

HISTORICAL OVERVIEW OF THE STUDIES OF ALIEN FLORA OF UKRAINE

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Abstract: This review has shown that the alien fraction of the Ukrainian flora have been identified and studied comprehensively. Thus, a total richness of alien fraction is about 1,000 species. The structure, typical trends, and regional peculiarities of this component of the Ukrainian flora have been analyzed. The main results of investigations are summarized. The alien floras of some regions, cities and towns, protected areas of Ukraine have been studied. The species composition of some habitats, partial floras with a high abundance of non-native plants, tolerance to anthropogenic influences, the segetal potential, and the role in developing of the human-made biotopes and in evolution of the plant cover have been determined. The changes in the species composition over 160 years, and the trends forming the stable and unstable elements of the alien flora of Ukraine, have been shown. The peculiarities of the distribution of archaeophytes and neophytes of the regional floras and urban floras as latitudinal gradients have been revealed. The plant invasions and expansions of 30 species have been reconstructed, analyzed and reviewed. A group of highly invasive potential species is selected. Some important characteristics of alien species, such as their activity in plant communities and their ecological effects, the trends of distribution and abundance, the participation and role under the influence of anthropogenic environmental change or climate change in various types of biotopes and geographical zones etc., have been analyzed.

Key words: Ukraine, alien flora, review, trends of investigation, peculiarities, invasive alien species

Received 09 November 2018

Accepted 17 November 2018

Introduction

The problem of alien organisms, their impact on the flora, fauna and human society attract special attention from botanists in Ukraine (Protopopova et al. 2002a), because there is more than 80% of human-made plant cover in its territory.

Complex historical factors (the invasion and relocation of nomads, the wars, the early occurrence of agriculture in the I-II centuries B.C., the settled population, the passing of important trade routes through the territory, the foundation of colonies by

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immigrants from the Mediterranean, Southern and Central Europe etc.) and further intensive development of agriculture, industry, transport, socio-economic relations, urbanization, favorable natural and climatic conditions, etc. gave wide opportunities for the invasion of alien plants (Protopopova 1973). The current state of the flora of Ukraine is characterized by a significant increase of the anthropophilic component's role in it (Protopopova et al. 2002a), which is over 15.2% of the total number of species (Fig. 1.).

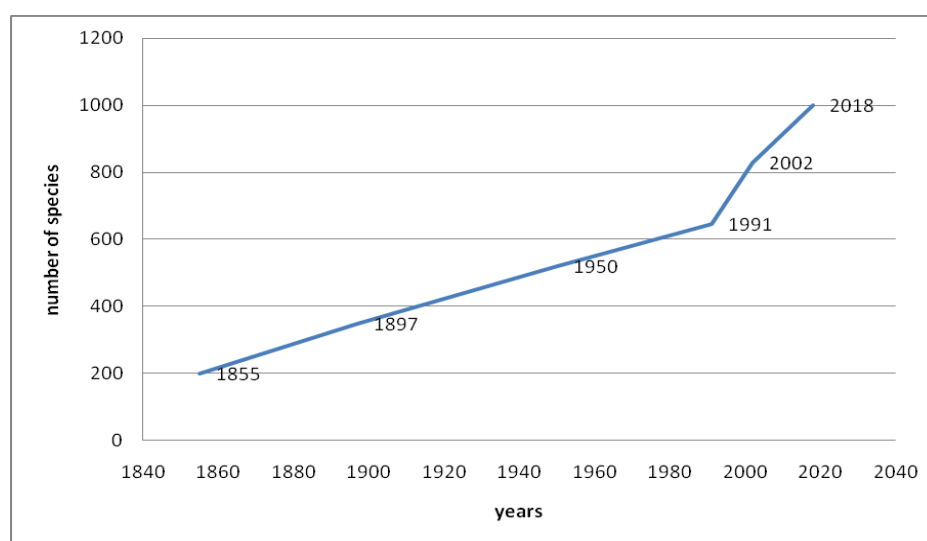


Fig. 1. The increase of the number of species of alien plants in the flora of Ukraine during a period of more than 160 years

Ukraine is situated in several natural climatic zones (forest, forest-steppe, steppe); the presence of the Carpathian and the Crimean mountain ranges, a variety of natural conditions, specificity of the historical development of the country and the current ecological situation allow us to consider it as a model object for the study of the peculiarities of alien plant migration.

The process of flora adventization in different regions of the country occurs with varying intensity. The negative impact of invasive species on biodiversity is most noticeable in the regions with fragmented natural vegetation cover. The total cumulative influence of alien plants increases the insularization of populations of native plant species caused by human activity, accelerating this process significantly. There is also destructive impact to the populations of certain species or ecosystems by phytocoenically active invasive plants, established in the natural plant communities that were weakened by the anthropogenic press (Protopopova et al. 2002a, 2003). In this connection, phytinvasions continue to attract the attention of many florists; various aspects of research in this direction are developing.

To find out the current state of the alien fraction of the flora of Ukraine at the regional level, a large amount of diverse factual material was accumulated, it is characterized by the multidimensional nature of its research. This material allows us to

perform a retrospective analysis of the alien flora formation and identify the directions and trends of the further course of adventization of the plant cover of Ukraine.

Material and methods

The object of the research was the alien flora of Ukraine, and, in particular, the alien plant species which are characterized by a high degree of naturalization and discovered to have high biogeographic and coenotic activity. The main materials for the analysis and generalizations were literary sources that depicted the results of the study of alien plant species of the flora of Ukraine. The collections of herbaria have been critically studied (CHER, CWU, DNZ, DSU, KHEM, KHER, KW, KWHA, KWHU, LW, LWS, LWKS, MSUD, SIMF, UU, YALT, etc.), as well as data from the field research of the authors since 1965. The classic comparative morphological-ecological-geographical method is used in this work.

Results and discussion

The high degree of adventization of the flora of Ukraine has defined a wide range of studies. Publications on these themes from 1787 to 2017 are summarized in five issues of bibliographic references (Burda et al. 2018), which included 1697 works, of which 1183 are directly related to alien plants, and 514 – contain more or less complete information about them. The main directions of research are: floristics – 719 publications, chorology – 139, biology (primarily of weeds) – 117, ecology – 79, distribution control and control means – 75, taxonomy – 28 population – 17, general issues – 14, molecular genetics – 2, economic evaluation – 2, paleobotany – 2. The most complete studies were made on the species of the listed genera: *Ambrosia* L. – 32 publications, *Impatiens* L. – 18, *Heracleum* L. – 17, *Oenothera* L. – 14, *Phalacrolooma* Cass. – 13, *Amaranthus* L., *Solidago* L. – 11, *Asclepias* L. – 10.

The study of the alien fraction has over 220 years of history and is connected with the general research of the flora of Ukraine or its regions. Accumulation of information on alien plants began in the process of studying regional flora back in the 18th century. Initial and fragmented information about alien plants is recorded in the works of naturalists of the 18th- 19th centuries (Güldenstädt 1787, 1791, Bieberstein 1808a, b, c, Besser 1809, 1822, Andrzejowski 1823, 1860, 1862, Zawadzki 1835, Ledebour 1842, Rogovich 1855, 1869, Chernyaev 1859, Herbich 1859, Knapp 1872, Montrezor 1886, 1887, 1888, 1890a, 1890b, Shmalhausen 1886, Paczoski 1897, 1899, 1900, 1911, Zapałowicz 1906, 1911a, 1911b). From the middle of the 19th century the authors began to indicate the origin of the alien species. The first such information is found in the works of P. Rogovich (1855) and I. Schmalhausen (1895-1897).

From the end of the 19th and beginning of the 20th century, due to the intensive farming of the steppes and the increase of arable lands, the focus was on the study of alien weeds. This direction had been actively developing in the 1920-1930s. Investigation of alien weeds, in addition to the usual morphological and agronomic characteristics, also included the analysis of the causes and ways of rapid resettlement of these plants, and peculiarities of their biology. The most informative among these publications are: the work by J. Paczoski (1911), on the distribution of *Amaranthus albus* L., by O. Yanata (1927) on the weeds of Ukraine, that includes the means of prevention, control and containment of their distribution, by A. Kuzmenko (1927) on

the distribution and biological features of *Fagopyrum tataricum* (L.) Gaertn., by O. Baranovskyi (1938) on the biology and control of *Galinsoga parviflora* Cav., etc. The general summary on the weeds of the country was published at 1937 under the editorship of E. Bordzilovsky. It contains information about a number of alien plants, their origin, and means of spreading in Ukraine.

V. Taliev (1900, 1902) was the first to note that anthropogenic activity had become a botanical and geographical factor. The anthropogenic factor, in his opinion, was determining the history of development and distribution of vegetation. His ideas stimulated the development of new perspectives on the introduction of alien plant species, as one of the aspects of modern changes in plant cover. In the 1920s a special study of alien plants as a special group began. M. Kotov investigated the mass resettlement of alien plants associated with human activity (1921, 1923, 1926, 1927a, 1927b–1929, 1934, 1949). In these works, he establishes the reasons for the appearance of alien plants in the country, the ways of their spreading, conditions that promote their distribution, etc. In parallel, the main floristic trend was developed. So, by the middle of the 20th century, large floristic material and datasets were collected, processed and published.

In the second half of the 20th century a comprehensive study of the regional alien flora of the Forest-Steppe, Steppe and Crimea was started with the works by V. Protopopova (1965) and S. Kozhevnikova (1970). In particular, their species composition was established, the structural analysis was conducted, and the degree of naturalization and regional differences were determined. In the study of the alien flora of forest-steppe and steppe zones (Protopopova 1965, 1973) particular attention is paid to the correlations between the distribution of alien plants and changes in the plant cover, determined by human activity. Based on numerous herbarium and literary data, the time of introduction and ways of resettlement of more than 100 species of alien plants from the end of the 18th century until the second half of the 20th century was established. The centers of introduction, ways of forming of the areals of these plants in the region, and analysis of the effectiveness of the means of distribution and biological characteristics are described. In particular, it is noted that anthropochory provides mainly the remoteness of new localities, and widespread depends on the effectiveness of natural methods of distribution of the propagule. Some taxa (*Xanthium* L., *Iva* L.) are revised, new species and forms are revealed. As a result of the historical reconstruction of the expansion of a number of species (*Galinsoga parviflora*, *Iva xanthiifolia* Nutt., *Amaranthus albus*, *A. blitoides* S. Watson, *Impatiens parviflora* DC., *Ambrosia artemisiifolia* L., *Solanum rostratum* Dunal., *Xanthium albinum* (Widder) H.Scholz, *Grindelia squarrosa* (Pursh) Dunal, *Cenchrus longispinus* (Hack.) Fernald, *Echinocystis lobata* (Michx.) Torr. & A. Gray, etc), it is shown that their distribution is conditioned by the influence of some favorable factors. In parallel, an inventory of the species of the alien fraction of Crimean flora was conducted. An annotated checklist of this group in the region's flora consisted of 133 species of vascular plants (Kozhevnikova, Rubtsov, 1971). In this work, its ways of introducing and distributing of the species of alien plants on the peninsula were considered in detail. The analysis of the geographical structure showed that the origin of the alien fraction of the Crimean flora is dominated by the species of the Ancient Mediterranean. Second place was occupied by North American species, most of which were weeds, and the third – East Asian species. The

bioecological structure of the fraction by the author based on the original material was characterized. By the degree of naturalization, the majority are ephemerophytes, and the least number belong to neophytes. According to modern data, the alien fraction of the Crimean flora comprise 375 taxa; interesting information about the dynamics of its composition for almost 50 years and changes in the structure are given by N. Bagrikova (2013). In particular, only the numerosity of this group has increased by 242 species of vascular plants. According to the comprehensive analysis, the author established an increase in the modernization of flora, increased participation of Asian species, and in the spectrum of life forms – participation of trees (11.2%) and shrubs (6.9%). A specific feature of the alien fraction of the flora of Crimea is a high rate of the index of instability (0.56), which according to the author, is due to a significant number of ephemerophytes (23.7%) and colonophytes (32.0%).

For the first time, the alien fraction of the flora of Ukraine was allocated as a part of synanthropic flora at the end of the 20th century; in total there were 646 species of vascular plants (Protopopova 1991) (Fig. 1). Structural analysis of the fraction was carried out and its characteristic features and regional peculiarities were determined. It was proven that the group of alien species generally caused changes to the systematic, geographical, and ecological structure of the flora of Ukraine and changes to the phytocenotic spectrum and spectrum of life forms, as well as expanded the florogenetic bonds with floras of the xerophytic regions of other continents. It was established that the distribution of alien plant species in Ukraine is characterized by certain patterns, which is evidenced by, for example, the calculated digital indicator of relative equilibrium of unstable and stable components in the species composition of the alien and synanthropic regional floras. A new version of the florogenetic classification of alien plants is proposed; in it the main criterion is the differentiation of species on the basis of their florogenetic bonds with some phytochorions within the climatic regions. This allowed us to establish that the main role in the formation of the alien fraction of the flora of Ukraine was played by the arid floras of the Ancient Mediterranean, North American prairie, Areas of Rocky Mountains, the Madrean Region of North America, and Chilean Patagonian arid regions of South America. That is, the process of adventization occurs through thermoxerophytization. Analysis of zonal-regional relationships in allocation of synanthropic species showed that everywhere anthropogenic localities are dominated in number by alien plants, especially in Crimea and the forest-steppe zone. Their number increases in the latitudinal direction to the south. However, their percentage in synanthropic flora increases in the opposite direction. Distribution of archeophytes and neophytes is characterized also by different trends: the number of archeophytes is increasing in the northern direction, and the neophytes – in the southern. Parameters of modernization and instability indexes also increase in the southern direction. It is shown that the unstable component of the alien fraction of flora (ephemerophytes and ergasiophytes) do not affect the trends of zonal distribution of alien plants. The hypothesis of the origin of a number of narrow-endemic races of the regional flora from archeophytes in the process of their adaptation to new climatic conditions or ecotops is proposed.

One of the interesting trends in the investigation of the alien fraction of the flora of Ukraine of that time is the research of the anthropogenic transformation of ecosystems, first of all, their phytodiversity. For the first time, the reasoning of such a

research trend as an analysis of composition and structure of flora for a directed transformation of plant cover is proposed. Also, the method of flora-isolates (an elementary territorial unit of anthropogenic flora) is introduced. The first typologies of transformed flora and macroecotops of partial floras for the role in florogenesis have been developed. The functional role of various types of anthropogenic floras in reproduction and preservation of plant cover was substantiated. A significant role of phytovasions in the processes of transformation of modern flora has been proved. These problems are best covered by an example of the structure, genesis, transformation and development of measures for the conservation of the flora of the southeast of Ukraine (Kondratyuk et al. 1980, 1985, 1988, Burda 1991).

In fact, the results that were published in the early 1990's, have intensified the development of the research of the regional alien flora at the end of the last century, which continues to this day. The alien fractions of the flora of some regions (Ostapko et al. 2009, 2010, Oitsius' 2011, Bagrikova 2013, Dvirna 2014, 2015, Kucher 2016, 2017, etc.), different florocomplexes (incl. railways and human-made ecotops (Burda & Tokhtar, 1992, Tokhtar 1993, 2005, Drel' 1997) and seaports (Petryk 1993), agroecosystems (Dzyuba 1990, 2000, Burda 2001, 2003, 2018, Mariyushkina 2003), urban floras (Mosyakin & Yavorska, 2002, Khlystun 2006, Zavyalova 2008, Baranovskiy et al. 2012), protected areas (Dubyna & Protopopova 1985, Protopopova et al. 1999, Shevchyk & Senchylo 2009, Melnychuk & Trokhymenko 2014, Burda et al. 2015, Zavalova 2017, etc.), and water reservoirs (Konogray 2008), etc., were investigated. During that time, there were numerous publications devoted to the finds of new species of aliene plants, which are collected in the bibliographic references (Burda et al. 2018). The amount of information about this group in general floristic publications has increased (Manual ..., 1987, Mosyakin & Fedoronchuk, 1999), in the checklists of the regional floras (Kondratiuk et al. 1985, Bairak 1997, Chopyk et al. 1998, Kucherevskiy 2003, Vasylyeva & Kovalenko, 2003, Tarasov 2005, 2012, Dzhuran et al. 2007, Kucherevskiy & Shol, 2009, Lukash 2008, Moysiienko 2011, etc.).

Among the recent regional studies, there are those in which the study of alien plants was one of the tasks. In particular, as a result of the study of plant contamination of the plant cover of the Middle Dnipro in its composition, 574 alien species were identified (Dzhuran et al. 2007). The adventization of the flora of Eastern Polissya is caused by 268 species of alien plants (Lukash 2008, 2009) and the Northern Black Sea Region – 565 (Moysiienko 2011). At the same time, there are works devoted exclusively to the comprehensive study of the alien species in the flora of some of the forest-steppe (Dvirna 2015) and steppe (Kucher 2017) territories of Ukraine. The specificity of both of the investigated floras is manifested in their mesophilic character, the general predominance of species with a wide range and wide ecological-coenotic amplitude, prevalence of a stable component over unstable, which in general corresponds to the characteristics of the alien fraction of the flora of Ukraine.

The similar comprehensive investigations of the alien fractions of regional floras allowed to find out the general features of the distribution of alien plants species, the peculiarities of the structure of this group and naturalization of species with the different origin, the causes of "outbreaks", the spreading of some species, etc.

Another important trend in the investigation of non-native plants in the flora of Ukraine is the special study of phytovasions that was started at the beginning of the

21st century (Protopopova et al. 2002a, 2003). The composition of the fraction of 830 species of alien plants was established and the process of adventization of the flora over 150 years (1855–2002) was analyzed in these publications. In general, the progressive character of the adventization process, the tendency of increasing of the species number and the stepping up of the rates of introduction, distribution and naturalization, the outspread of ecotopological differentiation were generally noted. The participation of alien plants in the flora of Ukraine has increased from 3% (1855) to 15% (2018). Only 60% of species of the total fraction are successfully naturalized in all of the botanical and geographical zones of Ukraine. The role of species of alien plants in ecosystems according to the classification by J. Falinsky was evaluated. Most of the species have achieved biogeographic success, they have become widespread mainly in man-made areas with reduced competition. About 100 species of alien plants have become phytocoenotically successful: they have become established in semi-natural and natural plant communities. This has begun to affect their composition, structure, dynamics, and functional relationships. The least species of alien plants of the flora of Ukraine have acquired genetic success, that is, they are adapted mainly by hybridization (*Xanthium albinum*, *Centaurea diffusa* Lam., *Salix fragilis* L.).

The expansion of 30 species of alien plants, which took place during the second half of the 20th century, have been analyzed. It was found that in some species this process differs according to the continuance, the rate of distribution, or the character of development (outbreak, gradual stable distribution, fluctuations). Stress tolerance, a high degree of naturalization, effective means and a rapid rate of distribution, high coenotic activity, and wide ecological amplitude are the characteristics of all species in the state of expansion. There is a tendency of growth to the degree of naturalization and invasive ability for many species. As a result of the large amount of information on the changes caused by the widespreading and establishing of the species of alien plants in the plant communities, authors conclude that the adventization of the flora of Ukraine is increasing. Its impact is significant for the environment at the species, population, coenoses and ecosystem levels. Taking that into account, the working version of the National Strategy for the Control of Invasive Plant Species in Ukraine and supplementing the relevant national legislation has been proposed (Protopopova et al. 2002a, 2003).

At the same time, plant invasions in agroecosystems are investigated, according to the results of which, the threats of alien plants for agro-landscapes of Ukraine were evaluated (Burda 2001, 2003). Also, the ecological peculiarities in agroecosystems of Ukraine (Mariyushkina 2001, 2002a, 2002b, 2003), segetal potential (Burda 2003), and expansion of some species on the regional level were investigated (Lytvynenko & Vynokurov 2003–2004, Prots et al. 2011, Vykhor & Prots 2012, Kucher 2012, Dvirna 2014, etc.). The inventory of the species composition of alien plants in agricultural biotopes in Ukraine was conducted, in total 743 taxa were found (702 species, 24 subspecies and 17 hybrids). Some of them (129 species) are widespread in 49 countries of Europe. It has also been established that the species composition of alien plants, which is the biological contamination of agricultural biotopes in Ukraine, is similar to other European countries (Burda 2018).

In Ukraine, invasive plants were studied actively at different levels of organization, in particular, species, population, coenosis, biotope, etc. (Panchenko 2005,

Protopopova et al., 2009, Vykhor & Prots, 2012, 2014, Vykhor 2015, Didukh et al. 2016, Tokaryuk et al. 2018, etc.). The inventory of the species composition of alien plants at the different territorial levels is still relevant. At the beginning of this century, for the first time in Ukraine, an annotated list of species (94) of alien plants with a high invasive ability was proposed; the species displayed their biogeographic and phytocoenotic activity. Taking into account previous studies and the current state of phytoinvasions in Ukraine, the species of vascular plants, most harmful for the phytodiversity on the Protected Areas of national importance, have been revealed. 100 invasive alien species occurring in Protected Areas of Ukraine are given as a brief compendium of three lists: Black (17), Grey (50) and Watch (33) (Zavyalova, 2017).

Some publications are devoted to the means of control of highly-invasive plant species (Maryushkina 1986, Mariyushkina & Hrytsenko 2000, Mariyushkina 2001, 2002a, 2002b, 2006, Petryk 2006, Borzykh 2014, etc.). As the results of investigation of 58 invasive species in the flora of the Northern Black Sea Region, their degree of naturalization, structural peculiarities, and participation in plant communities were established. The regional features of the group are a higher percentage of trees, shrubs and perennials, compared to the alien fraction of the total Ukrainian flora, as well as a prevalence of mesophytes, even though the region is situated in xerophilic conditions. These features can be explained by climate changes in recent decades, as a result of which it has become milder and more humid. The plant communities of some classes of native vegetation, such as, *Koelerio-Corynephoretea canescentis* Klika in Klika bet Novak 1941 (incl. *Festucetea vaginatae* Soó ex Vicherek 1972 (Mucina et al., 2016)), *Mollinio-Arrhenatheretea* Tx. 1937, *Festuco-Brometea* Br.-Bl. et Tx. ex Soó 1947, and others, have the highest invasibility. Invasive species have been noted in all types of habitats of the region, in particular *Centaurea diffusa* – in 6 anthropogenic and 4 native, *Conyza canadensis* (L.) Cronquist – in 7 and 3, *Grindelia squarrosa* – in 5 and 3 (Protopopova et al. 2009).

In the flora of Transcarpathia 43 species of invasive plants were found. Among them neophytes prevail, mostly those of North American origin; hemicryptophytes and therophytes, mesophytes, heliophytes (Prots 2015, Vykhor 2015). Dynamics trends of the distribution of invasive species in the flora of Transcarpathia and their ecological-cenototic confinement were analyzed. The distribution pattern of invasive species consists of a long lag-phase and an exponential phase. According to the study results, the growth of populations of invasive plants is slow in the lag-phase; the lower chronological limit of the exponential phase is established; the majority of the species are confined to the belt of lowland oak forests. Based on the study of spreading, the author developed predictive climate models of *Heracleum sosnowskyi* distribution. It is established, that the plants of the species can potentially populate all big riverside habitats, and the upper limit of their distribution will shift higher and reach the altitude of alpine meadows. This will be a threat to the structural and functional integrity of the high mountain river habitat types, meadows, subalpine and alpine areas. The assessment of the negative impact of invasive species, such as, *H. sosnowskyi*, *Helianthus tuberosus* L., *Reynoutria japonica* Houtt., *Solidago canadensis* L. was carried out (Vykhor 2015).

The invasive species of the flora of Bukovinian Cis-Carpathia region (29 species, including 5 transformers) was comprehensively studied. The current distribution was characterized, the cadastres and maps have been created, their participation in plant

communities has been analyzed, and a syntaxonomic scheme has been proposed (Tokaryuk et al. 2012, 2018).

The nonnative species as well as transformers were studied in different regions of Ukraine: Transcarpathia, Bukovinian Cis-Carpathia, the Middle Dnipro Region, Ukrainian Polissya, the Northern Black Sea Region, the South Coast of Crimea, Romensko-Poltavsky geobotanical district and Starobilsk grass-meadow Steppe (Protopopova et al. 2009, 2010a, 2012, 2014a, 2015, Dvirna 2014, Kucher 2015). According to the results of these investigations the different composition of this group has been detected. The common features of the transformers of all studied areas were established. Among them, the prevalence of alien species with their origin from America or Eastern Asia, mesophytes – in ecological spectra, the higher percentages of trees or shrubs were revealed. The prevalence of species with Mediterranean origin and plants from the xerothermic habitats in the composition of transformers of the South Coast of Crimea has been noted.

The ergasiophytes of the flora of Ukraine (458 species, which comprised about half of its alien fraction (46.5%) and every time a new ones appear) were analyzed (Protopopova & Shevera 2014). There is the prevalence of the species of Mediterranean and North American origin in the composition of this group. A high percentage of trees and shrubs in the spectrum of life forms and mesophytes in the hygromorphs spectrum of ergasiophytes of the flora of Ukraine were revealed. By the degree of naturalization [according to the classification by A. Thellung (1915)], 78.8% of species are ergasiofigophytes. There was an increase in the degree of naturalization in 23.2% of species over the last 150 years. There are transformers in this group. The spreading of some ergasiophytes as a result of population growth has reached expansion (there are 20-120 years from the first records to expansion). High levels of propagule pressure some of ergasiophytes as a result of planting lead to species eventually escaping from cultivation, regardless of biological traits.

One of the trends of the study of alien plants of the flora of Ukraine is a special comprehensive research of the urban floras in the different botanical and geographical zones of Ukraine initiated by R.I. Burda (1982) and has been conducted since the late 1980's. The urban floras of Kherson (Moysienko 1999), Mykolaiv (Melnyk 2001), Uzhhorod (Protopopova & Shevera 2003), Kamyianets-Podilskiy (Kagalo et al. 2004), Kryvyi Rig (Shol 2004), Netishyn, Ostrog, Slavuta, Shepetivka (Gubar 2006), Kirovograd (now Kropyvnytskyi) (Arkushina 2007), Simferopol (Epikhin 2008), Lutsk, Chernihiv (Zavyalova 2012), Kuznetsovsk, Dubrovytsia, Sarny, Kostopil, Berezne (Hutsman 2013), and urban area of the Donetsk-Makiivka (Derevenska 2014), Kharkiv (Zviagintseva 2015), etc. The results of this investigation have found the portion of the alien fraction of the studied urban floras in Ukraine is approximately the same and does not exceed 28% of the total species composition (Fig. 2).

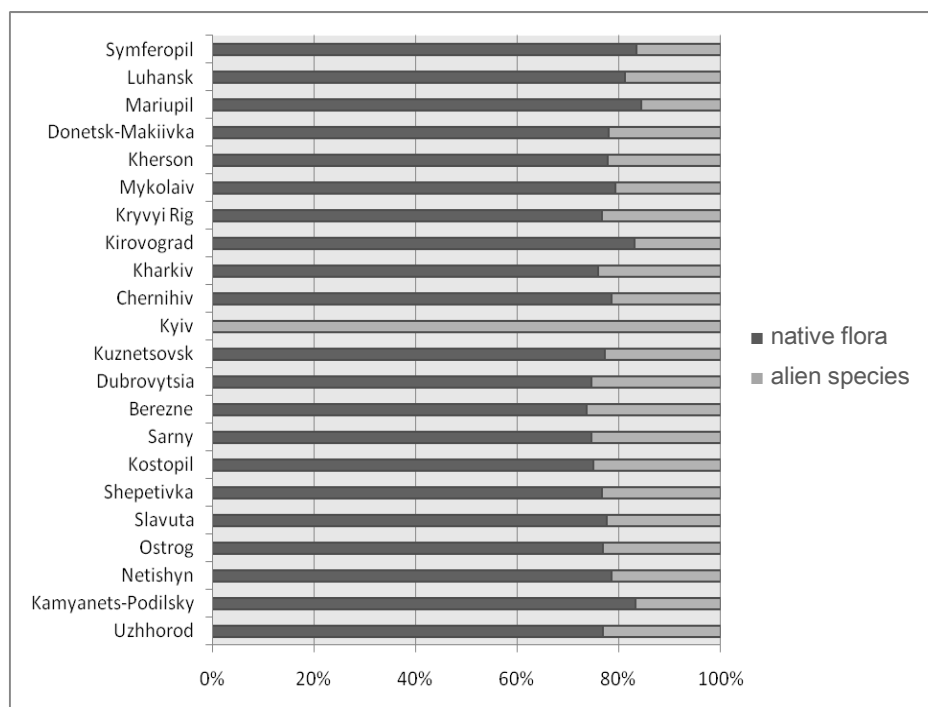


Fig. 2. The total species richness of the urban floras of Ukraine and shares of their alien fractions

The annotated checklists of the urban floras of Donetsk, Luhansk, Mariupol, Sloviansk (Burda 1997), Uzhhorod (Protopopova & Shevera 2002), Kryvyi Rig (Kucherevskiy & Shol 2003, 2009), Kamianets-Podilskiy (Kagalo et al. 2004), Lutsk, Kirovograd (Arkushina & Popova 2010), Pereyaslav-Khmelnytskyi (Fedoronchuk et al. 2010), Chernihiv (Zavyalova 2010), Kharkiv (Zviagintseva 2015) or some of these fractions, such as, the synanthropic flora of Odesa (Vasylyeva-Nemertsalova 1996), the nonnative flora of the Kyiv urban area (Mosyakin & Yavorska 2002), etc., were published. As the results of these studies of the urban floras of Ukraine the general and regional features were revealed. Such as, highest species richness, the high levels of the synanthropization (46.7%–68.6%) and adventization, extension of habitats differentiation, the changes of structure in comparison with regional floras, the leveling of zonal peculiarities, for example, the mesophytization of the floras of Steppe zone cities, S and V-similar character of distribution of the species, etc. (Vasylyeva-Nemertsalova 1996, Moysyenko 1999, Shevera 2005, Zavyalova 2012). The comparative analysis of the species composition of neophytes and archeophytes of 12 urban floras using the mathematical statistics methods are provided. The peculiarities of their distribution, in particular, of zonal-regional conditions, and character of anthropogenic impact, and socio-economic or historical factors have been detected (Protopopova & Shevera 2008b, Protopopova et al. 2010, 2013). Methods of study of

adaptive strategy of alien plants on urban territory was generalized by R. Burda & O. Ignatyuk (2011).

The adventization of the plant cover of the Protected Areas of Ukraine began to be studied in the 1980s. One of the first studies in this trend was the investigation of the alien fraction of the floras of the “Mys Martyan” Nature Reserve (Golubyeva 1982) and Danube Nature Reserve (Dubyna & Protopopova 1985). In fact, the total species composition of the fraction, its structure and regional peculiarities have been investigated. After that, similar studies of the alien species in the floras were carried out in the National Nature Parks “Synevyr” (Protopopova et al. 1999), “Vyzhnytsky” (Chorney et al. 2005), Kaniv Nature Reserve (Shevchyk & Senchylo 2009), protected areas of the Kerch Peninsula in the Crimea (Bagrikova 2011), National Nature Park “Biloberezhzha Sviatoslava” (Melnychuk & Trokhymenko 2014), protected areas of the Forest-Steppe of Ukraine (Burda et al. 2015), etc. Some data about alien plant species in the floras of the Protected Areas consist of its checklists (Bioriznomanittia Karpatskoho ..., 1997, Bioriznomanitnist Dunayskoho..., 1999, Nechytaylo et al. 2002, Oliyar 2002, Dubyna et al. 2003, Panchenko 2005, Derzhypilskiy et al. 2006, Kostina & Bagrikova 2010, Kolomiychuk & Yaroviyi 2010, Orlov 2013, Karpenko, 2016, Baranovskiy et al. 2017, etc.). The biological contamination of the National Econet began to study in the 2013th (Zavyalova & Korniyenko 2014).

For the first time the state of the biological contamination of the floras of Protected Areas of the Forest Steppe of Ukraine have been summarized early in the 21st century. The investigation of alien invasive species with an assessment of their environmental impact were carried out for 14 local floras of the forest-steppe zone (Burda et al. 2015). A total species composition (354 taxa: 345 species, 2 subspecies and 7 hybrids) and 17 transformers was established. According to the authors' data the peculiarities of the life forms spectrum is the prevalence of therophytes and a high proportion of phanerophytes. The features of the non ability of ecosystems of the Protected Areas for resistance to the threats of phyto-invasions have been defined. According to the assessment of the impact of alien plants to the plant cover of the investigated objects (with the exception of *Salix fragilis*) its reverse character was revealed (Burda et al. 2015). At the same time, the study of invasive alien species in the plant cover of Protected Areas of national importance to Ukraine was conducted and they are given as a brief compendium of three lists: Black, Grey and Watch. These lists were compiled on the basis of set criteria. The participation of the studied species in the composition of plant communities was established as well as their representation in the territory of more than 50 protected areas of Ukraine of different categories. We have found that about a third of the studied species have had a significant impact on the species, coenotic and ecosystem levels, and threatening the native biodiversity of the Protected Areas of Ukraine. The rest is a potential threat. At the same time, some alien species of the Grey and Watch lists threaten native biodiversity at local or regional level in some native areas of Ukraine. They are dangerous only for certain types of natural habitats or plant communities of certain vegetation types (Zavialova 2017).

The main results of the critical taxonomic revisions, including of alien plant species, are available in multi-volume publications, manuals of plants, monographs and articles: Flora of the RSS Ucr. (1935-1965), Flora URSS (1934-1964), Manual of vascular plants of Ukraine (1950, 1965, 1987), Buriyany Ukrainy (1970), Flora Partis

Europaeae URSS (1974-1996), Flora Europaeae Orientalis (1996–2004), Ecoflora of Ukraine (Didukh et al. 2000-2010), Zlaki Ukrainy [Grasses of the Ukraine] (Prokudin et al. 1977), The genus *Oenothera* L. in Eastern Europe (Rostański et al. 2004), and many other taxa (Protopopova 1964, 1974, Mosyakin 1988, 1989, 1992, 1995a, b, Mosyakin & Korniyenko 2006, etc.). Mostly, the critical taxonomic study was concerned with the alien plant species of the families of Asteraceae Dumort., Poaceae Barnhart, Brassicaceae Burnett, Cucurbitaceae Juss., Malvaceae Juss., Boraginaceae Juss., Solanaceae Juss., Amaranthaceae Juss., Balsaminaceae A. Rich., etc.

Conclusion

During the analyzed period of study of the alien fraction in the flora of Ukraine, rich and diverse factual material has been accumulated and summarized. Thereby, a large many-sided or various factual material on different trends of research for the analyzed period of the study of the alien fraction of the flora of Ukraine. Its species composition at different territorial levels: national, regional and local, which significantly differs quantitatively and qualitatively as a result of the constant gain of the adventization process have been established. The checklists of the alien fraction of the flora of Ukraine, and numerous regional and urban floras etc., have been consisted. A group of invasive species, including transformers, have been dedicated and researched. Some characteristics of non-native species in the plant cover of the Protected Areas of national importance of Ukraine, in particular, the composition, representation, participation, impact etc., have been investigated. The populations of some alien species have been researched. Some practical aspects of the problem, such as, bioecological features, segetal potential of weeds and its role in agroecosystems have been included to the investigations too. Consequently, these and other studies represent a great variety of floristic, chorological, ecological, phytocoenotical, taxonomical, and other directions of comprehensive scientific work in Ukraine, the results of range from the first records of non-native species of plants to the theoretical generalizations and conclusions about the peculiarities of the alien fraction of the flora formation in the country.

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