

# Participation of alien species in urban floras in different botanical and geographical zones of Ukraine: a preliminary assessment

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**Abstract:** Results of a study on the participation of the group of alien species (kenophytes) in urban floras of different botanical and geographical zones of Ukraine are presented. The total list of kenophytes (497 species of vascular plants) is provided. The floristic composition, peculiarities of the taxonomic and geographical (according to the areas of origin) structures, and the degree of naturalization of kenophytes are analyzed. The results indicate a low floristic similarity between towns and cities. Climatic conditions play a more essential role in determining distribution patterns of kenophytes in urban areas in terms of the origin and the degree of naturalization parameters, whereas the taxonomic structure depends more on the area studied and economic development of a town/city.

**Key words:** alien species, naturalization, kenophytes, urban floras, taxonomic and geographical structures, Ukraine

## 1. Introduction

Study of urban floras is a research focus of modern floristics, which is intensively developing in many West European countries. These studies have resulted in new approaches, research methodologies and methods, and establishment of some tendencies and peculiarities of the pattern and processes of formation and development of urban floras (Sudnik-Wojcikowska 1987; Sukopp 1990; Jackowiak 1990, 1998, 2003; Wittig 1991, 2002, 2004; Kowarik 1992; Ilminskikh 1993).

At present the urban floras in Ukraine are being thoroughly studied and analyzed. As a result, several PhD projects on urban floras (Moysiyenko 1999; Melnyk 2001; Arkushyna 2007; Iepikhin 2008) or alien fractions of urban floras of Ukraine have been completed (Yavorska 2002; Khlystun 2006). However, many relevant checklists that constituted the basis of these studies usually remain unpublished. Several checklists of urban floras (Burda 1997; Protopopova & Shevera 2002; Kucherevsky & Shol 2003; Kagalo *et al.* 2004) or alien fractions (Mosyakin & Yavorska 2003) and important articles on the subject have been published to date. However, no generalizing publica-

tions on the alien fraction of Ukrainian urban floras are available at present.

Some years ago the authors started their investigations on the participation and role of alien species in urban floras of Ukraine. Results of this comparative investigation on the participation and distribution of archaeophytes in urban floras of different botanical and geographical zones of Ukraine showed that in general the percentage of this group in urban floras increases from north to south (Protopopova & Shevera 2008), in sharp contrast to the opposite pattern of their participation in zonal floras of Ukraine (Protopopova 1984, 1991).

Investigation of kenophytes, as a mobile group in any flora, including urban floras, is very important for clarifying issues concerning the history of flora and modern tendencies of its development, as well as for studies on adaptability of alien species, including their migration pathways, formation of structures and modern dynamics of the alien fraction of urban floras, and tolerance of this group to urbanisation. Contribution of kenophytes to alien fractions of floras in different regions of Ukraine increases from north to south (Protopopova 1984, 1991). Naturally, a question arises:



Fig. 1. Ukraine administrative division and location of the studied towns and cities

is there a similar regularity in the contribution of kenophytes to urban floras of different botanical and geographical zones of Ukraine? The answer to this question and results of studies on some peculiarities of distribution of kenophytes in urban floras of Ukraine are analyzed in the present article. Our study is focused on the analysis of (i) similarities of species composition; (ii) taxonomic structure; (iii) differentiation by areas of origin; (iv) differentiation by the degree of naturalization of kenophytes of urban floras in various botanical and geographical zones of Ukraine.

## 2. Material and methods

The subject of the present investigation is the group of kenophytes in urban floras of Ukraine. We selected seven cities and towns located in different regions of

the country (Fig. 1). These urban areas are characterized by different age, size, economic characteristics, anthropogenic transformation, and – last, but not least – availability of published floristic lists of urban floras, or/and lists of alien species. Comprehensive general information about towns and cities, including the total area, population, year of foundation (or the first mention in historical records), geographical position and some climatic characteristics, general species composition and the number of kenophytes in urban floras, is presented in Tables 1 and 2. In some cases we used data for Kherson, Mykolayiv and Simferopol (Moysiienko 1999; Melnyk 2001; Iepikhin 2008). The analyses were based on a cumulative list of kenophyte species in urban floras of Ukraine. The list was prepared by the authors by generalization of the literature data with some corrections, as well as our original data, and herbarium

Table 1. Historical and climatic characteristics of the urban areas of Ukraine

City, town	Area [km <sup>2</sup> ]	Population	Geographical position	Climate	Mean air temp. of January/July [°C]	Precipitation [mm/year]	Year or century of foundation or first record
Kyiv	839.0	4.130.000	50° 26' N, 30° 31' E	T-c	-5.5/+19.2	649	V-VI
Uzhgorod	40.0	117.000	48° 37' N, 22° 18' E	T-c	-4.3/+20.0	700-750	872
Kamyanets-Podilsky	40.0	99.610	48° 40' N, 26° 34' E	T-c	-5.0-6.0/+18.0-19.0	510-580	XII-XIII
Donetsk	358.3	988.000	48° 00' N, 37° 48' E	T-c	-5.0/+18.0	556	1869; as a town – 1917
Lugansk	255.0	455.000	48° 34' N, 39° 18' E	T-c	-6.0-8.0/+21.8-23.1	400-550	1795
Kryviy Rig	407.3	684.693	47° 55' N, 33° 15' E	T-c	-5.0-6.0/+21.0-22.0	268	1775
Mariupol	243.9	492.176	47° 06' N, 37° 34' E	T-cdf	-5.2/+22.7	450	1778

Explanations: T-c – temperate-continental, T-cdf – temperate-continental with droughts and frosty weather

**Table 2.** General species composition and floristic proportions in the kenophyte group of the urban floras of Ukraine

City, town	Total flora	Author/s	Number of species	Number of genera	Number of families	Number of species per number of families	Number of genera per number of families	Number of species per number of genera
Kyiv	ca 1600*	Yavorska 2002; Mosyakin, Yavorska 2003	373	215	59	6.32	3.64	1.73
Uzhgorod	789	Protopopova, Shevera 2002	148	108	46	3.14	2.29	1.37
Kamyanets-Podilsky	1064	Kagalo <i>et al.</i> 2004	123	100	45	2.7	2.20	1.23
Donetsk	685	Burda 1997	105	73	32	3.28	2.28	1.43
Lugansk	484	Burda 1997	69	55	23	3.00	2.39	1.25
Kryviy Rig	1009	Kucherevsky, Shol 2003	126	101	43	2.80	2.35	1.20
Mariupol	921	Burda 1997	82	74	31	3.19	2.38	1.33

Explanations: \* the authors provisional data

materials of the KW Herbarium (M. G. Kholodny Institute of Botany, National Academy of Sciences of Ukraine, Kyiv).

The taxonomical structure of the analyzed group was given by A. Tolmachev (1974), ecological groups (xerophytes, subxerophytes or mesexerophytes, submesophytes

**Table 3.** List of common species in the whole studied urban flora of Ukraine

1	2	3	4	5	6	7
Aceraceae	<i>Acer negundo</i>	F	N Am	Agr	X	A, S-n (parks, river banks, herbaceous slopes)
Amaranthaceae	<i>Amaranthus albus</i>	T	N Am	Ep	S-m	A
	<i>Amaranthus blitoides</i>	T	N Am	Ep	S-m	A
	<i>Amaranthus retroflexus</i>	T	N Am	Ep	S-m	A, S-n (river banks)
Asteraceae	<i>Ambrosia artemisiifolia</i>	T	N Am	Ep	S-m	A, S-n (sandy habitats, river banks, parks)
	<i>Conyza canadensis</i>	T	N Am	Agr-Ep	S-x	A, S-n (sandy habitats, river banks, among shrubs, xerothermic habitats)
	<i>Galinsoga parviflora</i>	T	S Am	Ep	M	A, S-n (moist areas with herbaceous vegetation)
	<i>Iva xanthiifolia</i>	T	N Am	Agr-Ep	S-m	A, S-n (river banks, among shrubs)
	<i>Helianthus tuberosus</i>	H	N Am	Agr-Ep	M	A, S-n (river banks)
	<i>Lepidothea suaveolens</i>	T	N Am & E Asia	Ep	M	A, S-n (herbaceous plots)
	<i>Xanthium albinum</i>	T	Middle European	Agr-Ep	S-m	A, S-n (river banks)
	<i>Xanthium spinosum</i>	T	N Am	Ep	S-m	A
Brassicaceae	<i>Diploaxis muralis</i>	T	S Eur	Ep	S-m	A
	<i>Cardaria draba</i>	H	S Eur & Asia	Ep	S-m	A, S-n (petrophytic slopes)
	<i>Lepidium perfoliatum</i>	H	Mediterranean-Iran-Turanian	Ep	M	A
	<i>Sisymbrium loeselii</i>	H	S Eur & Asia	Ep	S-m	A
Caryophyllaceae	<i>Saponaria officinalis</i>	T	Mediterranean-Iran-Turanian	Ep	S-x	A, S-n (parks)
Chenopodiaceae	<i>Atriplex hortensis</i>	T	Asia	Ep	M	A
	<i>Atriplex tatarica</i>	T	Mediterranean-Turanian	Ep	S-m	A, S-n (river banks)
Convolvulaceae	<i>Ipomoea purpurea</i>	T	S Am	Ep	S-m	A
Cucurbitaceae	<i>Echinocystis lobata</i>	T	N Am	Agr-Ep	M	A, S-n (parks, river banks, among shrubs)
Fabaceae	<i>Amorpha fruticosa</i>	K	N Am	Agr	M	A, S-n (river banks, parks)
	<i>Robinia pseudoacacia</i>	F	N Am	Ep	S-m	A, S-n (parks)
Onagraceae	<i>Oenothera biennis</i>	H	N Am	Agr-Ep	S-m	A, S-n (river banks, sandy habitats)
Poaceae	<i>Eragrostis minor</i>	T	S Eur	Ep	S-m	A, S-n (sandy habitats)
Solanaceae	<i>Hyoscyamus niger</i>	H	Mediterranean-Iran-Turanian	Ep	X-m	A

Explanations: 1 – family, 2 – species, 3 – life form, 4 – origin, 5 – degree of naturalization, 6 – ecology, 7 – type of biotope; F – phanerophyte, H – hemicryptophyte, K – cryptophyte, T – therophyte; Am – America, E – Europe; Agr – agriophyte, Ep – epocophyte; M – mesophyte, S-m – submesophyte, S-x – subxerophyte, X – xerophyte; A – anthropogenic, S-n – semi-natural biotope

or xeromesophytes, mesophytes) are given according to the *Ecoflora of Ukraine* (Didukh 2000). The zonal and geographical botanical subdivision of Ukraine is given following the *Flora of the Ukrainian SSR* (Kotov & Barbarych 1950).

For the determination of similarity of the lists of kenophytes and structural characteristics in different urban floras, we used the coefficients proposed by Jaccard (Jaccard's similarity coefficient), Kendall (Kendall's tau rank correlation coefficient) and Spearman (Spearman's rank correlation coefficient). The nomenclature of species mainly follows the *Check-list of vascular plants of Ukraine* (Mosyakin & Fedoronchuk 1999). The terminology and classification of alien flora used in the article in general follows that used in European publications (Thellung 1918; Kornaś 1968), with some corrections, it although is not commonly used in English-speaking countries.

### 3. Results and discussion

According to our data, the total list of kenophytes of the analyzed urban floras in different botanical and geographical zones of Ukraine consists of 497 species of vascular plants belonging to 250 genera and 70 families.

The number of species found in all towns and cities is 26 (5.2%), including 5.1% in Kyiv, 12.8% in Uzhgorod, 15.3% in Kamyanets'k-Podilsky, 27.5% in Lugansk, 18.1% in Donetsk, 15.8% in Kryvyi Rig, and 19.2% in Mariupol. The list of common kenophyte species for all studied urban floras of Ukraine is presented in Table 3. Most of them are widely distributed in the territory of Ukraine, mainly connected to anthropogenic biotopes, but they also tend to penetrate semi-natural habitats, thus are characterized as epocophytes (species successfully naturalized anthropogenic biotopes)

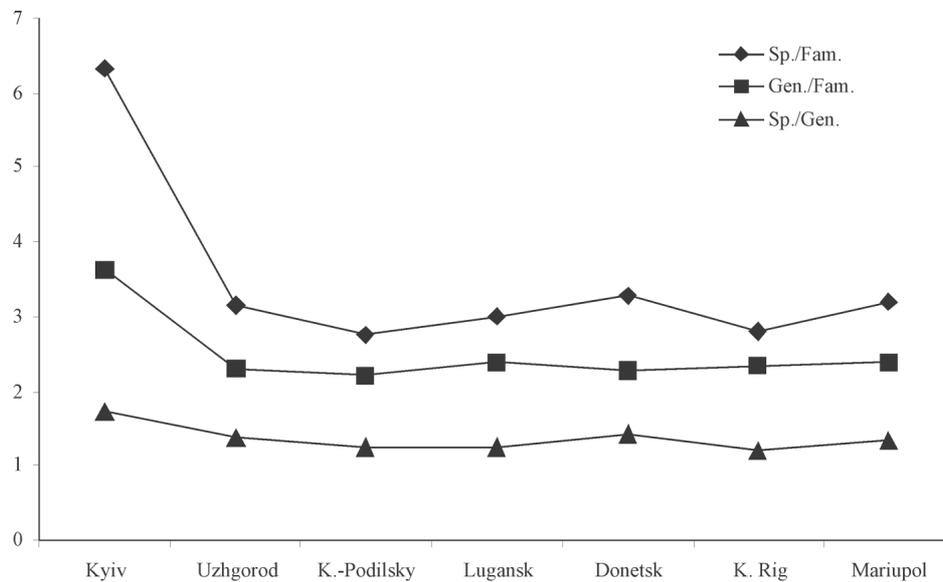


Fig. 2. Proportions between taxa of different rank in the kenophyte urban floras of Ukraine

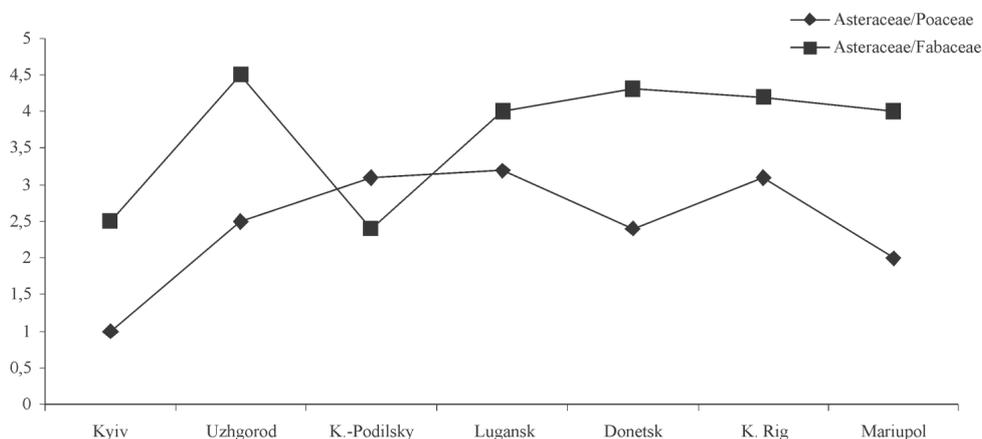


Fig. 3. Proportions between families most abundant in kenophytes in the urban floras of Ukraine

or agriophytes (species successfully naturalized and widely distributed in anthropogenic biotopes, and becoming permanent in semi-natural or natural biotopes). Therophytes, species of North American origin, and submesophytes (or xeromesophytes) prevail among them. These species are usually distributed both in urban and suburban zones.

Proportions of kenophytes in urban floras (Table 2) and the alien fraction of the Ukrainian flora (species/family=7.1, genus/family=3.6, species/genus=2.0) are different. The urban flora of Kyiv is characterized by the highest floristic richness and taxonomic diversity of kenophytes (372 species), while the lowest values are registered for the Lugansk urban flora (69 species). A higher percentage of monospecific genera (61.2%) and monospecific families (28.6%) results in a reduction of the mean number of species in genera and families, but also in some increase of the mean number of genera per family.

These indexes (species/family, genus/family, species/genus) do not differ considerably in the studied urban areas (Fig. 2). The only exception is Kyiv, which is characterized by a large area, diverse landscape, a well-developed infrastructure and transportation, and considerable destruction of the plant cover.

Indexes of Asteraceae/Poaceae, and Asteraceae/Fabaceae, which indicate zonal differences of floras, show little variation in the kenophyte group of urban floras of Ukraine (Fig. 3), which does not correlate with the geographical position of a town and city. It indicates that these differentiation patterns are very poorly manifested within a limited latitudinal range (50°26' N in Kyiv, and 47°06' N in Mariupol).

The comparative similarity of kenophyte species compositions in the studied urban floras of Ukraine according to the Jaccard index shows that Donetsk (Forest-Steppe zone, Eastern part) and Mariupol (Steppe zone, coast of the Sea of Azov) urban floras (0.58) are most closely associated; Lugansk (Forest-Steppe zone, Eastern part) is also close (0.55), while urban floras of Kyiv (Forest zone) and Lugansk (0.13) are the most different from the others (Table 4). Therefore, according to our preliminary data, distribution patterns of kenophytes in

urban floras of Ukraine are greatly influenced by the climatic conditions of regions.

The study of peculiarities of the taxonomic structure of the kenophyte group in the analyzed urban floras of Ukraine shows that despite the presence of many common features, according to our data on the dendrogram (Fig. 4) there is clear differentiation of two groups: (i) a group of three large industrial cities (Kyiv, Donetsk, and Mariupol), and (ii) a group of four towns and cities with a less transformed plant cover. Because towns and cities located in different zones are present in each group, similarities depend more on the size and degree of economic development of a given urban area, rather than on the climatic conditions of the region.

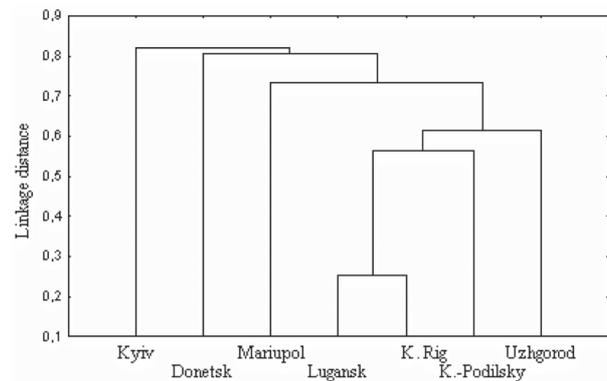


Fig. 4. Dendrogram of similarity of the kenophyte group taxonomic structure in the urban floras of Ukraine (Spearman index)

In terms of the origin of kenophyte species, Mediterranean, and Mediterranean-Irano-Turanian, and North American taxa prevail both in the geographical structure and in urban floras and the alien fraction of Ukraine (Table 5). The similarity of kenophytes in urban floras of Ukraine, obtained for the quantitative characters of species according to their origin (using the Spearman index), results in grouping of species by regional conditions in two clusters (Fig. 5): (i) southern and southeastern urban areas, excluding Kyiv, and (ii) forest-steppe urban areas, excluding Kherson. Therefore, the climatic conditions essentially influence the composition of aliens of similar geographical origin in the urban

Table 4. Similarities in kenophyte composition in the urban floras of Ukraine (Jaccard index)

	Kyiv	Uzhgorod	Kamyanets-Podilsky	Lugansk	Donetsk	Kryvyi Rig	Mariupol
Kyiv	-	0.25	0.23	<b>0.13</b>	0.18	0.23	0.15
Uzhgorod	0.25	-	0.36	0.21	0.23	0.33	0.31
Kamyanets-Podilsky	0.23	0.36	-	0.26	0.27	0.35	0.28
Lugansk	<b>0.13</b>	0.21	0.26	-	<b>0.55</b>	0.29	0.43
Donetsk	0.18	0.23	0.27	0.55	-	0.32	<b>0.58</b>
Kryvyi Rig	0.23	0.33	0.35	0.29	0.32	-	0.31
Mariupol	0.15	0.20	0.28	0.49	<b>0.58</b>	0.31	-

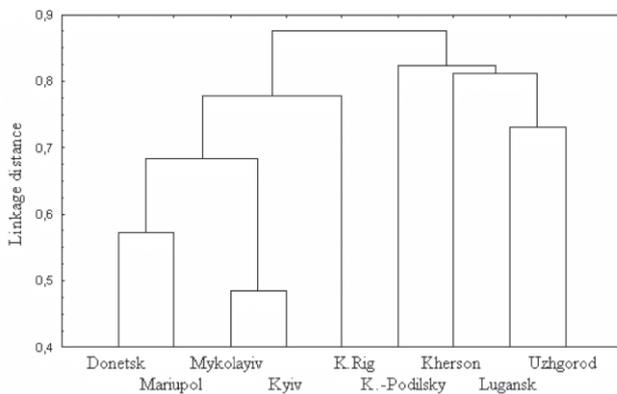
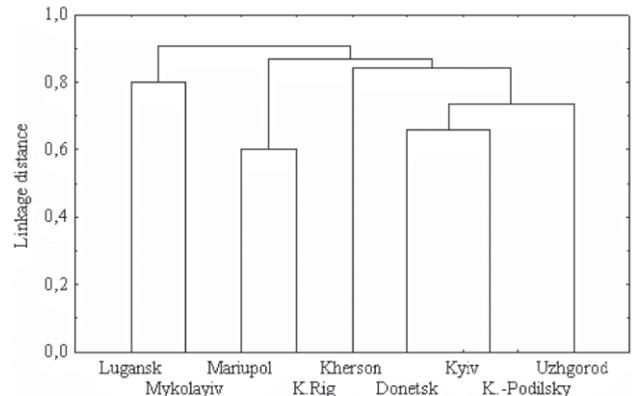
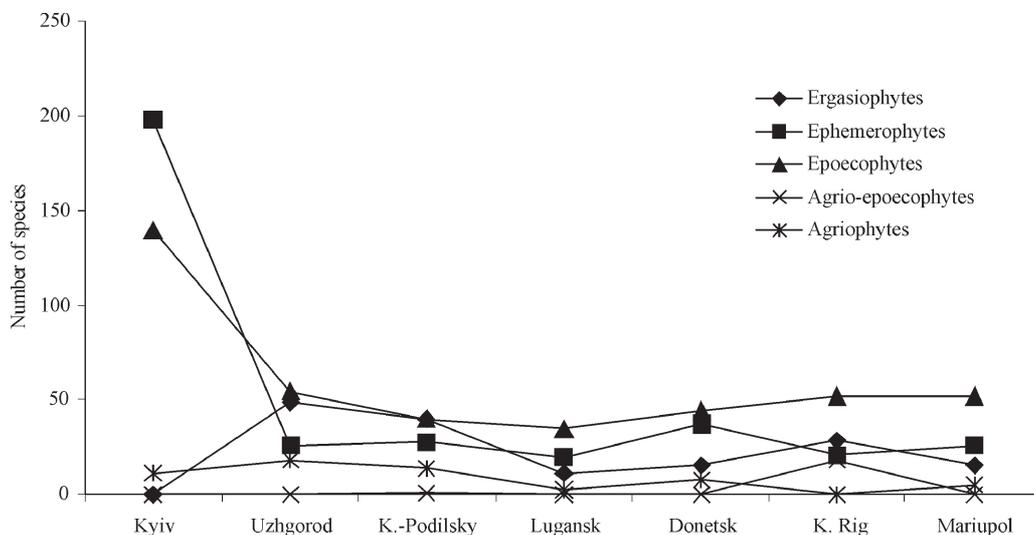
**Table 5.** Main geographical groups of kenophytes in the urban floras of Ukraine according to origin

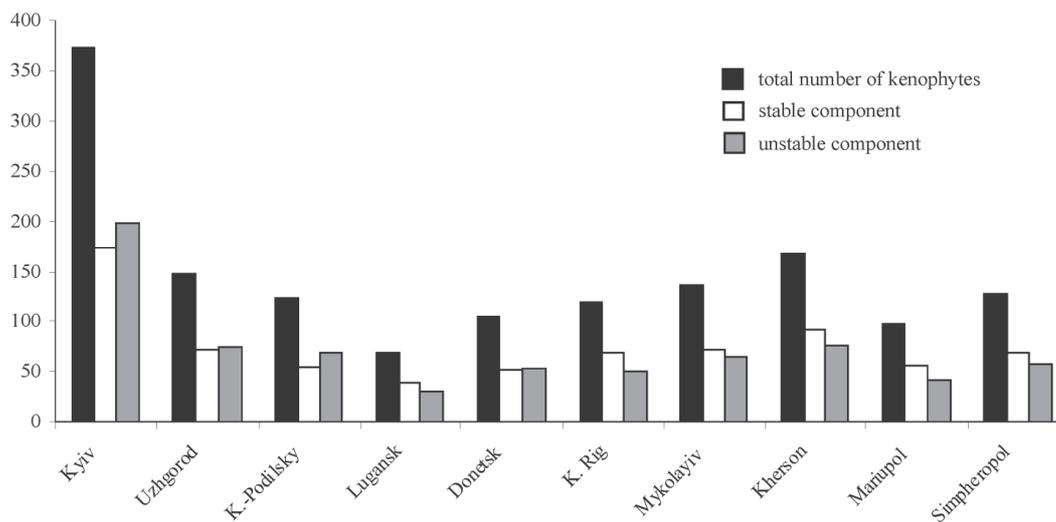
Chorological groups according to the origin of species	Town/city						
	Kyiv	Uzhgorod	Kamyanets-Podilsky	Lugansk	Donetsk	Kryvyi Rig	Mariupol
Mediterranean	75	26	24	12	16	19	23
Mediterranean-Irano-Turanian	52	11	12	12	17	17	20
Irano-Turanian	26	7	7	6	7	7	5
N America	92	48	29	18	35	35	23
S America	12	9	6	4	9	5	3
S Europe	5	6	4	2	2	3	3
C et W Europe	9	6	8	3	4	5	4
E Asia	6	8	7	2	3	4	4
SE Asia	35	6	7	2	2	3	1

flora of Ukraine, although they do not play a decisive role, at least for kenophytes.

The results of studies on the degree of naturalization of kenophytes in urban floras of various zones in Ukraine show that the quantitative characteristics of different groups, with the only exception of Kyiv

(ephemerophytes and epocophytes), do not differ considerably (Fig. 6). These results in general correlate with data on the dendrogram of the Kendall index (Fig. 7). The investigation of species with a high degree of naturalization, or stable components (agriophytes and epocophytes), and species with a low degree of naturalization

**Fig. 5.** Dendrogram of similarity of the kenophyte group in the urban floras of Ukraine according to geographical origin (Spearman index)**Fig. 7.** Dendrogram of similarity of the kenophyte group in urban floras of Ukraine according to the degree of naturalization of species (Kendall index)**Fig. 6.** Differentiation of the kenophyte group in the urban floras of Ukraine according to the degree of naturalization



**Fig. 8.** Differentiation of stable and unstable components of the kenophyte group in the urban floras of Ukraine

zation, or unstable components (ephemerophytes and ergasiophytes), among kenophytes in urban floras of Ukraine (Fig. 8) shows more essential differentiation; for example, unstable components prevail in urban floras of the Forest and Forest-Steppe Right-Bank regions (Kyiv, Uzhgorod, Kamyanyets-Podilsky); in urban floras of the Donetsk Forest-Steppe (Donetsk, Lugansk) and Steppe zones (Kryvyi Rig and Mariupol), the stable components prevail.

These regularities are explained to some extent by a more active primary immigration of plants in a border town (Uzhgorod), and large industrial and transportation centers (Kyiv), the effect of urbanization, and economic conditions. It also indicates that in urban floras of the western areas of the Forest and Forest-Steppe zones, which are floristically richer than the corresponding eastern regions, the process of naturalization by new alien species is difficult, or at least hampered.

#### 4. Conclusions

1. According to our data, the total list of kenophytes in the analyzed urban floras of different zones of Ukraine comprises 497 species of vascular plants. We observed major differences in species composition patterns in urban floras; only 26 species (5.2%)

are common to all studied urban areas. In general, the distribution of kenophytes in the analyzed urban floras is greatly influenced by the climatic conditions in the regions.

2. Our data indicate that the structural peculiarities of the kenophyte group in the analyzed urban floras of Ukraine are not clearly differentiated. In Ukraine the climatic conditions play a more essential role in the distribution of kenophytes in urban areas in terms of the origin and degree of naturalization parameters, while the taxonomic structure depends more on the area and economic development of a town or city. According to the degree of naturalization, agriophytes and epocophytes prevail only in towns/cities of the southeastern region.
3. Trends in the distribution of kenophytes in the analyzed urban floras of different botanical and geographical zones of Ukraine do not correlate with the known tendencies in the distribution of this group in regional floras.

**Acknowledgements.** We are grateful to our colleagues from the M.G. Kholodny Institute of Botany, National Academy of Sciences of Ukraine, Prof. Dr. Sergei L. Mosyakin, for useful comments on the content and style of the manuscript, Iryna M. Anischenko, for mathematic analysis, and Natalya V. Morgart, for technical assistance.

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