alien plant species of ruderal vegetation, or man-made habitats, of Europe. Most of them have dealt with the vegetation of large cities (Pyšek, 1998, Chocholoušková & Pyšek, 2003, Pyšek et al., 2004, Celesti-Grapow & Blasi, 2006). Less attention has been paid to the alien plants of anthropogenic vegetation in general (Simonová & Lososová, 2008, Medvecká et al., 2010, Šilc et al., 2012).

Although in Ukraine the ruderal vegetation is characterized by high coenotic diversity, research on alien plants assessment across different types of such plant communities has not been conducted yet. In general, 205 associations of ruderal vegetation belonging to 8 classes, 36 alliances and 16 orders have been identified in Ukraine (Dubyna et al., 2019). They represent different types of plant communities across on gradients of water-mineral nutrition of habitats, which significantly expands the range of abiotic and phytocoenotic conditions for the spread of alien species of different ecological valention. In this aspect, it is important to study the non-native components of floras of these ruderal phytocoenoses and to identify the main directions and trends of invasion processes to prevent irreversible phytocoenotic losses in adjacent natural habitats.

The aims of the study were (i) to identify the species composition of aliens of the ruderal phytocoenoses of Ukraine; (ii) to analyze the division of alien plant species by life forms, ecological requirements, arrival time, origin and naturalization degree; (iii) to analyze the invasive plant species, to investigate the most dangerous ones (transformers) and to establish their participation in the ruderal plant communities of Ukraine.

2. Materials and methods

The basic data set included 8381 phytosocological relevés from the "Database of the ruderal vegetation of Ukraine" stored using TURBOVEG software (Hennekens & Schaminée, 2001) and registered with the number EU-UA-011 in the Global Index of Vegetation Plot Databases (Dengler et al., 2011). The database included phytosociological plots of ruderal vegetation from man-made habitats in Ukraine (Table 1). The vegetation plots were sampled from the whole territory of Ukraine. The list of alien species was compiled according to Protopopova (1991). We also took into account information about findings of the new alien plants over the last 30 years in the territory of Ukraine (Protopopova & Shevera, 2014, Alien…, 2021). Species characteristics, such as family, life-form, ecology, origin are presented by Raunkiaer (1934), Didukh (2011), Protopopova (1991), Protopopova & Shevera (2014).

The historical-geographical classification of alien species is presented by Kornaś (1968). To establish which ruderal plant communities are most invaded we used indices of anthropogenization (IAn), archaeophytization (IArch), kenophytization (IKen), modernization (IM) and fluctuation (IF) proposed by Jackowiak (1990). Invasion statuses, particularly of transformers, were stated according to Richardson et al. (2000). Analysis of similarity of the ruderal phytocoenoses' alien flora was performed using the Jacquard index (Shmidt, 1980). The nomenclature of taxa is given according to Euro+Med PlantBase (2006). Names of syntaxa follow Dubyna et al. (2019).

Table 1. Overview of ruderal vegetation types with the characterization of their habitats

№	Phytosociological unit	№ of plots	Vegetation	Habitats
1	*Stellarietea mediae*	2722	Annual vegetation of ruderal habitats	Industrial zones, edges of sidewalks, roads or railway and tram tracks, factory yards, flower beds, foots of ornamental trees, trampled village yards, fowl runs, dumps, farms, construction sites
2	*Artemisietea vulgaris*	2997	Thermophilous vegetation of sunny and dry habitats composed mainly of biennial and perennial species	Waste places, roadsides, building rubble, building ruins, along fences, disturbed river banks, railway banks, disturbed lawns, human settlements, industrial zones, field margins
3	*Polygono-Poetea annuae*	719	Disturbed vegetation formed by annual plants with a ruderal or stress-tolerant life strategy	Trampled sites, roadsides, sidewalks, playgrounds, paving fissures
4	*Plantaginetea majoris*	458	Temporarily flooded zoo-anthropogenic nutrient-rich vegetation	Pastures, disturbed river floodplains, wet ditches, wet trampled sites
5	*Galio-UIrticetea*	728	Nutrient-demanding perennial vegetation types of mesic to wet habitats, dominated by broad-leaved dicots	Forest fringes, riparian fringes, places with a high density of animals, roadsides, waste places, unmanaged parks and gardens
6	*Epilobietea angustifolii*	149	Tall-herb perennial semi-natural vegetation on acidic soils	Forest clearings, sites deforested as a result of wildfire, wind storms, canopy gaps, forest fringes
7	*Bidentetea*	209	Vegetation of tall-growing, competitively strong annual wetland herbs	Disturbed river banks, wet ditches, wet forest clearings, wet arable fields, edges of dung hills and places with agricultural waste water input
8	*Robinietea*	399	Spontaneous tree vegetation of parks and other artificial plants	Abandoned residential areas, railway slopes, riverbanks, abandoned gardens and parks

3. Results

Of the total number of 1637 species recorded in the ruderal phytocoenoses of Ukraine, 325 were aliens, which belonged to 58 families and 198 genera. The total anthropogenization index of the studied phytocoenoses was 19.8% (Fig. 1) and, as expected, this exceeded the value of the same index for the flora of Ukraine as a whole (14%) (PROTOPOPOVA ET AL., 2002). This proportion is comparable with the northwest Balkans, at 12.7% (ŠILC ET AL., 2012). Whereas the same proportion is much higher in Central Europe and ranges from 39.3% in man-made habitats of Czech Republic (CHYTRÝ ET AL., 2005, SIMONOVÁ & LOSOSOVÁ, 2008) to 40.3% in large Central European cities (PYŠEK, 1998). We realize that these sampling units are not directly comparable due to their different areas. However, ruderal vegetation is the most typical type of plant communities in man-made habitats and an important part of urban areas which allows us to make such comparisons.

The highest proportions of alien species were found in the phytocoenoses of *Polygono-Poetea annuae* (36.8%), *Stellarietea mediae* (31.5%) and *Plantaginetea majoris* (27.2%). The high level of invasion of plant communities dominated by annuals is comparable with Central Europe (SIMONOVÁ & LOSOSOVÁ, 2008) and the Balkan region (ŠILC ET AL., 2012). In such phytocoenoses, which represent the pioneer stages of succession there is a free abiotic space for the appearance and spread of new alien plants due to the constant disturbance of these habitats. On the other hand, unlike the mentioned regions, we found that communities of *Polygono-Poetea annuae* and *Plantaginetea majoris* are more easily invaded. In our opinion, this is caused by a surplus of nitrogen, and other nutrients, as well as the significant role played by humans and animals in the distibution of propagules of alien species within the mentioned phytocoenoses because in Ukraine these sites are often used for grazing (in rural settlements) or as places for walking dogs (in urban areas). A high proportion of alien species are also characteristic of black locust groves (21.4%), and vegetation of the classes *Artemisietea vulgaris* (23%) and *Bidentetea* (21.4%). It was found that the vegetation of *Galio-Urticetea* was not so influenced by anthropogenic disturbances. The stands of this class include tall herbs with a high competitive ability, which form dense stands and most alien species are not able to invade these habitats (SIMONOVÁ & LOSOSOVÁ, 2008, MEDVECKÁ ET AL., 2010). The lowest number of alien plant species were recorded in the vegetation of forest clearings belonging to the *Epilobietea angustifolii* class (5.8%). The main reason why these stands are almost unaffected is their isolation from areas that might be a source of propagules of alien species (MEDVECKÁ ET AL., 2010).

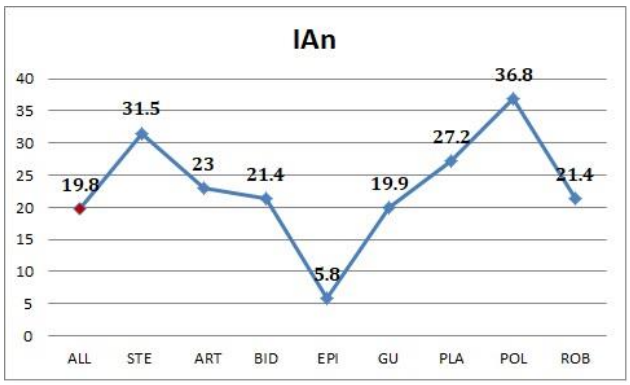


Fig. 1. Anthropogenization (IAn) indices of the ruderal phytocoenoses of Ukraine

Here and below: ALL – flora of the ruderal vegetation of Ukraine; STE – *Stellarietea mediae*; ART – *Artemisietea vulgaris*; BID – *Bidentetea*; EPI – *Epilobietea angustifolii*; GU – *Galio-Urticetea*; PLA – *Plantaginetea majoris*; POL – *Polygono-Poetea annuae*; ROB – *Robinietea*

The analysis of species composition similarity showed that the lowest similarities with other ones were the phytocoenoses of *Epilobietea angustifolii* and *Bidentetea* (Fig. 2). The main reason for this is that coenoses of *Epilobietea angustifolii* are characteristic of slightly acidic, or acidic soils, and plant communities of *Bidentetea* develop in conditions of increased brief-changing of the soil humidity during the growing season. The similarity was also established for the alien species compositions of the (i) *Polygono-Poetea annuae* and *Plantaginetea majoris* due to the presence in both types of phytocoenoses stress-tolerant species adapted to constant trampling (Simonová & Lososová, 2008); (ii) *Robinietea* and *Galio-Urticetea* due to similar nitrophilic hemi-scyophytic species; (iii) *Artemisietea vulgaris* and *Stellarietea mediae* due to close successional connections.

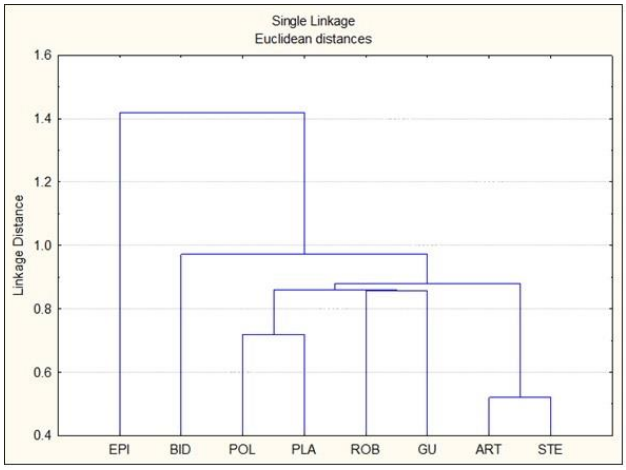


Fig. 2. Similarity of the alien species composition of the ruderal phytocoenoses of Ukraine

The spectrum of the ten leading families is formed by 213 species or 65.5% of their total number. *Asteraceae* (65/20%), *Brassicaceae* (38/11.7%) and *Poaceae* (29/8.9%) take the first three places, as well as for alien flora of Ukraine as a whole (Protopopova, 1991). Other numerous families are: *Fabaceae* (16/4.9%), *Chenopodiaceae* (15/4.6%), *Apiaceae* (13/4%), *Boraginaceae* (10/3%), *Lamiaceae* (10/3%), *Polygonaceae* (9/2.8%) and *Amaranthaceae* (8/2.5%). Such ordering indicates the significant role played by arid areas in the formation of the non-native core of the studied phytocoenoses. The recent intensification of the role of North American floristic centers is shown by the appearance among the leading families species belonging to the families of *Polygonaceae* and *Amaranthaceae*. This is also confirmed by the systematic spectrum at the genera level. The largest polymorphism is characteristic of *Xanthium* L. (9 species), *Amaranthus* L. (8), *Chenopodium* L. (6), *Sisymbrium* L. (6) and *Veronica* L. (6). Genera represented by one species prevail (69%). The systematic spectra of the alien flora of separate classes match with the general one. Exceptions are the coenoses of *Epilobietea angustifolii*, which together with the representatives of *Asteraceae* dominate species of the *Lamiaceae*.

With regard to Raunkiaer's system of life-forms, 57.2% of alien plants are therophytes. The proportions of hemicryptophytes and cryptophytes reach 26.1% and 7.4% respectively. Phanerophytes (8.6%) and chamaephytes (0.7%) are typical only for phytocoenoses of *Robinietea* and *Epilobietea angustifolii*. Such differentiation by life-forms keeps on within all classes of ruderal vegetation of Ukraine. The increasing proportion of therophytes, which use opportunities for establishing in gaps after disturbances, is characteristic of man-made habitats and reflects the mechanisms of plant adaptations to the conditions of regular disturbance (Pyšek et al., 1995, Pfadenhauer & Klötzli, 2014, Axmanová et al., 2021).

The ecological structure of the alien flora of the ruderal vegetation of Ukraine is determined by the complex influence of different abiotic gradients, which indicate the high diversity of man-made habitats. By the soil humidity submesophytes (39.3%) and mesophytes (35.5%) are predominant (Fig. 3A). The proportions of other hydromorphs are much lower: subxerophytes constitute 12.8%, hygro-mesophytes – 9.3%, xerophytes – 1.2%, hygrophytes – 0.8%, perhydrophytes – 0.4%. The distribution of species according to soil acidity (Fig. 3B) showed that the ruderal plant communities of Ukraine are formed in conditions of neutral or slightly acid pH. That is why these ecological groups are almost equally to each other and account for 49.2% and 42.9% respectively. Analysis of floras of separate syntaxonomic classes by soil acidity gradient

revealed that the plant communities of *Bidentetea*, *Epilobietea angustifolii*, *Plantaginetea majoris* and *Polygono-Poetea annuae* prefer mostly sub-acidophilic conditions, while phytocoenoses of *Stellarietea mediae*, *Artemisietea vulgaris* and *Robinietea* are more common on neutral soils. In terms of the salt regime semieutrophic (51.9%) and eutrophic (31.1%) plants are predominant (Fig. 3C). According to the nitrogen content heminitrophilic plants are dominant with a proportion of 48.8% (Fig. 3D). Also 38.3% nitrophyles, 7.9% eunitrophyles and 5% subanitrophyles participate in the formation of the studied phytocoenoses. It was found that nitrophyles prevail in the spectra of *Bidentetea*, *Galio-Urticetea*, *Plantaginetea majoris*, *Polygono-Poetea annuae* and *Robinietea*. In the other plant communities the distribution of alien species by nitrophilicity corresponds to the general correlation. The spectra of heliomorphs of the alien plants of the ruderal vegetation of Ukraine is dominated by species that prefer open and well-lit habitats. Thus, the proportion of heliophytes is 54%, hemi-heliophytes – 44.4%. Plants that prefer shaded habitats are found mainly in artificial tree plantations. Heliophytes prevail in *Stellarietea mediae*, *Artemisietea vulgaris*, *Polygono-Poetea annuae* and *Plantaginetea majoris*. In contrast, in the coenoses of *Bidentetea*, *Galio-Urticetea*, *Robinietea* and *Epilobietea angustifolii* most alien plants can tolerate slight shading. In general, the floras of ruderal phytocoenoses are characterized by the predominance of species with very broad tolerances to most abiotic gradients. This is caused by the requirement for rapid adaptations to unfavourable abiotic factors under the constant and varying intensity of human impact.

The analysis of alien plant species according to the arrival time revealed a total predominance of kenophytes with a proportion of 63.4% (Fig. 4). Archaeophytes reach 36.6% of all alien species. Positions of mentioned groups in the separate ruderal phytocoenoses are mainly similar. Exceptions are the phytocoenoses of *Bidentetea* and *Epilobietea angustifolii*, where the majority of alien plants are archaeophytes. In the coenoses of *Bidentetea* rapidly-changing environmental conditions, in particular soil humidity, limit the appearance, adaptation and further spread of new alien plants. Unlike plant communities of *Epilobietea angustifolii* which are rather stable and in which forest shrub and herb species play a crucial role that is limited by the ecological spectrum of new alien species (MEDVECKÁ ET AL., 2010).

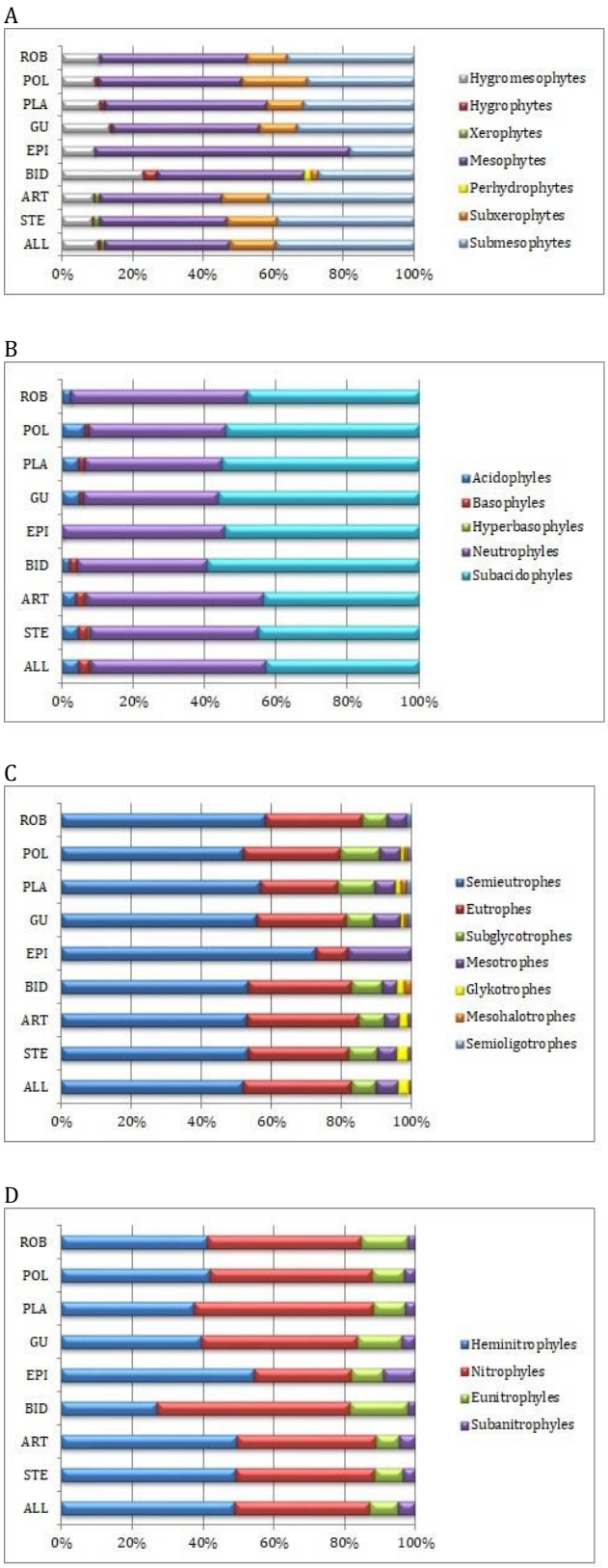


Fig. 3. Distribution of alien species in ruderal vegetation by: A - soil humidity, B – acidity, C – salt regime, D - nitrogen content

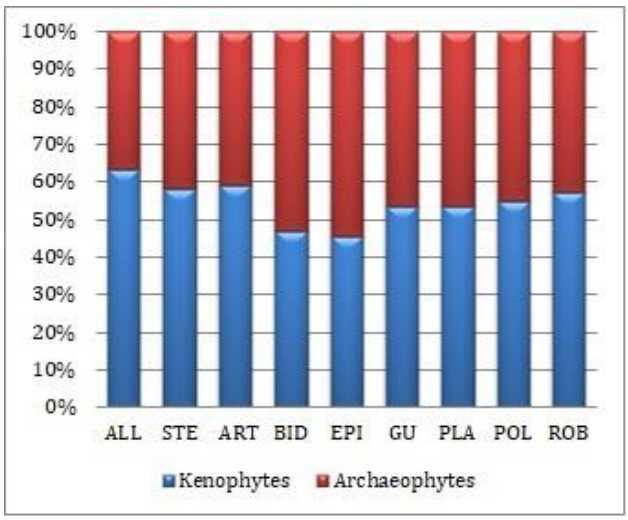


Fig. 4. Distribution of alien species in ruderal vegetation by arrival time

Of the total number of alien species, Mediterranean species prevail (30%) (Fig. 5). Plants of Mediterranean-Iranian-Turanian (16.6%), North American (16.3%) and Asian origin (15.9%) also play a significant part in the formation of the species composition of the studied plant communities. Species that have originated from other floristic centers are far fewer. Some differences with the general spectra were revealed within–*Bidentetea*, *Galio-Urticetea* and *Plantaginetea majoris.* These phytocoenoses are dominated by North American species. This can be explained by the similar ecological conditions between the donor and the recipient plant communities, and thus the faster adaptation process.

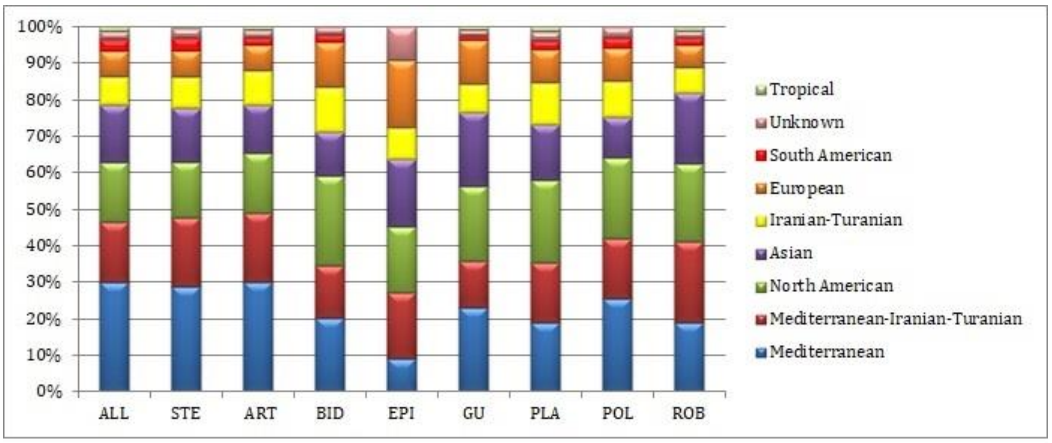


Fig. 5. Distribution of alien species in ruderal vegetation by origin

According to the degree of naturalization, epoecophytes (69.2%) significantly prevail (Fig. 6). The spectra is also composed of ergasiophytes (12.3%), agriophytes (6.8%), ephemerophytes (6.8%) and hemiepoecophytes (4.9%). The proportions of these groups differ a little in *Bidentetea* and *Galio-Urticetea*, which are semi-natural, and where there are a larger proportion of agriophytes.

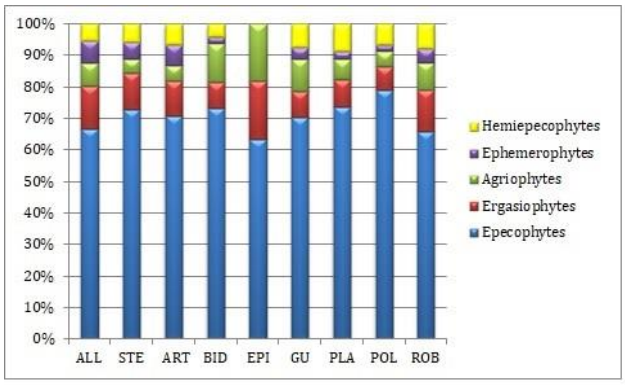


Fig. 6. Distribution of alien species in ruderal vegetation by the degree of naturalization

The analysis of archaeophytes and kenophytes by florogenetic relationships and degree of naturalization revealed some tendencies and peculiarities in the processes of distribution of alien species and their adaptation in the phytocoenoses of the ruderal vegetation of Ukraine (Table 2). Among archaeophytes, most species have a genetic connection with the flora of the Mediterranean and Iranian-Turanian regions, and less so with the Asian ones. According to the degree of naturalization, the archaeophytes are dominated by epoecophytes. The proportions of ergasiophytes and ephemerophytes are also insignificant. Unlike archaeophytes, kenophytes are equally associated with both Mediterranean and North American floristic centers, with the active participation of Asian ones. The penetration and active distribution of plants from North America are associated both with the development of transport and economic communications between countries, and with the similarity of the ecological and coenotic environments of species. As expected, among kenophytes was found the highest proportions of epoecophytes, and also many

ergasiophytes and ephemerophytes. The latter ones in ruderal coenoses undergo ecological adaptation and later can successfully be naturalized in different habitats. The relatively high proportion of agriophytes among kenophytes is a consequence of the fact that the processes of naturalization of plants in natural phytocoenoses have now significantly accelerated in time and are associated with the already mentioned ecological affinity of donor and recipient areas, as well as increasingly different types of human impact. No less important in these processes are global climate changes, which lead to the xerophytization of the soil-hydrological conditions of habitats and acceleration of the naturalization of alien plants, especially of southern origin (FINCH ET AL., 2021).

To identify the main trends and directions of the transformation processes, including potential ones, which threaten the natural phytocoenoses we calculated the indices of the floras' archaeophytization, kenophytization, modernization and fluctuation for each type of ruderal plant communities (Table 3).

Table 2. Distribution of alien species groups in the structure of archaeophytes and kenophytes

Criterion	Group	Archaeophytes		Kenophytes	
		Number	%	Number	%
By the origin	Mediterranean	44	37.0	53	25.7
	Mediterranean-Iranian-Turanian	34	28.5	17	8.3
	Iranian-Turanian	16	13.4	8	3.9
	Asian	15	12.6	38	18.5
	European	4	3.4	21	10.2
	North American	-	-	53	25.7
	South American	-	-	11	5.3
	Tropical	2	1.7	2	0.9
	Unknown	4	3.4	3	1.5
By the degree of naturalization	Agriophytes	2	1.7	20	9.7
	Hemiepecophytes	12	10.2	4	1.9
	Epoecophytes	103	86.5	122	59.3
	Ergasiophytes	1	0.8	39	18.9
	Ephemerophytes	1	0.8	21	10.2

Table 3. Indices of archaeophytization, kenophytization, modernization and fluctuation of ruderal phytocoenoses of Ukraine

INDEX	ALL	STE	ART	BID	EPI	GU	PLA	POL	ROB
IArch	7.3	13.1	9.4	11.4	3.2	9.2	12.6	16.6	9.1
IKen	12.6	18.3	13.6	10	2.6	10.7	14.6	20.3	12.3
IM	63.4	58.3	59.2	46.9	45.5	53.8	53.8	55	57.4
IJ	3.8	5	3.9	2.2	1.1	2.2	2.4	3.4	3.4

The general indices of archaeophytization and kenophytization are 7.3% and 12.6%, respectively. When comparing the proportions of archaeophytes and kenophytes between different regions it is apparent that the number of kenophytes is more numerous in Ukraine than in Czech Republic (SIMONOVÁ & LOSOSOVÁ, 2008), Northern Slovakia (MEDVECKÁ ET AL., 2010) and North West Balkans (ŠILC ET AL., 2012), but comparable with large cities of Central Europe (PYŠEK, 1998). On the other hand, levels of archaeophytization are much higher in man-made habitats of Czech Republic (SIMONOVÁ & LOSOSOVÁ, 2008). However, we did not take into account agricultural landscapes where archaeophytes prevail. We focused on habitats in urban areas and rural settlements as the most invaded areas with the richest alien flora and the places where alien species are less affected by competition from native species (CELESTI-GRAPOW ET AL., 2006). Another reason for such a high proportion of kenophytes is that Ukraine is located on the crossroads of migration channels of alien species from east to west and in the reverse direction. Besides, the very important role on plant invasions plays coastal areas which designate as hot spots of invasive plant richness.

These areas have concentrated historical and recent high levels of development, trading and tourism activities, and hence should be associated with higher rates of species introductions (GASSO ET AL., 2009).

The total index of modernization of the alien flora of ruderal plant communities is 63.4%. It has been established that the phytocoenoses of *Artemisietea vulgaris* and *Stellarietea mediae* are now the most changed due to the influence of non-native plants. These phytocoenoses are also characterized by the highest fluctuation changes in their floras. In total, the proportion of unstable elements in the ruderal plant communities is 3.8% and is quite high.

64 highly invasive species have been identified in the flora of Ukraine (PROTOPOPOVA & SHEVERA, 2019) and their distribution has been analyzed in the different regions of Ukraine (PROTOPOPOVA ET AL., 2009, 2010, 2012, 2014, 2015). In the ruderal vegetation of Ukraine 23 transformer species have been identified (Fig. 7) and the participation of these species in ruderal coenoses has been analyzed. The most frequent were: *Erigeron canadensis*, *Ambrosia artemisiifolia*, *Erigeron annuus* (frequent in all classes), *Anisantha tectorum*, *Helianthus tuberosus*, *Iva xanthiifolia*, *Impatiens parviflora*, *Solidago canadensis* and *Robinia pseudoacacia* (recorded in 1 to 6 classes).

Fig. 7. Transformer species in the ruderal plant communities of Ukraine: A – *Acer negundo* in the "Seimskyi" Regional Landscape Park (Sumy Region), B – *Ambrosia artemisiifolia* near Rakoshyno village (Transcarpathian Region), C – *Heracleum sosnowskyi* and *Helianthus tuberosus* in Uzhgorod (Transcarpathian Region), D – *Reynoutria japonica* in Beregovo (Transcarpathian Region) (photo by M. Shevera)

The characteristics of some transformers (arrival time, origin, chorology, coenotic activity), which could be a big danger for native biodiversity, are presented:

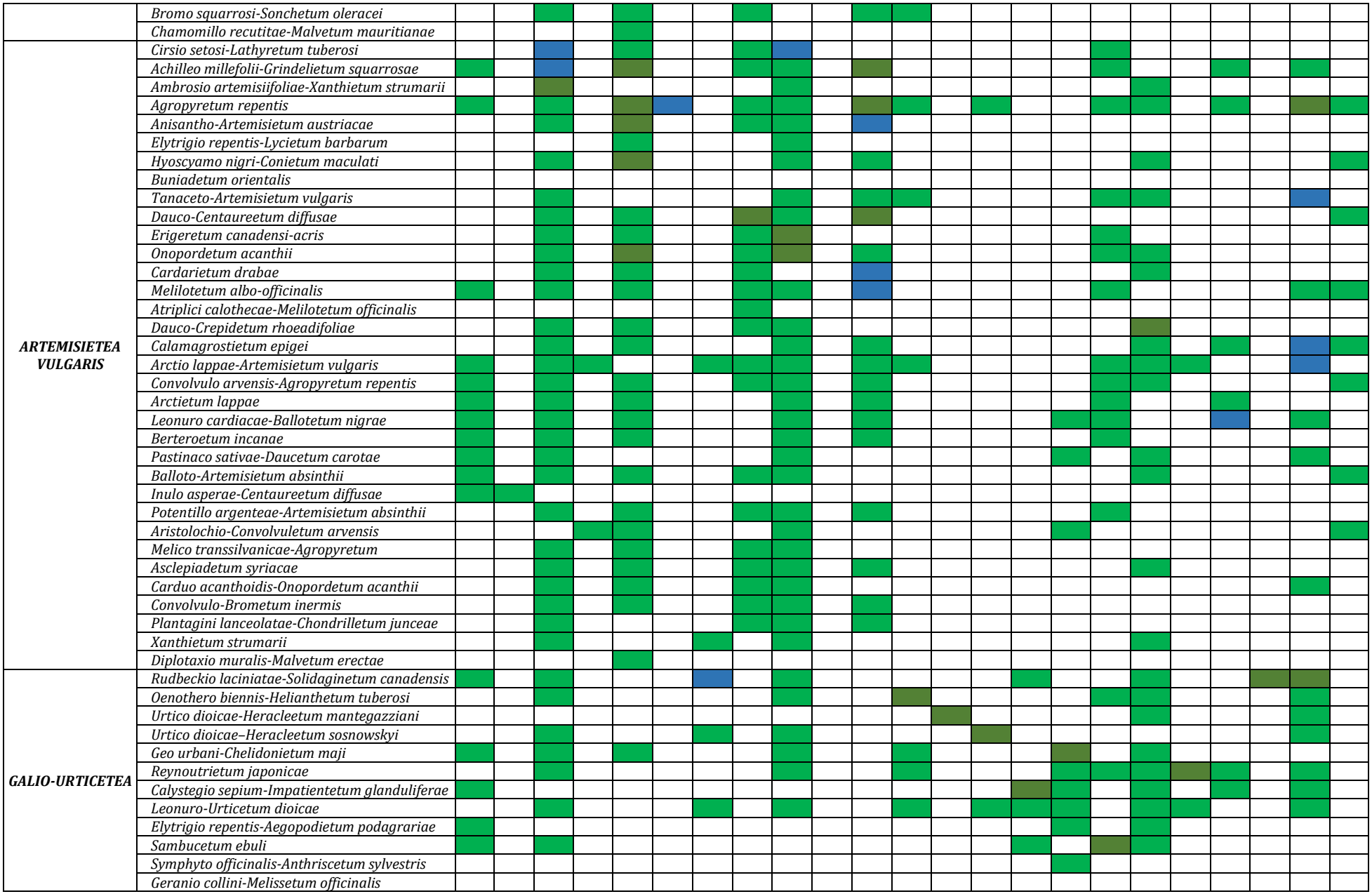
Ambrosia artemisiifolia is a kenophyte of North American origin, its distribution is common in the Steppe, Forest-Steppe and the southern part of Polissia. It is one of the most coenotically active species and a diagnostic one for many associations of different ruderal vegetation classes (Table 4). Most often, *A. artemisiifolia* is observed in plant communities of *Stellarietea mediae* and *Artemisietea vulgaris*. Thus, in the associations *Ambrosietum artemisiifoliae* and *Chenopodietum stricti*, the species occurs with a coverage of up to 50%. In the phytocoenoses of *Setario pumilae-Echinochloetum cruris-galli* and *Ambrosio artemisiifoliae-Chenopodietum albi* the species has a significant participation in the central and western regions of Ukraine.

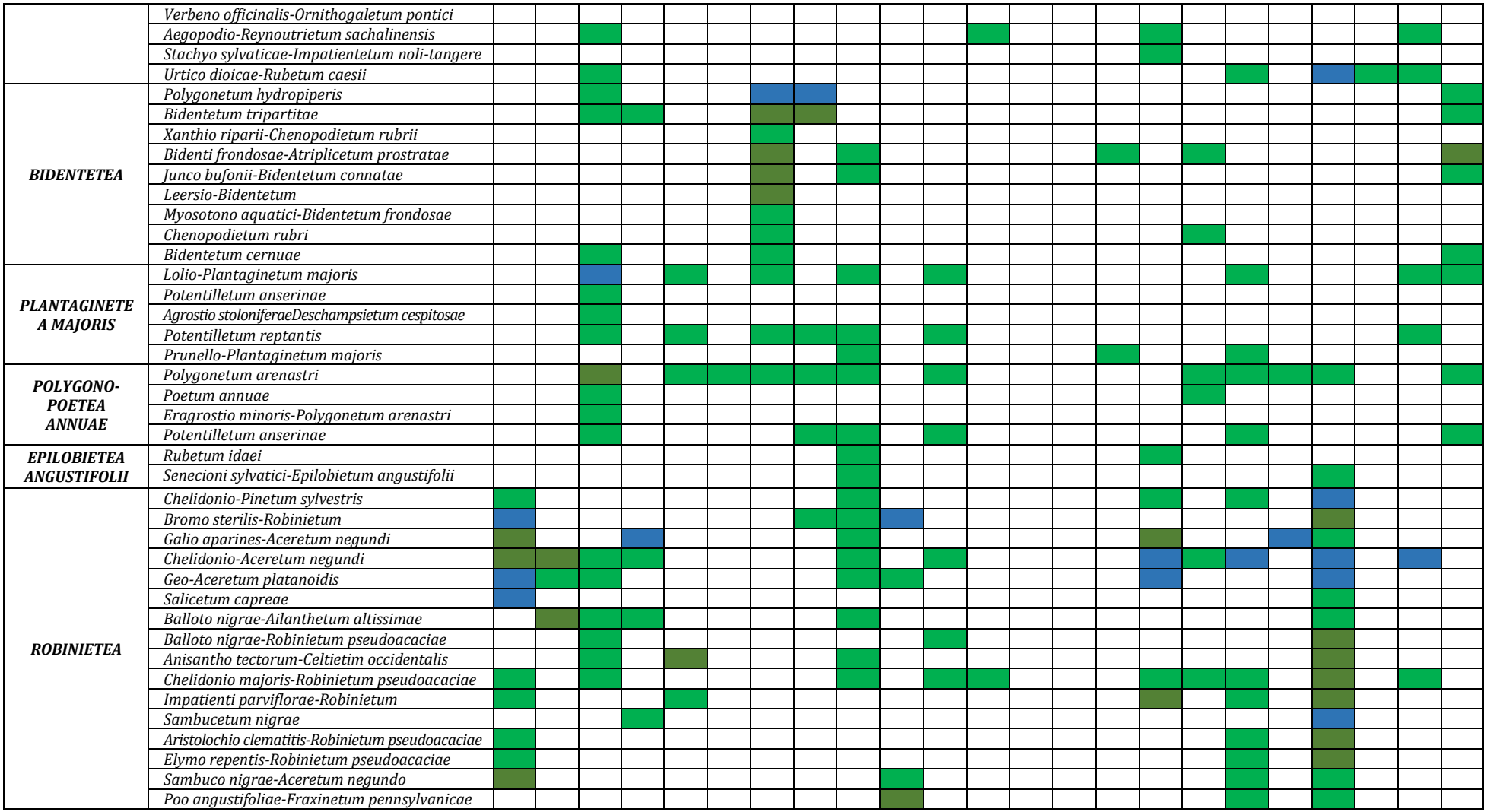
Table 4. Participation of highly invasive species in different ruderal plant communities of Ukraine

CLASSES	ASSOCIATIONS	Highly invasive species																							
		Acer negundo	*Ailanthus altissima*	*Ambrosia artemisiifolia*[*]	*Amorpha fruticosa*	*Anisantha tectorum*	*Apera spica-venti*	*Bidens frondosus*	*Centaurea diffusa*	*Erigeron canadensis*[**]	*Fraxinus pennsylvanica*	*Grindelia squarrosa*	*Helianthus tuberosus*	*Heracleum mantegazzianum*	*Heracleum pubescens*	*Impatiens glandulifera*	*Impatiens parviflora*	*Iva xanthiifolia*	*Erigeron annuus*	*Reynoutria japonica*	*Robinia pseudoacacia.*	*Rudbeckia laciniata*	*Solidago canadensis*	*Xanthium orientale ssp. riparium*
STELLARIETEA MEDIAE	*Setario pumilae-Echinochloetum cruris-galli*																							
	Digitario sanguinalis-Eragrostietum minoris																							
	Ambrosio artemisiifoliae-Chenopodietum albi																							
	Ambrosietum artemisiifoliae																							
	Chenopodietum stricti																							
	Atriplicetum tataricae																							
	Brometum tectorum																							
	Artemisietum annuae																							
	Setario-Digitarietum																							
	Atriplicetum hastatae																							
	Setario viridis-Erigeronetum canadensis																							
	Conyzo canadensis-Lactucetum serriolae																							
	Cirsio-Lactucetum serriolae																							
	Lactuco serriolae-Diplotaxietum tenuifoliae																							
	Matricarietum perforatae																							
	Cynodontetum dactyli																							
	Bromo sterilis-Asperugetum procumbentis																							
	Ivaetum xanthiifoliae																							
	Kochietum densiflorae																							
	Hordeetum murini																							
	Amarantho retroflexi-Echinochloetum cruris-galli																							
	Sisymbrietum loeselii																							
	Sisymbrietum altissimi																							
	Lactucetum tataricae																							
	Portulacetum oleracei																							
	Salsoletum ruthenicae																							
	Digitarietum ischaemii																							
	Setario glaucae-Galinsogetum parviflorae																							

[*] *Ambrosia artemisiifolia*, exept marked associations, with coverage of up to 25% is common in 7 associations of the class *Stellarietea mediae* and 7 associations of the class *Artemisietea vulgaris*

[**] *Erigeron canadensis,* exept marked associations, with coverage of up to 25% is common in 9 associations of the class *Stellarietea mediae* and 6 associations of the class *Artemisietea vulgaris*


Bromo squarrosi-Sonchetum oleracei
Chamomillo recutitae-Malvetum mauritianae
ARTEMISIETEA VULGARIS
Cirsio setosi-Lathyretum tuberosi
Achilleo millefolii-Grindelietum squarrosae
Ambrosio artemisiifoliae-Xanthietum strumarii
Agropyretum repentis
Anisantho-Artemisietum austriacae
Elytrigio repentis-Lycietum barbarum
Hyoscyamo nigri-Conietum maculati
Buniadetum orientalis
Tanaceto-Artemisietum vulgaris
Dauco-Centaureetum diffusae
Erigeretum canadensi-acris
Onopordetum acanthii
Cardarietum drabae
Melilotetum albo-officinalis
Atriplici calothecae-Melilotetum officinalis
Dauco-Crepidetum rhoeadifoliae
Calamagrostietum epigei
Arctio lappae-Artemisietum vulgaris
Convolvulo arvensis-Agropyretum repentis
Arctietum lappae
Leonuro cardiacae-Ballotetum nigrae
Berteroetum incanae
Pastinaco sativae-Daucetum carotae
Balloto-Artemisietum absinthii
Inulo asperae-Centaureetum diffusae
Potentillo argenteae-Artemisietum absinthii
Aristolochio-Convolvuletum arvensis
Melico transsilvanicae-Agropyretum
Asclepiadetum syriacae
Carduo acanthoidis-Onopordetum acanthii
Convolvulo-Brometum inermis
Plantagini lanceolatae-Chondrilletum junceae
Xanthietum strumarii
Diplotaxio muralis-Malvetum erectae
GALIO-URTICETEA
Rudbeckio laciniatae-Solidaginetum canadensis
Oenothero biennis-Helianthetum tuberosi
Urtico dioicae-Heracleetum mantegazziani
Urtico dioicae–Heracleetum sosnowskyi
Geo urbani-Chelidonietum maji
Reynoutrietum japonicae
Calystegio sepium-Impatientetum glanduliferae
Leonuro-Urticetum dioicae
Elytrigio repentis-Aegopodietum podagrariae
Sambucetum ebuli
Symphyto officinalis-Anthriscetum sylvestris
Geranio collini-Melissetum officinalis


Verbeno officinalis-Ornithogaletum pontici
Aegopodio-Reynoutrietum sachalinensis
Stachyo sylvaticae-Impatientetum noli-tangere
Urtico dioicae-Rubetum caesii
BIDENTETEA
Polygonetum hydropiperis
Bidentetum tripartitae
Xanthio riparii-Chenopodietum rubrii
Bidenti frondosae-Atriplicetum prostratae
Junco bufonii-Bidentetum connatae
Leersio-Bidentetum
Myosotono aquatici-Bidentetum frondosae
Chenopodietum rubri
Bidentetum cernuae
PLANTAGINETEA MAJORIS
Lolio-Plantaginetum majoris
Potentilletum anserinae
Agrostio stoloniferaeDeschampsietum cespitosae
Potentilletum reptantis
Prunello-Plantaginetum majoris
POLYGONO-POETEA ANNUAE
Polygonetum arenastri
Poetum annuae
Eragrostio minoris-Polygonetum arenastri
Potentilletum anserinae
EPILOBIETEA ANGUSTIFOLII
Rubetum idaei
Senecioni sylvatici-Epilobietum angustifolii
ROBINIETEA
Chelidonio-Pinetum sylvestris
Bromo sterilis-Robinietum
Galio aparines-Aceretum negundi
Chelidonio-Aceretum negundi
Geo-Aceretum platanoidis
Salicetum capreae
Balloto nigrae-Ailanthetum altissimae
Balloto nigrae-Robinietum pseudoacaciae
Anisantho tectorum-Celtietim occidentalis
Chelidonio majoris-Robinietum pseudoacaciae
Impatienti parviflorae-Robinietum
Sambucetum nigrae
Aristolochio clematitis-Robinietum pseudoacaciae
Elymo repentis-Robinietum pseudoacaciae
Sambuco nigrae-Aceretum negundo
Poo angustifoliae-Fraxinetum pennsylvanicae
- Coverage of species up to 25%
- Coverage of species is 25-50%
- Coverage of species more then 50%

In the plant communities of *Artemisietea vulgaris* participation of the species is most noticeable in the associations *Cirsio setosi-Lathyretum tuberosi*, *Achilleo millefolii-Grindelietum squarrosae*, *Ambrosio artemisiifoliae-Xanthietum strumariae*, which are distributed mainly in the Black Sea region. Participation of this species in plant communities of other classes is more less and does not exceed 25-35%.

Anisantha tectorum is an archaeophyte of the Mediterranean-East-Turanian origin. It is distributed mainly in the eastern regions of the steppe and forest-steppe zones of Ukraine and Crimea. The most noticeable participation of the species was observed in the central and southern parts of Ukraine in the associations *Brometum tectori*, *Artemisietum annuae*, *Anisantho-Artemisietum austriacae*, *Achilleo millefolii-Grindelietum squarrosae* and *Hyoscyamo nigri-Conietum maculati*. *Anisantha tectorum* has a significant coverage, or is included, in the diagnostic species of the *Polygonetum arenastri* and *Anisantho tectori-Celtietim occidentalis* coenoses.

Grindelia squarrosa is a kenophyte of North American origin, distributed mainly in the steppe and southern part of the forest-steppe zone. Some isolated localities were also noted in Polissia (north of Chernihiv and Sumy Regions), in the Carpathians and Crimea. It is most often found in the plant communities of *Artemisietea vulgaris* (associations *Agropyretum repentis*, *Anisantho-Artemisietum austriacae*, *Dauco-Centaureetum diffusae*, *Achilleo millefolii-Grindelietum squarrosae*, *Cardarietum drabae*, *Melilotetum albo-officinalis*). The coverage of *Grindelia squarrosa* in the phytocoenoses of *Stellarietea mediae* reaches 20–25%, and in *Plantaginetea majoris*, *Polygono-Poetea annuae* and *Robinietea* is up to 15%.

Heracleum mantegazzianum and *H. pubescens* are kenophytes of Caucasic origin. The first one is distributed sporadically in the Carpathian region, Western Polissia and western Forest-Steppe of Ukraine. *Heracleum pubescens* is most often found in the Transcarpathian, Cis-Carpathian and Polissia. The coenotic optimum of both species is the plant communities of *Galio-Urticetea*.

Xanthium orientale ssp. *riparium* is a kenophyte of European origin, which is mostly distributed in the steppe zone of Ukraine. The species plays a most significant role in the plant communities of *Setario-Digitarietum*, *Cynodontetum dactyli*, *Ambrosietum artemisiifoliae*, *Atriplicetum hastatae*, *Brometum tectorum*, *Bromo sterilis-Asperugetum procumbentis*, *Ivaetum xanthiifoliae* and *Bidenti frondosae-Atriplicetum prostratae*.

The penetration of transformer-species in the phytocoenoses of natural habitats, even with low coverage, can be a potential danger. Such species are actively spreading, as a rule, and dominate in the phytocoenoses, suppressing aboriginal plants, which are the most negatively affected by changes in the environment caused by transformers and, thus, block the demutation processes. Transformer species can change the phytocoenoses by disrupting successional connections and form new syntaxa, the diagnostic blocks of which are composed of both alien plants and apophytes in combination with aboriginal species. Changes in the floristic composition of plant communities are due to hybridization with related species. This can lead to the extinction of aboriginal species. In the European area *Reynoutria japonica* hybridizes with *R. bohemica* of different ploidy; *Heracleum mantegazzianum* forms hybrids with *H. sphondylium* and probably with *H. pubescens* (FORMAN & KESSELI, 2003). Other species, e.g. the alien *Bidens frondosa* displaces the native *B. tripartita*, the alien *Xanthium orientale* ssp. *riparium* exclude aboriginal *X. strumarium*, etc. (PROTOPOPOVA ET AL., 2009). Therefore, such species, as well as the plant community into which they penetrate, need special attention and constant monitoring.

4. Conclusions

The alien flora of ruderal plant communities of Ukraine is composed of 325 species which belong to 58 families and 198 genera. The total anthropogenization index of the ruderal phytocoenoses of Ukraine is 19.8%. Among all the studied plant communities, the highest quantity of alien species were found in the phytocoenoses of *Polygono-Poetea annuae*, *Stellarietea mediae* and *Plantaginetea majoris*. The highest similarity of alien species composition was in the plant communities of *Polygono-Poetea annuae* and *Plantaginetea majoris*, *Robinietea* and *Galio-Urticetea*, as well as *Artemisietea vulgaris* and *Stellarietea mediae.* The greatest ecological separation is characteristic of non-native fractions of *Bidentetea* and *Epilobietea angustifolii.*

Analysis of the alien plant species of the ruderal vegetation of Ukraine according to the arrival time revealed a total predominance of kenophytes and showed that in almost all plant communities the formation of floristic composition occurs actively due to new alien species of Mediterranean, Mediterranean-Iranian-Turanian, North American and Asian origin. According to the degree of naturalization epoecophytes significantly prevail. The proportion of agriophytes is a consequence of the fact that the processes of naturalization of these plants have now significantly accelerated in time, associated with

the ecological affinity of donor and recipient areas, increasing human impact and global climate changes.

In the ruderal vegetation of Ukraine 23 transformer species were identified and they are an influential factor. They cause significant changes in the composition and structure of the flora and plant communities, their phytocoenotic activity and participation in plant communities indicates an intensification of the process of vegetation synanthropization and an increasing degree of susceptibility of phytocoenoses.

References

Alien species in the flora of Ukraine: years and authors. Bibliographic list. Edition 8 / Compiliers by R.I. Burda, V.V. Protopopova, M.V. Shevera, O.O. Kucher, S.M. Koniakin. 2021, Kyiv [in Ukrainian].

Axmanová I., Kalusová V., Danihelka J., Dengler J., Pergl J., Pyšek P., Večeřa M., Attorre F., Biurrun I., Boch S., Conradi T., Gavilán R.G., Jiménez-Alfaro B., Knollová I., Kuzemko A., Lenoir J., Leostrin A., Medvecká J., Moeslund J.E., Obratov-Petkovic D., Svenning J.-C., Tsiripidis I., Vassilev K., Chytrý M. 2021. Neophyte invasions in European grasslands. *Journal of Vegetation Science*, 32: e12994.

Celesti-Grapow L., Blasi C. 1998. A comparison of the urban flora of different phytoclimatic regions in Italy. *Global Ecology & Biogeography Letters*, 7: 367–378.

Celesti-Grapow L., Pyšek P., Jarošík V., Blasi C. 2006. Determinants of native and alien species richness in the urban flora of Rome. *Diversity and Distribution*, 12: 490–501.

Chocholoušková Z., Pyšek P. 2003. Changes in composition and structure of urban flora over 120 years: a case study of the city Plzeň. *Flora*, 198: 366–376.

Chytrý M. (ed.). 2009. *Vegetation of the Czech Republic. 2: Ruderal, weed, rock and scree vegetation*. Praha: Academia [in Czech].

Chytrý M., Pyšek P., Tichý L., Knollová I., Danihelka J. 2005. Invasions by alien plants in the Czech Republic: a quantitative assessment across habitats. *Preslia*, 77: 339–354.

Dengler J., Jansen F., Glöckler F., Peet R.K., De Cáceres M., Chytrý M., Ewald J., Oldeland J., Finckh M., Lopez-Gonzalez G., Mucina L., Rodwell J.S., Schaminée J.H.J., Spencer N. 2011. The Global Index of Vegetation-Plot Databases (GIVD): a new resource for vegetation science. *Journal of Vegetation Science*, 22, 4: 582–597.

Didukh Ya.P. 2011. *The ecological scales for the species of Ukrainian flora and their use in synphytoindication*. Phytosociocentre, Kyiv.

Dubyna D.V., Dziuba T.P., Iemelianova S.M., Bagrikova N.O., Borysova O.V., Borsukevych L.M., Vynokurov D.S., Gapon S.V., Gapon Y.V., Davydov D.A., Dvoretsky T.V., Didukh Y.P., Zhmud O.I., Kozyr M.S., Konyschuk V.V., Kuzemko A.A., Paskevych N.A., Ryff L.E., Solomakha V.A., Felbaba-Klushyna L.M., Fitsailo T.V., Chorna G.A., Chorney I.I., Shelyag-Sosonko Y.R., Iakushenko D.M. 2019. *Prodrome of the vegetation of Ukraine*. Kyiv, Naukova Dumka [in Ukrainian].

Euro+Med (2006-): Euro+Med PlantBase - the information resource for Euro-Mediterranean plant diversity. http://ww2.bgbm.org/EuroPlusMed/[accessed 06.10.2021].

Finch D.M., Butler J.L., Runyon J.B., Fettig C.J., Kilkenny F.F., Jose S., Frankel S.J., Cushman S.A., Cobb R.C., Dukes J.S., Hicke J.A., Amelon S.K. 2021. Effects of climate change on invasive species. [in:] T.M. Poland, T. Patel-Weynand, D.M. Finch, C.F. Miniat, D.C. Hayes, V.M. Lopez (eds) *Invasive Species in Forests and Rangelands of the United States*. Springer, Cham.

Forman J. & Kesseli R.V. 2003. Sexual reproduction in the invasive species *Fallopia japonica* (Polygonaceae). *American Journal of Botany*, 90, 4: 586–592.

Gasso N., Sol D., Pino J., Dana E.D., Lloret F., Sanz-Elorza M., Sobrino E., Vilà M. 2009. Exploring species attributes and site characteristics to assess plant invasions in Spain. *Diversity and Distribution*, 15: 50–58.

Guo P., Yu F., Ren Y., Liu D., Li J., Ouyang Z., Wang X. 2018. Response of ruderal species diversity to an urban environment: implications for conservation and management. *International Journal of Environmental Research and Public Health*, 15, 12: 2832.

Hennekens S.M., Schaminée J.H.J. 2001. TURBOVEG, a comprehensive datebase management system for vegetation data. *Journal of Vegetation Science*, 12: 589–591.

Hobbs R.J., Humphries S.E. 1995. An integrated approach to the ecology and management of plant invasions. *Conservation Biology*, 9, 4: 761–770.

IUCN Council. 2000. "Guidelines for the prevention of biodiversity loss caused by alien invasive species." in prepared by IUCN SSC Invasive species specialist group (ISSG), 1: 12–25.

Jackowiak B. 1990. *Antropogeniczne przemiany flory roślin naczyniowych Poznania*. Wydawnictwo Naukowe Uniwersytetu Adama Mickiewicza, Seria Biologia, 42, Poznań.

Kornaś J. 1968. Geograficzno-historyczna klasyfikacja roślin synantropijnych. *Materiały Zakładu Fitosocjologii Stosowanej Uniwersytetu Warszawskiego*, 25: 33–41.

Levine J.M., Vila M., D'Antonio C.M., Dukes J.S., Grigulis K., Lavorel S. 2003. Mechanisms underlying the impacts of exotic plant invasions. *Proceedings of the Royal Society. B: Biological Sciences*, 270: 775–781.

Lonsdale W.M. 1999. Global patterns of plant invasions and the concept of invasibility. *Ecology*, 80: 1522–1536.

Medvecká J., Jarolímek I., Zaliberová M. 2010. Dynamics and distribution of neophytes in ruderal vegetation of the Horná Orava Region (Northern Slovakia). *Hacquetia*, 8, 2: 147–157.

Mucina L., Grabherr G., Ellmauer T. 1993. *Die Pflanzen-gesellschaften O¨sterreichs. Teil I. Anthropogene Vegetation*. Gustav Fischer, Jena.

Pfadenhauer J.S., Klötzli F.A. 2014. *Die Vegetation der Erde*. Grundlagen, Ökologie, Verbreitung. Springer.

Protopopova V.V. 1991. Synanthropic flora of Ukraine and ways of its development. Kyiv: Naukova Dumka [in Ukrainian].

Protopopova V.V., Shevera M.V. 2014. Ergasiophytes of the Ukrainian flora. *Biodiversity: Research and Conservation*, 35: 31–46.

Protopopova V.V., Shevera M.V. 2019. Invasive species in the flora of Ukraine. I. The group of highly active species. *GEO&BIO*, 17: 116–135 [in Ukrainian].

Protopopova V.V., Shevera M.V., Bagrikova N.O., Ryff L.E. 2012. Transformer species in the flora South bank of Crimea. *Ukrainian Botanical Journal*, 69, 1: 54–68 [in Ukrainian].

Protopopova V.V., Shevera M.V., Chorney I.I., Tokaryuk A.I., Budzhak V.V., Korzhan K.V. 2010. Transformer species in the flora of Bukovinian Cis-Carpathian. *Ukrainian Botanical Journal*, 67, 6: 852–864 [In Ukrainian].

Protopopova V.V., Shevera M.V., Fedoronchuk M.M., Shevchyk V.L. 2014. Transformer species in the flora of Middle Cis-Dnipro. *Ukrainian Botanical Journal*, 71, 5: 563–572 [in Ukrainian].

Protopopova V.V., Shevera M.V., Mosyakin S.L., Solomakha V.A., Solomakha T.D., Vasilyeva T.V., Petryk S.P. 2009.

Transformer species in the flora of Northern Black Sea Region. *Ukrainian Botanical Journal*, 66, 6: 770–782 [in Ukrainian].

Protopopova V.V., Shevera M.V., Orlov O.O., Panchenko S.M. 2015. The transformer species of the Ukrainian Polissya. *Biodiversity: Research and Conservation*, 39: 7–18.

Pyšek P. 1998. Alien and native species in Central European urban floras: a quantitative comparison. *Journal of Biogeography*, 25: 155–163.

Pyšek P., Chocholoušková Z., Pyšek A., Jarošík V., Chytrý M., Tichý L. 2004. Trends in species diversity and composition of urban vegetation over three decades. *Journal of Vegetation Science*, 15: 781–788.

Pyšek P., Jarošík V., Hulme P.E., Pergl J., Hejda M., Schaffner U., Vilà M. 2012. A global assessment of alien invasive plant impacts on resident species, communities and ecosystems: the interaction of impact measures, invading species' traits and environment. *Global Change Biology*, 18: 1725–1737.

Pyšek P., Prach K., Šmilauer P., Rejmánek M., Wade M. 1995. Relating invasion success to plant traits: an analysis of the Czech alien flora. [in:] P. Pyšek, K. Prach, M. Rejmanek, M. Wade (eds.) *Plant lnvasions: Gerneral Aspects and Special Problems*, SPB Academic Publishing, Amsterdam: 39–60.

Raunkiaer C. 1934. *The Life Forms of Plants and Statistical Plant Geography, being the collected papers of C. Raunkiær*. Translated by H. Gilbert-Carter, A. Fausbøll, and A. G. Tansley. Oxford University Press, Oxford.

Ricciardi A., Hoopes M.F., Marchetti M.P., Lockwood J.L. 2013. Progress toward understanding the ecological impacts of non-native species. *Ecological Monographs*, 83: 263–282.

Richardson D.M., Pyšek P., Rejmánek M., Barbour M.G., Panetta F.D., West C.J. 2000. Naturalization and invasion of alien plants: concepts and definitions. *Diversity and Distributions*, 6: 93–107.

Schmidt V.M. 1980. *Statistical Methods in Comparative Floristics*. Leningrad [in Russian].

Šilc U. 2010. Synanthropic vegetation: pattern of various disturbances on life history traits. *Acta Botanica Croatica*, 69: 215–227.

Šilc U., Vrbničanin S., Božić D., Čarni A., Stevanović Z. 2012. Alien plant species and factors of invasiveness of anthropogenic vegetation in the Northwestern Balkans — a phytosociological approach. *Open Life Sciences*, 7, 4: 720–730.

Simonová D., Lososová Z. 2008. Which factors determine plant invasions in man-made habitats in the Czech Republic? *Perspectives in Plant Ecology, Evolution and Systematics*, 10: 89–100.

Sousa W.P. 1984. The role of disturbance in natural communities. *Annual Review of Ecology, Evolution and Systematics*, 15: 353–391.

Sukopp H., Werner P. 1983. Urban environment and vegetation. [in:] W. Holzner, M.J.A. Werger, I. Ikusima (eds.) *Man's Impact on Vegetation*. Dr. W. Junk, The Hague: 247–260.

Vilà M., Espinar J.L., Hejda M., Hulme P.E., Jarosik 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.

Wittig R. 2002. *Siedlungsvegetation*. Ulmer, Stuttgart.