



The non-native woody species of the flora of Ukraine: Introduction, naturalization and invasion

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The process of invasion, naturalization, dispersion and invasive activity of non-native woody species in 5 regional floras, 5 urban floras and over 30 floras of the protected areas is discussed. It has been established that 182 non-native species out of 95 genera and 45 families are currently at different naturalization stages in the spontaneous flora of Ukraine. In terms of life-forms, they may be divided as follows: trees – 41%, shrubs – 35%, trees/shrubs – 15%, lianas – 9%. Most species spread both via seed dispersal and the vegetative way – 56%, using only seed dispersal – 42%, only the vegetative way – 2%. According to the preliminary rating of species-wise invasive activity, 71 species (40%) have naturalized completely, among them 20 invasive species, including 12 transformer species, 29 potentially invasive species, and 22 naturalized species which demonstrate no invasive tendencies. The initial stages of invasion of 111 species are as follows: introduction – 9%, survival – 36%, adaptation of the reproductive sphere – 28%, establishment, formative of local populations – 27%. In terms of dispersion, non-naturalized species are divided as follows: rare – 45%, local – 16%, sporadic – 6%, unique – 12%, spreading under control beyond collections and expositions in botanical gardens and arboreta – 21%. Twelve transformer species, the greatest threat to local diversity, are *Acer negundo*, *Ailanthus altissima*, *Amorpha fruticosa*, *Bupleurum fruticosum*, *Elaeagnus angustifolia*, *E. rhamnoides*, *Fraxinus ornus*, *Parthenocissus quinquefolia*, *P. vitacea*, *Robinia pseudoacacia*, *Rhamnus alaternus*, *Salix × blanda* and 8 invasive proper species: *Berberis aquifolia*, *Colutea orientalis*, *Daphne laureola*, *Prunus cerasifera*, *P. serotina*, *Quercus ilex*, *Viburnum tinus*, *Vitis vinifera*. The list of alien species, most widespread in 50 regions of Europe, includes *Robinia pseudoacacia* (42 regions), *Ailanthus altissima* (40), *Acer negundo* (38), *Prunus cerasus* (34), *Quercus rubra* (34), *Rosa rugosa* (34), *Prunus domestica* (31). The mitigation of the impacts of these species on local biodiversity is possible via the restoration of local native plant communities, land use organization, strict selection of introduced species prior to the introduction, culture of planting management, preventive measures and extending awareness and sharing of information about plant invasions. Therefore, Ukraine's spontaneous flora is notable for the active process of naturalization of non-native woody species with considerable involvement of invasive alien species. This is the first and preliminary evaluation of the invasive activity of woody species in Ukraine's flora. The manifestations of the global tendency of increased involvement and invasive activity of alien woody species in domestic flora have been confirmed. These conclusions are also relevant for elaborating the system of preventive, containing and mitigating measures regarding plant invasions in Ukraine.

Keywords: invasive alien species; tree; shrub; liana; species invasive activity.

Introduction

It is hard to overestimate the role of woody plants in creating plant cover and nutrient cycling, transfer of energy and information in the biosphere. They are dominants of plant community complexes and nuclei of consortia in ecosystems. While improving the environment, humans have long tried to draw woody plants nearer, to use all their diversity in order to satisfy intellectual, aesthetic, recreational and utilitarian needs. Since the end of the 18th century, Ukraine has had the oldest introduction centers – arboreta "Alexandria" and "Sofiivka", and somewhat younger collections of world flora treasures – the Nikitsky Botanical Garden, the arboretum of the biosphere reserve "Askania Nova", academic and university botanical gardens. In addition to their decorative, educational, aesthetic value and favourable impact on the environment, the establishment of the reserves of alien woody species (so called exotic plants) is relevant for greenery building, forestries and protective forestation, etc. However, the accumulation of exotic plants in cultivation is a remote risk of further invasions, naturalization, some of them penetrate to natural plant communities, which causes changes in the composition, structure and functions of the latter and poses a threat to the local gene fund.

Information on the distribution of alien plant species in the world is dramatic. The Global Naturalized Alien Flora (GloNAF) database contains 13,168 species or 3.9% of the extant global flora of vascular

plants. These alien species have secondary regions (van Kleunen et al., 2015; Pyšek et al., 2017a, b). At least 75% and 93% of the world's naturalized alien flora is grown in home and botanical gardens, respectively (van Kleunen et al., 2018). The role of evolutionary changes during biological invasions must be understood (Blackburn et al., 2014; Zenni et al., 2017). This is important for mitigating the impacts and threats of penetration of woody plants into the natural flora (Pollegioni et al., 2013; Hirsch et al., 2017; Gaskin et al., 2017).

The article starts the analysis of diversity of the woody species, introduced to Ukraine, in order to find those which have invaded native or native-related plant communities, formed stable self-restoring local populations in them, become naturalized, revealed the ability to invade, formed secondary ranges and their own ecological niches, become invasive; it aims to determine the level of invasive activity of alien woody species and cryptic (hidden) threats of non-native woody species at the initial stages of migration.

Materials and methods

Let us define the main terms used in this article. Non-native (adventive, non-indigenous, exotic) species are the species whose occurrence in a specific territory is not related to the processes of natural florogenesis. These have overcome the geographical barrier due to human activity. Among them, we

distinguish alien species – completely naturalized, which created secondary ranges, and non-naturalized species, which are undergoing the first stages of migration. Spontaneous species are those, the occurrence and distribution of which in a specific territory does not depend on humans.

There is no separate accessible database in Ukraine, related to a relevant group of vascular plants in human life – woody species, intentionally introduced into the culture. In order to form the total list and the volume of cultivated woody species, we have had to review current "Catalogues" of collection funds of the botanical gardens (Kondratyuk, 1988; Kokhno, 1997; Grevtsova, 2000; Solomakha, 2007; Kolisnychenko et al., 2011) and arboretums (Kosenko, 2000). We also used some articles about live botanical collections and spontaneous dispersion of woody exotic species from collections and expositions within introduction centers. The invasive activity of alien species in Ukraine's spontaneous flora was studied beyond introduction centers in native and approximately native community complexes within protected areas (Baranovski et al., 2016; Lykholat et al., 2017, 2018a, 2018b). Special attention was paid to studying urban floras. We also noted the results of evaluating the invasive activity in regional floras, floras of agrolandscapes and floras of the nature reserve fund of different zones (Burda, 2003, 2007, 2018). Only non-native and spontaneously spreading species of Ukraine's flora have been considered. Sometimes native species, specified in the mentioned articles, have not been included in the analytical lists (*Acer platanoides* L., *A. tataricum* L., *Sambucus nigra* L. and *Staphylea pinnata* L.).

Non-native woody species, found in Ukraine's flora, have been characterized by 6 categories, traditional for invasive botany. The degree of their invasive activity has been described in accordance to the categories, implemented by the European Botanical Gardens Consortium (Mayorov et al., 2013). These are three categories of alien species: transformer species – a group of species, changing the conditions and nature of ecosystems in their larger area, they pose a threat to environmental safety of the region; invasive species – naturalized species, capable of having great amounts of progeny, due to which they spread rapidly across large distances from their paternal plants, are capable of invading and persisting in large areas, have invaded local community complexes, they affect local species, their communities and ecosystems; potentially invasive species – also naturalized species, which may become invasive upon future increase in their number, they do not have any visible impacts on local diversity; species, which have become naturalized, but have not demonstrated invasive activity. Additional consideration has been given to non-naturalized species in the process of naturalization, which are sometimes restored via seed dispersal or in a vegetative way near the area of native species, but are not capable of further invasion yet (a small number of diaspores, no functional connections). These plants do not demonstrate expressed tendencies of naturalization, their presence depends on constant stable input of diaspores from cultivated plants, though they do reproduce in some cases.

The species of the abovementioned groups are characterized in accordance to traditional classifications, used by Ukrainian authors in the abovementioned articles, which requires some elaboration (Didukh et al., 2000). The category "degree of naturalization" has 6 descriptors: agriophyte – naturalized species which invaded native and native-related habitats; hemiagriophyte – species naturalized mostly in habitats which are close to native or degraded ones; epoeophyte – species naturalized only in anthropogenically transformed habitats; ergasiophyte – species intentionally introduced by humans which sometimes escape the cultivation limits, but are usually in the immediate proximity to the place of cultivation; colonophyte, non-naturalized species, unstable element of flora, related to cultivation, somewhat adjusted to new conditions of survival, capable of periodic formation of seeds or reproduction in the vegetative way; ephemeroophyte – also non-naturalized species, unstable element of flora, which periodically occur in the places of cultivation of introduced woody species or among secondary habitats and vanish with time, as they are accidental migrants. The following species categories are distinguished in terms of occurrence: common species, widely and abundantly spread in the whole territory; local species, known in the whole territory, but abundant only in some locations; sporadic species, which occur frequently, but with low abundance, rare species, which are

present in 3–5 (7) locations, unique species, found in 1–2 locations, and controlled species, spread via seed dispersal or in the vegetative way beyond collections and expositions within the botanical gardens and arboretums. Three categories have been distinguished in terms of life-forms: a tree – a perennial woody plant with one well-formed stem and a crown, formed by side branches; a shrub – a perennial woody plant with multiple stems coming out of one source, the habitus does not have one well-formed main stem, and a liana – a perennial woody plant with a long stem, not capable of maintaining the vertical position without any additional support.

The names of the species are presented according to "The Plant List" database. The authors of all the names of the species, mentioned in the text, are given in Tables 5 and 6. The volumes of families of Magnoliophyta (Angiosperms) and the sequence of their location in Tables 2, 5 and 6 are in accordance to "Synopsis of Families and Orders of Angiosperms of the Flora of Ukraine" (Mosyakin, 2013).

The non-native woody species of the flora of Ukraine, escaping from cultivation in botanical gardens and arboretums

Over 50 centers of plant introduction are officially registered in Ukraine (Cherevchenko, 2011), and 10 of them are over 130 years old (Table 1). In addition, there are private commercial centers which import decorative plants, including trees, shrubs, and lianas, for sale. The attempts at finding and summarizing the diversity of live collections of the botanical gardens and arboretums have failed due to the absence of any unified database in free access mode. Our centers of plant introduction are mainly located in the temperate zone. They have been working for many years within creative cooperation of the Council of Botanical Gardens and Arboretums of Ukraine, exchanging their methods and seeds.

Taking into consideration these two circumstances, it becomes clear that the collections of woody plants in the introduction centers are somewhat duplicated. It would be reasonable to consider the richest collections of woody plants, collected in the arboretum "Sofiivka", the M. M. Hryshko National Botanical Garden, the O. V. Fomin Botanical Garden, and the arboretum of the Nititsky Botanical Garden, which is located in conditions, approximated to those of the eastern Mediterranean (Table 1).

However, it is common knowledge that "every garden is famous for its own collections". For instance, the National Arboretum "Sofiivka" is known for its rich collections of the genera *Corylus* – 28 species, *Fagus* – 21, *Picea* – 41, 100 species of lianas and over 320 varieties of roses (Kosenko, 2000). The O. V. Fomin Botanical Garden collected the most abundant generic complexes of *Juniperus*, *Pinus*, *Cotoneaster*, *Forsythia*, *Lonicera*, *Magnolia*, *Rhododendron*, *Spiraea* (Solomakha, 2007) and the Nikitsky Botanical Garden owns luxurious collections of genera *Cupressus*, *Berberis*, *Cotoneaster*, *Lonicera*, *Philadelphus*, *Quercus*, *Spiraea*, *Thuja* and *Viburnum* (Plugatar et al., 2015). As this statement reflects reality, it is noteworthy that the volume of the collections has neither changed much nor decreased for many years. For instance, the statistics for the arboretum of the Nikitsky Botanical Garden as of 1970 stated the presence of 1,704 species, including 689 trees, 879 shrubs, 136 lianas (Kormilitsin & Golubeva, 1970). In 1971 the collection of the National Botanical Garden contained 2,054 species, including Angiospermae – 1,884 species and Gymnospermae – 170 species (Rubtsov & Gordienko, 1971). The collections, exceeding 1,000 woody species, have been collected in each of 8 introduction centers. It was recorded that in 1994 there were 1,655 species, 32 varieties, 547 forms of introduced trees, shrubs, and lianas (Kokhno, 1994). It should be also noted that the ratio between trees and shrubs (different life-forms) is not significant. It may be balanced (arboretum "Alexandria", the Botanical Garden of the National University of Dnipro, the Donetsk Botanical Gardens), or the number of species whose life-form is a shrub may exceed the number of species belonging to the tree life-form (arboretum "Sofiivka", the Kryvyi Rih Botanical Garden), or the ratio between the species with these life-forms is reverse (the Botanical Garden of Odesa University). Thus, the volumes of the richest modern collections and their age permit the assumption that these collections may be a source of dispersing non-native woody species into the domestic flora, completely established quite a long time ago.

Table 1

The collection funds of woody plants in the leading Ukrainian centers of plant introduction

Center of plant introduction	Year of foundation	Source	Number of species			
			total	tree*	shrub*	liana*
The arboretum "Alexandria", NAS of Ukraine	1793	Galkin et al., 2017	1282	538	680	64
The National Arboretum "Sofivka", NAS of Ukraine	1796	Kosenko, 2000	2400	800	1600	
Botanical Garden of V. N. Karazin Kharkiv National University	1804	Alokhin et al., 2019	781	–	–	–
The Nikitsky Botanical Garden	1812	Plugatar et al., 2015	1690	–	–	–
The arboretum "Trostanets", NAS of Ukraine	1834	Medvedyev & Ilyenko, 2018	623	–	–	–
O. V. Fomin Botanical Garden of Taras Shevchenko National University of Kyiv	1839	Solomakha, 2007	1828	923	–	–
Botanical Garden of Ivan Franko L'viv National University	1852	Prokopiv, 2004	787	–	–	–
Botanical Garden of Odesa of I. I. Mechnikov National University	1867	Filatova et al., 2014; Slyusarenko et al., 2017	1025	611	341	73
Botanical Garden of Yuriy Fedkovych Chernivtsi National University	1877	Cherevchenko, 2011	1150	–	–	–
The arboretum of F. J. E. Falz-Fein "Askania Nova" Nature Biosphere Reserve, NAAS of Ukraine	1887	Rubtsov et al., 2012	1114	–	–	–
Botanical Garden of National University of Life and Environmental Sciences of Ukraine, Kyiv	1928	Kolisnychenko et al., 2011	604	–	–	–
Botanical Garden of Oles Honchar Dnipro National University	1933	Kvasha et al., 2010	389	159	147	83
M. M. Hryshko National Botanical Garden, NAS of Ukraine	1935	Kokhno, 1997	1025	–	–	–
The Donetsk Botanical Garden, NAS of Ukraine	1964	Kondratyuk, 1988	868	457	411	–
The Kryvyi Rih Botanical Garden, NAS of Ukraine	1980	Grevtsova, 2000	661	245	393	23

Note: "–" – marks: data is absent in source.

Only two published "Catalogues" of collection funds present systematized information about spontaneous dispersion of woody species from collections and expositions (Kondratyuk, 1988; Solomakha, 2007) (Table 2). Some fragments of the data are stated in special publications. After twenty years of introductory testing, 15 woody species, including 8 non-native cultivated ones, had natural regrowth in the Donetsk Botanical Garden of NAS of Ukraine (Kondratyuk, 1988). After 10 years, 54 species, including 13 aboriginal species, were found to be spontaneously distributing; 48 species had stable natural regrowth (Burda et al., 1998). It was noted

that the species of genus *Clematis*, in particular, *C. vitalba*, spread far from the place of initial introduction, while remaining in the garden. Later it was additionally reported that 19 non-native species had spontaneously spread within the boundaries of the garden (Eremenko & Ostapko, 2011, 2014). The total number amounted to 67 species. The location of *C. vitalba* was found 4 km from the garden and was interpreted as "escaping" from its collections (Ostapko et al., 2013). We place this assumption in question as *C. vitalba* was found on the roadside between the cities of Donetsk and Makiivka, which bordered summer cottages.

Table 2

The list of non-native species, spontaneously distributing in the centers of plant introduction

Family	Taxon*	Life-form	Spread	Center of introduction
Pinophyta				
Pinaceae	<i>*Larix decidua</i> Mill.	tree	seed	Donetsk Botanical Garden
Cupressaceae	<i>*Thuja occidentalis</i> L.	tree/shrub	seed	Botanical Garden of Ivan Franko National University of L'viv
Magnoliophyta				
Berberidaceae	<i>Berberis aquifolium</i> Pursh.	shrub	seed, vegetative way	Donetsk Botanical Garden
Berberidaceae	<i>*B. thunbergii</i> DC.	shrub	seed, vegetative way	Arboretum "Alexandria"
Berberidaceae	<i>B. vulgaris</i> L.	shrub	seed, vegetative way	Donetsk Botanical Garden
Ranunculaceae	<i>*Clematis gauriana</i> Roxb. ex DC.	liana	seed, vegetative way	Donetsk Botanical Garden
Ranunculaceae	<i>*C. jackmanii</i> T. Moore.	liana	seed, vegetative way	Donetsk Botanical Garden
Ranunculaceae	<i>*C. ligusticifolia</i> Nutt	liana	seed, vegetative way	Donetsk Botanical Garden
Ranunculaceae	<i>*C. tangutica</i> (Maxim.) Korsh.	liana	seed, vegetative way	Donetsk Botanical Garden
Ranunculaceae	<i>C. vitalba</i> L.	liana	seed, vegetative way	Arboretum "Alexandria", Donetsk Botanical Garden
Ranunculaceae	<i>*C. viticella</i> L.	liana	seed, vegetative way	Arboretum "Alexandria"
Hamamelidaceae	<i>*Parrotia subaequalis</i> (Hung T. Chang) R. M. Hao & H. T. Wei	tree/shrub	seed	M. M. Hryshko National Botanical Garden
Grossulariaceae	<i>*Ribes americanum</i> Mill.	shrub	seed	Donetsk Botanical Garden
Grossulariaceae	<i>R. aureum</i> Pursh	shrub	seed	Donetsk Botanical Garden
Grossulariaceae	<i>R. europaea</i> (L.) Mill.	shrub	seed	Donetsk Botanical Garden
Grossulariaceae	<i>R. rubrum</i> L.	shrub	seed	Donetsk Botanical Garden
Grossulariaceae	<i>R. spicatum</i> Robson	shrub	seed	Donetsk Botanical Garden
Vitaceae	<i>*Ampelopsis aconitifolia</i> Bunge	liana	seed, vegetative way	Donetsk Botanical Garden
Vitaceae	<i>*A. delavayana</i> var. <i>glabra</i> (Diels & Gilg) C. L. Li	liana	seed, vegetative way	Donetsk Botanical Garden
Vitaceae	<i>*A. bodinieri</i> (H. Lévl. & Vaniot) Rehder	liana	seed, vegetative way	Donetsk Botanical Garden
Vitaceae	<i>*A. glandulosa</i> var. <i>brevipedunculata</i> (Maxim.) Momiy	liana	seed, vegetative way	Donetsk Botanical Garden
Vitaceae	<i>Parthenocissus quinquefolia</i> (L.) Planch.	liana	seed, vegetative way	Botanical Garden of Oles Honchar National University of Dnipro, Donetsk Botanical Garden, O. V. Fomin Botanical Garden
Vitaceae	<i>P. vitacea</i> (Kner) Hitchc.	liana	seed, vegetative way	Donetsk Botanical Garden
Vitaceae	<i>*Vitis coignetiae</i> Bull. ex Planch	liana	seed, vegetative way	Donetsk Botanical Garden
Vitaceae	<i>V. vinifera</i> L.	liana	seed, vegetative way	Donetsk Botanical Garden, O. V. Fomin Botanical Garden
Fabaceae	<i>Amorpha fruticosa</i> L.	shrub	seed, vegetative way	Arboretum "Alexandria", Botanical Garden of Oles Honchar National University of Dnipro, Donetsk Botanical Garden
Fabaceae	<i>Caragana arborescens</i> Lam.	shrub	seed, vegetative way	Arboretum "Alexandria", Donetsk Botanical Garden
Fabaceae	<i>Gleditsia triacanthos</i> L.	tree	seed	Botanical Garden of Oles Honchar National University of Dnipro, Donetsk Botanical Garden
Fabaceae	<i>Gymnocladus dioica</i> (L.) K. Koch	tree	seed	Arboretum "Alexandria", Donetsk Botanical Garden

Family	Taxon*	Life-form	Spread	Center of introduction
Fabaceae	<i>Halimodendron halodendron</i> (Pall.) Voss	shrub	seed	Donetsk Botanical Garden
Fabaceae	<i>Robinia pseudoacacia</i> L.	tree	seed, vegetative way	Arboretum "Alexandria", Donetsk Botanical Garden, O. V. Fomin Botanical Garden, Botanical Garden of Ivan Franko National University of L'viv
Fabaceae	<i>R. viscosa</i> Vent.	tree	seed, vegetative way	Arboretum "Alexandria"
Rosaceae	<i>Cerasus tomentosa</i> (Thunb.) Wall. ex T. T. Yu & C. L. Li	shrub	seed	Donetsk Botanical Garden
Rosaceae	<i>Crataegus submollis</i> Sarg.	shrub	seed	Arboretum "Alexandria"
Rosaceae	<i>Crataegus</i> sp.	shrub	seed	Donetsk Botanical Garden
Rosaceae	<i>Malus domestica</i> Borkh.	tree	seed, vegetative way	Donetsk Botanical Garden
Rosaceae	<i>Mespilus germanica</i> L.	shrub	seed, vegetative way	Donetsk Botanical Garden
Rosaceae	<i>Physocarpus opulifolius</i> (L.) Maxim.	shrub	seed, vegetative way	Arboretum "Alexandria"
Rosaceae	<i>Prunus armeniaca</i> L.	tree	seed, vegetative way	Donetsk Botanical Garden
Rosaceae	<i>P. cerasus</i> L.	tree	seed, vegetative way	Donetsk Botanical Garden
Rosaceae	<i>P. cerasifera</i> Ehrh.	tree/shrub	seed, vegetative way	Arboretum "Alexandria"
Rosaceae	<i>P. mahaleb</i> L.	shrub	seed	Donetsk Botanical Garden
Rosaceae	<i>P. serotina</i> Ehrh.	tree/shrub	seed, vegetative way	Donetsk Botanical Garden
Rosaceae	<i>Rosa</i> sp.	shrub	seed, vegetative way	Donetsk Botanical Garden
Rosaceae	* <i>Rubus odoratus</i> L.	shrub	seed, vegetative way	Arboretum "Alexandria"
Rosaceae	<i>Sorbaria sorbifolia</i> (L.) A. Braun	shrub	seed, vegetative way	Arboretum "Alexandria", Donetsk Botanical Garden, O. V. Fomin Botanical Garden
Rosaceae	<i>Spiraea</i> × <i>billardii</i> Hérin	shrub	seed, vegetative way	Donetsk Botanical Garden
Rosaceae	<i>S. chamaedryfolia</i> L.	shrub	seed, vegetative way	Arboretum "Alexandria"
Rosaceae	<i>S. salicifolia</i> L.	shrub	seed, vegetative way	Arboretum "Alexandria"
Elaeagnaceae	<i>Elaeagnus angustifolia</i> L.	tree/shrub	seed, vegetative way	Donetsk Botanical Garden
Elaeagnaceae	<i>E. rhamnoides</i> (L.) A. Nelson	shrub	seed, vegetative way	Donetsk Botanical Garden
Elaeagnaceae	<i>E. umbellata</i> Thunb.	tree	seed, vegetative way	Arboretum "Alexandria"
Ulmaceae	<i>Celtis australis</i> L.	tree	seed	M. M. Hryshko National Botanical Garden
Ulmaceae	<i>C. occidentalis</i> L.	tree	seed	Donetsk Botanical Garden
Ulmaceae	<i>Ulmus pumila</i> L.	tree	seed, vegetative way	Donetsk Botanical Garden, O. V. Fomin Botanical Garden
Moraceae	<i>Morus alba</i> L.	tree	seed	Donetsk Botanical Garden
Fagaceae	<i>Quercus rubra</i> L.	tree	seed	Arboretum "Alexandria", Donetsk Botanical Garden, O. V. Fomin Botanical Garden
Fagaceae	* <i>Q. macranthera</i> Fisch. & C.A. Mey. ex Hohen.	tree	seed	M. M. Hryshko National Botanical Garden
Juglandaceae	<i>Juglans mandshurica</i> Maxim.	tree	seed	Donetsk Botanical Garden
Juglandaceae	<i>J. nigra</i> L.	tree	seed	Arboretum "Alexandria"
Juglandaceae	<i>J. regia</i> L.	tree	seed	Arboretum "Alexandria", Donetsk Botanical Garden, O. V. Fomin Botanical Garden
Celastraceae	<i>Celastrus angulata</i> Maxim.	liana	seed, vegetative way	Donetsk Botanical Garden
Celastraceae	<i>C. flagellaris</i> Rupr.	liana	seed	Donetsk Botanical Garden
Celastraceae	<i>C. orbiculatus</i> Thunb.	liana	seed	Arboretum "Alexandria", Donetsk Botanical Garden
Salicaceae	<i>Populus balsamifera</i> L.	tree	seed, vegetative way	Donetsk Botanical Garden
Salicaceae	<i>P. × canadensis</i> Moench	tree	seed, vegetative way	Donetsk Botanical Garden
Salicaceae	<i>P. trichocarpa</i> Torr. & A. Gray ex Hook.	tree	seed, vegetative way	Donetsk Botanical Garden
Anacardiaceae	<i>Rhus glabra</i> L.	tree/shrub	seed, vegetative way	Botanical Garden of Ivan Franko National University of L'viv
Anacardiaceae	* <i>R. typhina</i> L.	tree	vegetative way	Arboretum "Alexandria", Donetsk Botanical Garden, Botani- cal Garden of Ivan Franko National University of L'viv
Anacardiaceae	* <i>R. typhina</i> 'Laciniata'	tree	vegetative way	Arboretum "Alexandria"
Anacardiaceae	<i>Toxicodendron pubescens</i> Mill.	shrub	seed, vegetative way	Arboretum "Alexandria"
Anacardiaceae	<i>T. radicans</i> (L.) O. Kuntze	shrub	seed, vegetative way	Donetsk Botanical Garden
Aceraceae	<i>Acer negundo</i> L.	tree	seed	Arboretum "Alexandria", Botanical Garden of Oles Hon- char National University of Dnipro, Donetsk Botanical Garden, O. V. Fomin Botanical Garden, Botanical Garden of Ivan Franko National University of L'viv
Aceraceae	* <i>A. platanoides</i> L. f. <i>atropurpurea</i> 'Krimson King'	tree	seed	Donetsk Botanical Garden
Aceraceae	<i>A. saccharinum</i> L.	tree	seed	Donetsk Botanical Garden
Hippocastanaceae	<i>Aesculus hippocastanum</i> L.	tree	seed	Arboretum "Alexandria", Donetsk Botanical Garden, O. V. Fomin Botanical Garden
Simaroubaceae	<i>Ailanthus altissima</i> (Mill.) Swingle	tree	seed, vegetative way	Arboretum "Alexandria", Botanical Garden of Ivan Franko National University of L'viv, Donetsk Botanical Garden
Comaceae	<i>Cornus alba</i> L.	shrub	seed, vegetative way	Donetsk Botanical Garden
Hydrangeaceae	<i>Philadelphus coronarius</i> L.	shrub	seed, vegetative way	Donetsk Botanical Garden
Solanaceae	<i>Lycium barbarum</i> L.	shrub	seed, vegetative way	Arboretum "Alexandria"
Oleaceae	<i>Fraxinus ornus</i> L.	tree	seed	Nikitsky Botanical Garden
Oleaceae	<i>F. pennsylvanica</i> Marshall	tree	seed	Donetsk Botanical Garden
Oleaceae	<i>Syringa vulgaris</i> L.	shrub	seed, vegetative way	Arboretum "Alexandria", Donetsk Botanical Garden, O. V. Fomin Botanical Garden
Bignoniaceae	* <i>Campsis grandiflora</i> (Thunb.) K. Schum.	liana	vegetative way	Arboretum "Alexandria"
Bignoniaceae	* <i>C. radicans</i> (L.) Seem.	liana	vegetative way	Arboretum "Alexandria"
Caprifoliaceae	<i>Lonicera caerulea</i> L.	shrub	seed	Donetsk Botanical Garden
Caprifoliaceae	<i>L. caprifolium</i> L.	shrub	seed	Arboretum "Alexandria"
Caprifoliaceae	<i>L. tatarica</i> L.	shrub	seed	Arboretum "Alexandria", Donetsk Botanical Garden
Caprifoliaceae	<i>Symphoricarpos albus</i> (L.) S.F. Blake	shrub	seed, vegetative way	Donetsk Botanical Garden
Apiaceae	<i>Bupleurum fruticosum</i> L.	shrub	seed, vegetative way	Nikitsky Botanical Garden
Araceae	* <i>Aralia elata</i> (Miq.) Seem.	shrub	seed, vegetative way	Botanical Garden of Ivan Franko National University of L'viv

Note: * – the species whose dispersion is known only beyond the framework of collections and expositions in botanical gardens and arboreta.

The inspection of spontaneous spreading of intentionally introduced species from O. V. Fomin Botanical Garden of Taras Shevchenko National University of Kyiv resulted in issuing "The preliminary list of the species of the O. V. Fomin Botanical Garden, spreading beyond their place of cultivation" (Solomakha, 2007). This list contains 245 species, including 6 species – trees (*Acer negundo*, *Aesculus hippocastanum*, *Juglans regia*, *Quercus rubra*, *Robinia pseudoacacia* and *Ulmus pumila*), 2 species – shrubs (*Sorbaria sorbifolia* and *Syringa vulgaris*), 2 species – lianas (*Parthenocissus quinquefolia* and *Vitis vinifera*).

45 woody species, including 13 aboriginal ones, are spontaneously spreading using seed dispersal and vegetative reproduction within the arboretum "Alexandria". Some non-native species do not reproduce via seed dispersal, but reproduce actively via vegetative reproduction: *Campsis grandiflora*, *C. radicans*, *Rhus typhina*, *R. typhina* 'Laciniata', *Rubus odoratus*, *Syringa vulgaris*, *Toxicodendron pubescens* (Doyko et al., 2014).

Woody plants, capable of reproducing spontaneously via either seed dispersal or vegetative reproduction, were found among intentionally introduced plants in the Botanical Garden of the Ivan Franko L'viv National University. These were four species of trees (*Acer negundo*, *Ailanthus altissima*, *Robinia pseudoacacia* and *Thuja occidentalis*) and three species of shrubs (*Aralia elata*, *Rhus glabra*, *R. typhina*) (Borsukevych & Prokopiv, 2014). Among spontaneous species of the flora at the Botanical Garden of Oles Honchar National University of Dnipro, there are four known woody species (*Acer negundo*, *Amorpha fruticosa*, *Gleditsia triacanthos* and *Parthenocissus quinquefolia*). While analyzing the results of long-term observations, the authors noted the tendency towards the increase in their number and degree of naturalization within the garden (Tarasov et al., 1998). The "Catalogue" of plants of the M. M. Hryshko National Botanical Garden (Kokhno, 1997) does not have any data about seed dispersal. Occasionally there were some publications about seed dispersal of woody plants from its collections and expositions. Shinder (2013) considers the botanic-geographical area "Caucasus" to be the source of distribution of Caucasian species into anthropogenically altered locations within the garden. *Celtis australis* escaped the boundaries of the "Caucasus" area. Some Caucasian species have established stable spontaneous cenopopulations in the created simulated communities of this exposition. For instance, a rare species *Quercus macranthera* dominates in the growing stock of the planted dry oakery, constantly forming abundant natural self-sown plants. Periodic formation of abundant natural self-seeding of *Parrotia subaequalis* was recorded (Doroshenko et al., 2013).

The naturalization of plants in the oldest arboretums of the Nikitsky Botanical Garden must have occurred at the beginning of the 20th century. Without highlighting the collections of the garden, Stankov (1924–1925) noted the remarkable presence of the cultural element of the Mediterranean flora in the plant cover of the South Coast of Crimea. He mentioned 55 non-native species, which added unique Mediterranean charm to the landscape. S. S. Stankov observed the naturalization of the following 22 species in the Crimea personally: *Ailanthus altissima*, *Berberis aquifolium*, *Bupleurum fruticosum*, *Cercis siliquastrum*, *Clematis flammula*, *Cydonia oblonga*, *Elaeagnus angustifolia*, *E. rhamnoides*, *Ficus carica*, *Fraxinus ornus*, *Ilex aquifolium*, *Laburnum anagyroides*, *Maclura pomifera*, *Morus alba*, *Olea europaea*, *Prunus armeniaca*, *P. cerasifera*, *P. cerasus*, *P. domestica*, *P. domestica* subsp. *insititia*, *Rhamnus alaternus* and *Spartium junceum*. This list was later supplemented with *Laurus nobilis*, *Lonicera caprifolium*, *Viburnum tinus*, and S. S. Stankov doubted their going out of cultivation (Bagrikova, 2013). Obviously, we do not have any evidential materials to prove that all of these species have spread within the South Coast of Crimea after escaping the Nikitsky Botanical Garden. On the one hand, this institution had supplied many exotic trees, shrubs, and lianas to the market, being the only center of plant introduction in the Crimea, on the other hand, in different times, even with active dendrological collections of the Garden, amateurs of the garden art brought decorative woody plants to the Crimea, which could have spread beyond the locations of cultivation in different corners of the South Coast of Crimea. There is only one direct statement about two species (*Bupleurum fruticosum*, *Fraxinus ornus*), spreading within the nature reserve "Mys Martian" from the adjacent plant communities of the Nikitsky Botanical Garden (Bagrikova et al., 2014).

Therefore, 92 non-native woody species out of 49 genera and 28 families are spreading in collection areas and expositions or beyond them, but not escaping the boundaries of introduction centers in 6 abovementioned botanical gardens and arboretums. Table 2 presents 6 families, covering 5 or more species: Rosaceae – 17, Vitaceae – 8, Fabaceae – 7, Ranunculaceae – 6, Anacardiaceae – 5 and Grossulaceae – 5. Spontaneous distribution of most species has been noted only in one garden (73), in 5 gardens there is a noted distribution of only *Acer negundo*, and in 4 – *Robinia pseudoacacia*. Half of these species have long been naturalized and become common elements of spontaneous flora. However, spontaneous distribution of 23 species is known only in controlled conditions of the botanical gardens and arboretums. For instance, these are *Aralia elata*, *Parrotia subaequalis*, *Vitis coignetiae*, *Rhus typhina*, *R. typhina* 'Laciniata', *Rubus odoratus*. Thus, the assumption, expressed by us regarding the centers of initial introduction of plants in Ukraine as the sources of distributing non-native woody species, has not been confirmed.

The non-native woody species in the urban flora of Ukraine

The degree of invasive activity of alien woody species in the framework of urban flora plays an important role in determining their part in the spontaneous flora of Ukraine. The main centers of naturalization of non-native species are cities with their suburbs, which unite parks, public gardens, green zone plantings, botanical gardens and arboretums. We have analyzed the lists of four recently thoroughly studied urban floras of such cities as Kyiv (Mosyakin & Yavorska, 2002), Kryvyi Rih (Kuchrevskiy & Shol, 2009), Uzhhorod (Protopopova & Shevera, 2002), Kharkiv (Zvyagintseva, 2015), and combined floras of Sloviansk, Donetsk, Luhansk, and Mariupol, which have formed within industrial Donbas (Burda, 1997). These cities are in different regions of Ukraine and differ in the degree of environmental urbanization. Concluding the consideration of urban floras, we would like to highlight that the lists of alien species coincide in the main part (Table 3). This fact allowed us to combine woody species into a unified list to determine the degree of their naturalization. The authors of urban floras often added aboriginal species to them. They are absent in the combined list: *Betula pendula* Roth, *B. pubescens* Ehrh., *Lonicera xylosteum* L., *Rubus idaeus* L., *Sambucus racemosa* L., *Sorbus aucuparia* L., *Tilia platyphyllos* Scop., *Viburnum lantana* L., etc. Consideration was also given to the list of flora in Chernihiv, where the degree of naturalization was not indicated (Zavyalova, 2010). This urban flora contains about 50 non-native woody species, and the combined list of urban floras of Ukraine was added *Phellodendron amurense* and *Spiraea × vanhouttei* therefrom. The total list of alien woody species of 6 urban floras of Ukraine contains 80 species, 1 subspecies, and 1 hybrid (Table 3, 4). The picture of naturalization of non-native species in urban floras is very rich. They differ in terms of structure, degree of naturalization, species composition, and all of these are mutually related. The richest floras are noted for Kyiv, Kharkiv, Chernihiv, and the urban flora of Kryvyi Rih is not far behind them.

The degree of naturalization is also different. The only species, evaluated in all the floras as agriophyte, is *Salix × blanda*, and the one close to it is *Acer negundo*. The following species occur in one urban flora only: *Ficus carica*, *Rubus macrophyllus*, *Toxicodendron radicans*, *Vitis labrusca*. Agriophytes are concentrated in Kharkiv, hemiagriophytes and colonophytes – in Kyiv, ergasiophytes – in Kharkiv and Kryvyi Rih. Thus, urban floras have a high degree of naturalization of non-native woody species.

The course of invasion of non-native woody species in the regional floras and in the floras of protected areas

The regional studies, conducted by the specialists, headed by V. V. Protopopova, defined the following transformer species in the flora of 5 regions: Polissia – *Robinia pseudoacacia* (Protopopova et al., 2015); Bukovyna Cis-Carpathian region – *Acer negundo*, *Robinia pseudoacacia* (Protopopova et al., 2010); Middle Dniipro region – *Acer negundo*, *Amorpha fruticosa*, *Robinia pseudoacacia* (Protopopova et al.,

2014); North Black Sea region – *Amorpha fruticosa*, *Elaeagnus angustifolia* and *Salix × blanda* (Protopopova et al., 2009); South Coast of Crimea – *Ailanthus altissima*, *Bupleurum fruticosum*, *Fraxinus ornus* and *Rhamnus alaternus* (Protopopova et al., 2012). The authors distinguished 39 invasive species, including 13 woody species, in the flora of the Crimea. *Robinia pseudoacacia* is mentioned in four regions, *Acer negundo*, *Amorpha fruticosa* – in three, *Elaeagnus angustifolia* – in two and *Salix × blanda* – in only one region. According to our observations, the features of transformer species in the floras of 14 territories, which are subject to special protection in the Forest Steppe, are remarkable for 7 species: *Acer negundo*, *Elaeagnus angustifolia*, *E. rhamnoides*, *Parthenocissus quinquefolia*, *P. vitacea*, *Robinia pseudoacacia* and *Salix × blanda*. They occurred in at least 9 out of 14 floras, except for *E. rhamnoides*, noted in 3 floras only (Burda et al., 2015b). The study of alien flora species in 30 territories of the nature reserve fund in different natu-

ral zones revealed the same 7 species of transformers. These are three trees: *Acer negundo*, *Robinia pseudoacacia* and *Salix × blanda*; 2 shrubs: *Elaeagnus angustifolia* and *E. rhamnoides* and 2 lianas: *Parthenocissus quinquefolia* and *P. vitacea* (Burda et al., 2015a). While determining the "transformer species" status, the main feature is stated as the ability to change the ecosystem completely. Five invasive species proper have been distinguished in the same place: *Amorpha fruticosa*, *Morus alba*, *Prunus cerasus*, *P. serotina* and *P. virginiana*. The floras of the nature reserve fund contain 16 woody species, which have naturalized (according to the scheme, accepted in this article, this notion is close to the term, further used by us, – "potentially invasive species"). In addition to the mentioned species, let us mention 31 more species, related to the ones which reproduce spontaneously, sporadically or in a single way in the reserve areas.

Table 3

The degree of naturalization and the occurrence of non-native woody species in some urban floras of Ukraine

Species	Kyiv	Kyvyi Rih	Kharkiv	Uzhhorod	Donbas	Flora	Degree of naturalization
<i>Salix × blanda</i>	agriophyte	agriophyte	agriophyte	agriophyte	agriophyte	5	5 agriophytes
<i>Acer negundo</i>	agriophyte	hemiagriophyte	agriophyte	hemiagriophyte	agriophyte	5	3 agriophytes: 2 hemiagriophytes
<i>Berberis aquifolia</i>	agriophyte	ergasiophyte	agriophyte	ergasiophyte	0	4	2 agriophytes: 2 ergasiophytes
<i>Prunus cerasifera</i>	0	ergasiophyte	agriophyte	agriophyte	0	3	2 agriophytes: 1 ergasiophyte
<i>Amorpha fruticosa</i>	agriophyte	hemiagriophyte	ergasiophyte	ergasiophyte	ergasiophyte	5	1 agriophyte: 1 hemiagriophyte: 3 ergasiophytes
<i>Elaeagnus angustifolia</i>	0	hemiagriophyte	agriophyte	ergasiophyte	epoecophyte	4	1 agriophyte: 1 hemiagriophyte: 1 epoecophyte: 1 ergasiophyte
<i>Prunus serotina</i>	agriophyte	ergasiophyte	0	0	0	2	1 agriophyte: 1 ergasiophyte
<i>Parthenocissus vitacea</i>	hemiagriophyte	0	agriophyte	0	0	2	1 agriophyte: 1 hemiagriophyte
<i>Cydonia oblonga</i>	0	0	agriophyte	0	0	1	1 agriophyte
<i>Prunus domestica</i> subsp. <i>insititia</i>	0	0	0	agriophyte	0	1	1 agriophyte
<i>Robinia pseudoacacia</i>	hemiagriophyte	hemiagriophyte	ergasiophyte	ergasiophyte	ergasiophyte	5	2 hemiagriophytes: 3 ergasiophytes
<i>Lycium barbarum</i>	hemiagriophyte	hemiagriophyte	epoecophyte	epoecophyte	epoecophyte	5	2 hemiagriophytes: 3 epoecophytes
<i>Ulmus pumila</i>	hemiagriophyte	hemiagriophyte	ergasiophyte	0	0	3	2 hemiagriophytes: 1 ergasiophyte
<i>Caragana arborescens</i>	hemiagriophyte	ergasiophyte	ergasiophyte	0	ergasiophyte	4	1 hemiagriophyte: 3 ergasiophytes
<i>Acer saccharinum</i>	hemiagriophyte	ergasiophyte	ergasiophyte	0	0	3	1 hemiagriophyte: 2 ergasiophytes
<i>Quercus rubra</i>	hemiagriophyte	ergasiophyte	ergasiophyte	0	0	3	1 hemiagriophyte: 2 ergasiophytes
<i>Ptelea trifoliata</i>	hemiagriophyte	ergasiophyte	0	0	0	2	1 hemiagriophyte: 1 ergasiophyte
<i>Elaeagnus commutata</i>	0	hemiagriophyte	0	0	0	1	1 hemiagriophyte
<i>Morus alba</i>	epoecophyte	ergasiophyte	colonophyte	0	epoecophyte	4	2 epoecophytes: 1 ergasiophyte: 1 colonophyte
<i>Gleditsia triacanthos</i>	colonophyte	ergasiophyte	epoecophyte	ergasiophyte	0	4	1 epoecophyte: 2 ergasiophytes: 1 colonophyte
<i>Fraxinus pennsylvanica</i>	epoecophyte	epoecophyte	epoecophyte	0	0	3	2 epoecophytes: 1 ergasiophyte
<i>Elaeagnus rhamnoides</i>	0	epoecophyte	epoecophyte	ergasiophyte	0	3	2 epoecophytes: 1 ergasiophyte
<i>Lonicera tatarica</i>	colonophyte	epoecophyte	epoecophyte	0	0	3	2 epoecophytes: 1 colonophyte
<i>Populus deltoides</i>	colonophyte	epoecophyte	epoecophyte	0	0	3	2 epoecophytes: 1 colonophyte
<i>Parthenocissus quinquefolia</i>	colonophyte	epoecophyte	0	ergasiophyte	0	3	1 epoecophyte: 1 ergasiophyte: 1 colonophyte
<i>Ailanthus altissima</i>	epoecophyte	colonophyte	ergasiophyte	0	0	3	1 epoecophyte: 1 ergasiophyte: 1 colonophyte
<i>Spiraea salicifolia</i>	epoecophyte	0	ergasiophyte	0	0	2	1 epoecophyte: 1 ergasiophyte
<i>Symphoricarpos albus</i>	colonophyte	0	epoecophyte	0	0	2	1 epoecophyte: 1 colonophyte
<i>Parthenocissus tricuspidata</i>	0	0	epoecophyte	0	0	1	1 epoecophyte
<i>Cornus sericea</i>	0	0	epoecophyte	0	0	1	1 epoecophyte
<i>Juglans regia</i>	ephemerophyte	ergasiophyte	ergasiophyte	ergasiophyte	0	4	3 ergasiophytes: 1 ephemerophyte
<i>Prunus armeniaca</i>	colonophyte	ergasiophyte	ergasiophyte	0	ergasiophyte	4	3 ergasiophytes: 1 colonophyte
<i>P. cerasus</i>	colonophyte	ergasiophyte	ergasiophyte	0	ergasiophyte	4	3 ergasiophytes: 1 colonophyte
<i>Syringa vulgaris</i>	colonophyte	colonophyte	ergasiophyte	ergasiophyte	0	4	2 ergasiophytes: 2 colonophyte
<i>Vitis vinifera</i>	ephemerophyte	ergasiophyte	ergasiophyte	0	ergasiophyte	4	3 ergasiophytes: 1 ephemerophyte
<i>Aesculus hippocastanum</i>	0	ergasiophyte	ergasiophyte	ergasiophyte	0	3	3 ergasiophytes
<i>Ribes uva-crispa</i>	0	ergasiophyte	ergasiophyte	0	ergasiophyte	3	3 ergasiophytes
<i>Malus domestica</i>	colonophyte	ergasiophyte	ergasiophyte	0	0	3	2 ergasiophytes: 1 colonophyte
<i>Prunus mahaleb</i>	colonophyte	ergasiophyte	0	0	ergasiophyte	3	2 ergasiophytes: 1 colonophyte
<i>Catalpa bignonioides</i>	0	0	ergasiophyte	ergasiophyte	0	2	2 ergasiophytes
<i>Juglans nigra</i>	0	ergasiophyte	ergasiophyte	0	0	2	2 ergasiophytes
<i>Populus bolleana</i>	0	ergasiophyte	ergasiophyte	0	0	2	2 ergasiophytes
<i>P. nigra</i> var. <i>italica</i>	0	ergasiophyte	ergasiophyte	0	0	2	2 ergasiophytes
<i>Aronia melanocarpa</i>	colonophyte	0	ergasiophyte	0	0	2	1 ergasiophyte: 1 colonophyte
<i>Malus baccata</i>	colonophyte	0	ergasiophyte	0	0	2	1 ergasiophyte: 1 colonophyte
<i>Celtis occidentalis</i>	colonophyte	ergasiophyte	0	0	0	2	1 ergasiophyte: 1 colonophyte
<i>Lonicera caprifolium</i>	colonophyte	0	0	ergasiophyte	0	2	1 ergasiophyte: 1 colonophyte
<i>Rhus typhina</i>	0	colonophyte	ergasiophyte	0	0	2	1 ergasiophyte: 1 colonophyte
<i>Aesculus flava</i>	0	0	ergasiophyte	0	0	1	1 ergasiophyte
<i>Castanea sativa</i>	0	0	0	ergasiophyte	0	1	1 ergasiophyte
<i>Crataegus sanguinea</i>	0	0	ergasiophyte	0	0	1	1 ergasiophyte
<i>Juglans cinerea</i>	0	ergasiophyte	0	0	0	1	1 ergasiophyte
<i>Populus suaveolens</i>	0	0	ergasiophyte	0	0	1	1 ergasiophyte
<i>Persica vulgaris</i>	0	ergasiophyte	0	0	0	1	1 ergasiophyte
<i>Prunus virginiana</i>	0	0	ergasiophyte	0	0	1	1 ergasiophyte

Species	Kyiv	Kryvyi Rih	Kharkiv	Uzhhorod	Donbas	Flora	Degree of naturalization
<i>P. domestica</i>	0	ergasiophyte	0	0	0	1	1 ergasiophyte
<i>Tilia americana</i>	0	0	ergasiophyte	0	0	1	1 ergasiophyte
<i>Colutea arborescens</i>	0	ergasiophyte	0	0	0	1	1 ergasiophyte
<i>Cornus alba</i>	0	ergasiophyte	0	0	0	1	1 ergasiophyte
<i>Philadelphus coronarius</i>	0	0	ergasiophyte	0	0	1	1 ergasiophyte
<i>Salix babylonica</i>	0	0	ergasiophyte	0	0	1	1 ergasiophyte
<i>Ribes aureum</i>	0	ergasiophyte	0	0	0	1	1 ergasiophyte
<i>R. rubrum</i>	0	0	0	0	ergasiophyte	1	1 ergasiophyte
<i>Rosa rugosa</i>	colonophyte	0	ergasiophyte	0	0	2	1 colonophyte
<i>Robinia neomexicana</i>	0	0	ergasiophyte	0	0	1	1 ergasiophyte
<i>Robinia viscosa</i>	0	ergasiophyte	0	0	0	1	1 ergasiophyte
<i>Juglans mandshurica</i>	colonophyte	0	0	0	0	1	1 colonophyte
<i>Amelanchier ovalis</i>	colonophyte	0	0	0	0	1	1 colonophyte
<i>Berberis thunbergii</i>	colonophyte	0	0	0	0	1	1 colonophyte
<i>B. vulgaris</i>	colonophyte	0	0	0	0	1	1 colonophyte
<i>Populus balsamifera</i>	colonophyte	0	0	0	0	1	1 colonophyte
<i>Quercus palustris</i>	colonophyte	0	0	0	0	1	1 colonophyte
<i>Sorbaria sorbifolia</i>	colonophyte	0	0	0	0	1	1 colonophyte
<i>Spiraea douglasii</i>	colonophyte	0	0	0	0	1	1 colonophyte
<i>Physocarpus opulifolius</i>	colonophyte	0	0	0	0	1	1 colonophyte
<i>Cotoneaster melanocarpus</i>	colonophyte	0	0	0	0	1	1 colonophyte
<i>Clematis jackmanii</i>	colonophyte	0	0	0	0	1	1 colonophyte
<i>C. viticella</i>	colonophyte	0	0	0	0	1	1 colonophyte
<i>Ficus carica</i>	ephemerophyte	0	0	0	0	1	1 ephemerophyte
<i>Rubus macrophyllus</i>	0	0	0	0	ephemerophyte	1	1 ephemerophyte
<i>Toxicodendron radicans</i>	ephemerophyte	0	0	0	0	1	1 ephemerophyte
<i>Vitis labrusca</i>	ephemerophyte	0	0	0	0	1	1 ephemerophyte
Total	49	44	49	18	15	—	—

Note: here and in Tables 4 and 7 "0" – the species is absent.

Table 4

The degree of naturalization of woody exotic species in some urban floras of Ukraine

Degree of naturalization	Kyiv	Kryvyi Rih	Kharkiv	Uzhhorod	Donbas	Total*
Agriophyte	5	1	7	3	2	10
Hemiagriophyte	8	7	0	1	0	8
Epocophyte	4	5	8	1	3	12
Ergasiophyte	0	28	33	13	9	36
Colonophyte	27	3	1	0	0	12
Ephemerophyte	5	0	0	0	1	4
Total	49	44	49	18	15	82

Note: * – this column presents the data about the number of species in specific categories of the total list.

68 exotic species have spontaneously spread within the South Coast of Crimea. These are 27 agriophytes: *Acer negundo*, *Ailanthus altissima*, *Berberis aquifolia*, *Bupleurum fruticosum*, *Buxus sempervirens*, *Cercis siliquastrum*, *Clematis flammula*, *Colutea orientalis*, *Cydonia oblonga*, *Daphne laureola*, *Elaeagnus angustifolia*, *Ficus carica*, *Fraxinus ornus*, *Laburnum anagyroides*, *Lonicera etrusca*, *Lycium barbarum*, *Malus domestica*, *Platycladus orientalis*, *Prunus cerasifera*, *P. dulcis*, *Ptelea trifoliata*, *Pueraria montana* var. *lobata*, *Pyrus communis*, *Quercus ilex*, *Rhamnus alaternus*, *Viburnum tinus* and *Vitis vinifera*; 40 colonophytes: *Abies pinsapo*, *Amorpha fruticosa*, *Buddleja davidii*, *Caragana arborescens*, *Castanea sativa*, *Catalpa bignonioides*, *Cedrus atlantica*, *C. deodara*, *Celtis australis*, *C. caucasica*, *Cladrastis kentukea*, *Colutea arborescens*, *Cotoneaster glaucophyllus*, *Cupressus sempervirens*, *Diospyros lotus*, *Gleditsia triacanthos*, *Koeleria paniculata*, *Prunus laurocerasus*, *Laurus nobilis*, *Lonicera caprifolium*, *L. standishii*, *L. tatarica*, *Machura pomifera*, *Morus alba*, *M. nigra*, *M. rubra*, *Olea europaea*, *Parthenocissus quinquefolia*, *Prunus armeniaca*, *P. domestica*, *P. vulgaris*, *Pyracantha rogersiana*, *Ribes aureum*, *R. rubrum*, *R. spicatum*, *Robinia pseudoacacia*, *Sophora japonica*, *Spartium junceum*, *Syringa vulgaris* and *Zelkova carpinifolia* and ephemerophyte *Prunus cerasus*.

18 exotic woody species penetrated the flora of the Yalta Mountain-Forest Natural Reserve. All of them are agriophytes – 13 species, and colonophytes – 5 species (Bagrikova & Bondarenko, 2015). A number of alien woody species form local populations of normal type in the native communities of "Mys Martian" nature reserve: *Bupleurum fruticosum*, *Buxus sempervirens*, *Fraxinus ornus*, *Laburnum anagyroides*

and *Prunus cerasifera* (Bagrikova et al., 2014). In addition to the data about naturalization of plants in the botanical gardens, cities and nature reserve fund, we have considered articles about their separate records (Tyshchenko et al., 2013; Burda, 2014). It has also been noted that *Acer negundo* and *Robinia pseudoacacia* are viewed as diagnostic species of the synanthropic *Robinietaea* class, stable components of *Salicetea purpureae* class, capable of intruding into the phytocenoses of *Quercus-Fagetetea* class causing structural disruption. *Elaeagnus angustifolia* and *E. commutata* are transformer species in Steppe and Circum-Pontic regions, conditioning the colonization of river basins, changing the grass cover of salinized coastal depressions (Abduloyeva & Karpenko, 2009). *Ailanthus altissima*, *Celtis occidentalis*, *Juglans cinerea*, *J. mandshurica*, *J. regia*, *Prunus serotina*, *P. virginiana*, *Ribes uva-crispa*, spread spontaneously from forest culture in the nature reserve territories of the Forest-Steppe, also in the habitats of G type (forests and shrubs), *Acer negundo* and *Amorpha fruticosa* are involved in the cenoses of *Rhamno-Prunetea* class (Pashkevych & Burda, 2017).

The invasion of alien woody species into spontaneous flora in Ukraine

Therefore, 182 non-native woody species (172 species, 1 subspecies, 4 varieties and 5 hybrids) have been distinguished in the spontaneous flora of Ukraine (Tables 5, 6). This list is obviously incomplete. Only the articles in general access have been considered. The archive data on thorough studies of the course of initial introduction are inaccessible. Herbarium labels do not always highlight the origin of herborized samples, collected in the botanical gardens and arboreta. On the one hand, the compilation of a more precise list of woody exotic species is hindered by the absence of a unified inventory of collection funds and database of the course of naturalization of these species, and, on the other hand, the naturalization process is not over. On the contrary, it is getting stronger. Plant invasion is an extremely dynamic process. However, the presented list gives a general idea about the composition and character of non-native woody trees in the domestic flora.

71 alien completely naturalized plants have been differentiated (66 species, 1 subspecies, 1 variety and 3 hybrids). They belong to 47 genera and 28 families of two divisions – Pinophyta and Magnoliophyta (Table 5). This group presents the highest risk for the local diversity of species: 12 of them are transformers, 8 are invasive proper, 29 – potentially invasive, 22 – naturalized species, whose invasive activity has not been manifested. In terms of life-forms, the list of alien woody species contains

30 species – trees, 26 species – shrubs, and 8 species – lianas, 7 species develop their life-form as a tree or a shrub, depending on their environment.

Table 5
The invasive activity of alien woody species in spontaneous flora of Ukraine

Family	Taxon	Life-form	Spread	Degree of naturalization*	Occurrence	Invasive activity
Pinophyta						
Cupressaceae	<i>Platycladus orientalis</i> (L.) Franco	tree/shrub	seed	agriophyte _c	rare	naturalized
Magnoliophyta						
Berberidaceae	<i>Berberis aquifolia</i> Pursh	shrub	seed, vegetative way	agriophyte	local	invasive
Berberidaceae	<i>B. vulgaris</i> L.	shrub	seed, vegetative way	epoecophyte	sporadic	naturalized
Ranunculaceae	<i>Clematis flammula</i> L.	liana	seed, vegetative way	agriophyte _c	sporadic	potentially invasive
Buxaceae	<i>Buxus sempervirens</i> L.	shrub	seed	agriophyte _c	local	potentially invasive
Grossulariaceae	<i>Ribes uva-crispa</i> L.	shrub	seed, vegetative way	ergasiophyte	local	potentially invasive
Vitaceae	<i>Parthenocissus quinquefolia</i> (L.) Planch.	liana	seed, vegetative way	colonophyte _c , epoecophyte	common	transformer
Vitaceae	<i>P. tricuspidata</i> (Siebold & Zucc.) Planch.	liana	seed, vegetative way	epoecophyte	rare	naturalized
Vitaceae	<i>P. vitacea</i> (Knerr) Hitchc.	liana	seed, vegetative way	agriophyte	common	transformer
Vitaceae	<i>Vitis vinifera</i> L.	liana	seed, vegetative way	agriophyte _c , epoecophyte	common	invasive
Fabaceae	<i>Amorpha fruticosa</i> L.	shrub	seed, vegetative way	agriophyte, colonophyte _c	common	transformer
Fabaceae	<i>Caragana arborescens</i> Lam.	shrub	seed	colonophyte _c , hemiagriophyte	common	naturalized
Fabaceae	<i>Cercis siliquastrum</i> L.	tree/shrub	seed	agriophyte _c	rare	naturalized
Fabaceae	<i>Colutea orientalis</i> Mill.	shrub	seed	agriophyte _c	local	invasive
Fabaceae	<i>Gleditsia triacanthos</i> L.	tree	seed	colonophyte _c , epoecophyte	sporadic	naturalized
Fabaceae	<i>Laburnum anagyroides</i> Medik.	shrub	seed	agriophyte _c	local	potentially invasive
Fabaceae	<i>Pueraria montana</i> var. <i>lobata</i> (Willd.) Sanjappa & Prade	liana	seed, vegetative way	agriophyte _c	local	potentially invasive
Fabaceae	<i>Robinia pseudoacacia</i> L.	tree	seed, vegetative way	colonophyte _c , agriophyte	common	transformer
Rosaceae	<i>Amelanchier spicata</i> (Lam.) K. Koch	tree	seed, vegetative way	agriophyte	sporadic	potentially invasive
Rosaceae	<i>Cydonia oblonga</i> Mill.	tree/shrub	seed, vegetative way	agriophyte	common	potentially invasive
Rosaceae	<i>Malus domestica</i> Borkh.	tree	seed, vegetative way	agriophyte	common	potentially invasive
Rosaceae	<i>Physocarpus opulifolius</i> (L.) Maxim.	shrub	seed, vegetative way	epoecophyte	common	naturalized
Rosaceae	<i>Prunus armeniaca</i> L.	tree	seed, vegetative way	colonophyte _c , epoecophyte	common	naturalized
Rosaceae	<i>P. cerasus</i> L.	tree	seed, vegetative way	ephemerophyte _c , epoecophyte	common	naturalized
Rosaceae	<i>P. cerasifera</i> Ehrh.	tree/shrub	seed, vegetative way	agriophyte	common	invasive
Rosaceae	<i>P. domestica</i> L.	tree	seed, vegetative way	colonophyte _c , ergasiophyte	common	naturalized
Rosaceae	<i>P. domestica</i> subsp. <i>insititia</i> (L.) Bonnier & Layens	tree/shrub	seed, vegetative way	agriophyte	common	potentially invasive
Rosaceae	<i>P. dulcis</i> (Mill.) D.A. Webb	tree	seed	agriophyte _c	local	potentially invasive
Rosaceae	<i>P. serotina</i> Ehrh.	tree/shrub	seed, vegetative way	agriophyte	common	invasive
Rosaceae	<i>P. virginiana</i> L.	tree	seed, vegetative way	ergasiophyte	common	potentially invasive
Rosaceae	<i>Pyrus communis</i> L.	tree	seed, vegetative way	agriophyte	common	naturalized
Rosaceae	<i>Rosa rugosa</i> Thunb.	shrub	seed, vegetative way	ergasiophyte	common	naturalized
Rosaceae	<i>Sorbaria sorbifolia</i> (L.) A. Braun	shrub	seed, vegetative way	epoecophyte	common	potentially invasive
Elaeagnaceae	<i>Elaeagnus angustifolia</i> L.	tree/shrub	seed, vegetative way	agriophyte	common	transformer
Elaeagnaceae	<i>E. rhamnoides</i> (L.) A. Nelson	shrub	seed, vegetative way	agriophyte	common	transformer
Elaeagnaceae	<i>E. commutata</i> Bernh. ex Rydb.	tree	seed, vegetative way	hemiagriophyte	rare	potentially invasive
Rhamnaceae	<i>Rhamnus alaternus</i> L.	shrub	seed, vegetative way	agriophyte _c	local	transformer
Ulmaceae	<i>Ulmus pumila</i> L.	tree	seed, vegetative way	hemiagriophyte	common	potentially invasive
Moraceae	<i>Ficus carica</i> L.	tree/shrub	seed	agriophyte _c , ephemerophyte	local	potentially invasive
Moraceae	<i>Morus alba</i> L.	tree	seed	colonophyte _c , epoecophyte	common	potentially invasive
Fagaceae	<i>Quercus ilex</i> L.	tree	seed	agriophyte _c	local	invasive
Fagaceae	<i>Q. rubra</i> L.	tree	seed	emiagriophyte	local	potentially invasive
Celastraceae	<i>Celastrus scandens</i> L.	liana	seed, vegetative way	epoecophyte	rare	potentially invasive
Salicaceae	<i>Populus balsamifera</i> L.	tree	seed, vegetative way	ergasiophyte	rare	naturalized
Salicaceae	<i>P. bolleana</i> Lauche	tree	seed, vegetative way	ergasiophyte	common	naturalized
Salicaceae	<i>P. × canadensis</i> Moench	tree	seed, vegetative way	epoecophyte	common	naturalized
Salicaceae	<i>P. deltoides</i> Marshall	tree	seed, vegetative way	epoecophyte	common	naturalized
Salicaceae	<i>P. nigra</i> var. <i>italica</i> Münchh	tree	seed, vegetative way	ergasiophyte	common	naturalized
Salicaceae	<i>P. suaveolens</i> Fisch.	tree	seed, vegetative way	ergasiophyte	common	naturalized
Salicaceae	<i>P. richocarpa</i> Torr. & A. Gray ex Hook.	tree	seed, vegetative way	ergasiophyte	common	naturalized
Salicaceae	<i>Salix × babylonica</i> L.	tree	seed, vegetative way	ergasiophyte	common	naturalized
Salicaceae	<i>S. × blanda</i> Andersson	tree	seed, vegetative way	agriophyte	common	transformer
Anacardiaceae	<i>Toxicodendron radicans</i> (L.) O. Kuntze	shrub	seed, vegetative way	ergasiophyte	local	potentially invasive
Aceraceae	<i>Acer negundo</i> L.	tree	seed	agriophyte	common	transformer
Rutaceae	<i>Ptelea trifoliata</i> L.	shrub	seed, vegetative way	agriophyte _c , hemiagriophyte	common	potentially invasive
Simaroubaceae	<i>Ailanthus altissima</i> (Mill.) Swingle	tree	seed, vegetative way	agriophyte _c , epoecophyte	common	transformer
Tiliaceae	<i>Tilia americana</i> L.	tree	seed	ergasiophyte	common	naturalized
Thymelaeaceae	<i>Daphne laureola</i> L.	shrub	seed, vegetative way	agriophyte _c	local	invasive
Comaceae	<i>Cornus alba</i> L.	shrub	seed, vegetative way	ergasiophyte	common	potentially invasive
Comaceae	<i>C. sericea</i> L.	shrub	seed, vegetative way	epoecophyte	common	potentially invasive
Hydrangeaceae	<i>Philadelphus coronarius</i> L.	shrub	seed, vegetative way	ergasiophyte	common	naturalized
Solanaceae	<i>Lycium barbarum</i> L.	shrub	seed, vegetative way	agriophyte _c , epoecophyte	common	inspotentially invasive
Oleaceae	<i>Fraxinus americana</i> L.	tree	seed	epoecophyte	common	naturalized
Oleaceae	<i>F. ornus</i> L.	tree	seed	agriophyte _c	local	transformer

Family	Taxon	Life-form	Spread	Degree of naturalization*	Occurrence	Invasive activity
Oleaceae	<i>F. pennsylvanica</i> Marshall	tree	seed	epoecophyte	common	potentially invasive
Oleaceae	<i>Syringa vulgaris</i> L.	shrub	seed, vegetative way	colonophyte _c , ergasiophyte	common	naturalized
Viburnaceae	<i>Viburnum tinus</i> L.	shrub	seed, vegetative way	agriophyte _c	local	invasive
Caprifoliaceae	<i>Lonicera etrusca</i> Santi	shrub	seed	agriophyte _c	local	potentially invasive
Caprifoliaceae	<i>L. tatarica</i> L.	shrub	seed	colonophyte _c , epoecophyte	common	naturalized
Caprifoliaceae	<i>Symphoricarpos albus</i> (L.) S. F. Blake	shrub	seed, vegetative way	epoecophyte	common	naturalized
Apiaceae	<i>Bupleurum fruticosum</i> L.	shrub	seed, vegetative way	agriophyte _c	local	transformer

Note: * – here and in Table 6 interlinear "c" marks "Crimea".

The prevailing majority of alien woody species have both seed dispersal and vegetative reproduction (56 species). Vegetative reproduction was not observed in nature for 15 species. In terms of the naturalization degree of alien woody species, 35 species are agriophytes, 5 – hemiagriophytes, 16 – epoecophytes, 18 – ergasiophytes, 15 – colonophytes and 1 – ephemerophyte.

A number of species in specific regions have acquired different degrees of naturalization. For instance, *Ficus carica* is an agriophyte in the flora of the South Coast of Crimea, but an ephemerophyte – in the urban flora of Kyiv; *Ailanthus altissima* and *Lycium barbarum* are agriophytes in the Crimea, and in the rest of the territory they are epoecophytes. At the same time, *Caragana arborescens* and *Robinia pseudoacacia* have not naturalized completely on the peninsula, and have the status of colonophytes, while on the mainland they are hemiagriophyte and agriophyte, respectively, etc. The following species spread as agriophytes only on the Crimean Peninsula: *Bupleurum fruticosum*, *Buxus sempervirens*, *Clematis flammula*, *Cercis siliquastrum*, *Colutea orientalis*, *Daphne laureola*, *Laburnum anagyroides*, *Lonicera etrusca*, *Platycladus orientalis*, *Prunus dulcis*, *Pueraria montana* var. *lobata*, *Quercus ilex* and *Rhamnus alaternus*, etc.

Table 6
Non-native naturalizing woody species of spontaneous flora of Ukraine

Family	Taxon	Life-form	Spread	Degree of naturalization	Occurrence	Stage of naturalization
Pinophyta						
Pinaceae	<i>Abies pinsapo</i> Boiss.	tree	seed	colonophyte _c	rare	reproduction
Pinaceae	<i>Cedrus atlantica</i> (Endl.) Manetti ex Carrière	tree	seed	colonophyte _c	rare	reproduction
Pinaceae	<i>C. deodara</i> (Roxb. ex D. Don) G. Don	tree	seed	colonophyte _c	rare	reproduction
Pinaceae	<i>Larix decidua</i> Mill.	tree	seed	ephemerophyte	controlled	reproduction
Cupressaceae	<i>Cupressus sempervirens</i> L.	tree	seed	colonophyte _c	rare	reproduction
Cupressaceae	<i>Thuja occidentalis</i> L.	tree/shrub	seed	ephemerophyte	controlled	reproduction
Magnoliophyta						
Aristolochiaceae	<i>Aristolochia macrophylla</i> Lam.	liana	seed	ephemerophyte	unique	records
Lauraceae	<i>Laurus nobilis</i> L.	tree/shrub	seed	colonophyte _c	rare	reproduction
Berberidaceae	<i>Berberis thunbergasiophytei</i> DC.	shrub	seed, vegetative way	ephemerophyte	controlled	survival
Magnoliaceae	<i>Liriodendron thunbergii</i> DC.	tree	seed, vegetative way	ephemerophyte	unique	records
Ranunculaceae	<i>Clematis gauriana</i> Roxb. ex DC.	liana	seed, vegetative way	ephemerophyte	controlled	establishing
Ranunculaceae	<i>C. jackmanii</i> T. Moore.	liana	seed, vegetative way	ephemerophyte	controlled	establishing
Ranunculaceae	<i>C. ligusticifolia</i> Nutt	liana	seed, vegetative way	ephemerophyte	controlled	establishing
Ranunculaceae	<i>C. tangutica</i> (Maxim.) Korsh.	liana	seed, vegetative way	ephemerophyte	controlled	establishing
Ranunculaceae	<i>C. vitalba</i> L.	liana	seed, vegetative way	colonophyte	rare	establishing
Ranunculaceae	<i>C. viticella</i> L.	liana	seed, vegetative way	ephemerophyte	controlled	establishing
Platanaceae	<i>Platanus acerifolia</i> (Aiton) Willd.	tree	seed	colonophyte _c , ephemerophyte	unique	records
Hamamelidaceae	<i>Parrotia subaequalis</i> (Hung T. Chang) R.M. Hao & H.T. Wei	tree/shrub	seed	ephemerophyte	controlled	reproduction
Grossulariaceae	<i>Ribes americanum</i> Mill.	shrub	seed	ephemerophyte	controlled	reproduction
Grossulariaceae	<i>R. aureum</i> Pursh	shrub	seed	colonophyte _c	rare	reproduction
Grossulariaceae	<i>R. europaea</i> (L.) Mill.	shrub	seed	ephemerophyte	rare	reproduction
Grossulariaceae	<i>R. rubrum</i> L.	shrub	seed	colonophyte _c	rare	reproduction
Grossulariaceae	<i>R. spicatum</i> Robson	shrub	seed	colonophyte _c	rare	reproduction
Vitaceae	<i>Ampelopsis aconitifolia</i> Bunge	liana	seed, vegetative way	ephemerophyte	controlled	survival
Vitaceae	<i>A. delavayana</i> var. <i>glabra</i> (Diels & Gilg) C.L. Li	liana	seed, vegetative way	ephemerophyte	controlled	survival
Vitaceae	<i>A. bodinieri</i> (H. Lév. & Vaniot) Rehder	liana	seed, vegetative way	ephemerophyte	controlled	survival
Vitaceae	<i>A. glandulosa</i> var. <i>brevipedunculata</i> (Maxim.) Momi	liana	seed, vegetative way	ephemerophyte	controlled	survival
Vitaceae	<i>Vitis coignetiae</i> Bull. ex Planch	liana	seed, vegetative way	ephemerophyte	controlled	survival
Vitaceae	<i>V. labrusca</i> L.	liana	seed, vegetative way	colonophyte	rare	reproduction
Fabaceae	<i>Allbizia julibrissin</i> Durazz.	tree	seed, vegetative way	ephemerophyte _c	rare	survival
Fabaceae	<i>Cladrastis kentukea</i> (Dum. Cours.) Rudd	shrub	seed	colonophyte _c	sporadic	establishing
Fabaceae	<i>Colutea arborescens</i> L.	shrub	seed	colonophyte _c	rare	survival
Fabaceae	<i>Gymnocladus dioica</i> (L.) K. Koch	tree	seed	ephemerophyte	rare	survival
Fabaceae	<i>Halimodendron halodendron</i> (Pall.) Voss	shrub	seed	colonophyte	local	establishing

Family	Taxon	Life-form	Spread	Degree of naturalization	Occurrence	Stage of naturalization
Fabaceae	<i>Robinia hispida</i> L.	tree	seed, vegetative way	colonophyte	local	establishing
Fabaceae	<i>R. neomexicana</i> A. Gray	tree	seed, vegetative way	colonophyte	local	establishing
Fabaceae	<i>R. viscosa</i> Vent.	tree	seed, vegetative way	colonophyte	local	establishing
Fabaceae	<i>Sophora japonica</i> L.	tree	seed	colonophyte _c	unique	survival
Fabaceae	<i>Spartium junceum</i> L.	shrub	seed, vegetative way	colonophyte _c	sporadic	establishing
Rosaceae	<i>Amelanchier ovalis</i> Medik.	tree/shrub	seed	ephemerophyte	local	establishing
Rosaceae	<i>Aronia melanocarpa</i> (Michx.) Elliott	tree	seed	ephemerophyte	local	establishing
Rosaceae	<i>Cerasus tomentosa</i> (Thunb.) Wall. ex T.T. Yu & C.L. Li	shrub	seed	ephemerophyte	rare	reproduction
Rosaceae	<i>Chaenomeles japonica</i> (Thunb.) Lindl. ex Spach	shrub	seed, vegetative way	ephemerophyte	rare	reproduction
Rosaceae	<i>Cotoneaster glaucophyllus</i> Franch.	shrub	seed	colonophyte _c	rare	reproduction
Rosaceae	<i>C. lucidus</i> Schlecht.	shrub	seed	ephemerophyte	local	reproduction
Rosaceae	<i>C. melanocarpus</i> Fisch. ex A. Blytt	shrub	seed	ephemerophyte	local	reproduction
Rosaceae	<i>Crataegus coccinea</i> L.	shrub	seed	ephemerophyte	rare	reproduction
Rosaceae	<i>C. sanguineus</i> Pall.	shrub	seed	ephemerophyte	rare	reproduction
Rosaceae	<i>C. submollis</i> Sarg.	shrub	seed	ephemerophyte	rare	reproduction
Rosaceae	<i>Malus baccata</i> (L.) Borkh.	tree	seed	ephemerophyte	rare	reproduction
Rosaceae	<i>Mespilus germanica</i> L.	shrub	seed, vegetative way	ephemerophyte	rare	reproduction
Rosaceae	<i>Persica vulgaris</i> Mill.	tree	seed	ephemerophyte	rare	reproduction
Rosaceae	<i>Prunus laurocerasus</i> L.	shrub	seed, vegetative way	colonophyte _c	local	establishing
Rosaceae	<i>P. mahaleb</i> L.	shrub	seed	ephemerophyte	rare	reproduction
Rosaceae	<i>P. padus</i> L.	tree/shrub	seed	ephemerophyte	rare	reproduction
Rosaceae	<i>P. vulgaris</i> Schur	tree/shrub	seed, vegetative way	colonophyte _c	sporadic	establishing
Rosaceae	<i>Pyracantha rogersiana</i> (A. B. Jacks.) Coltm.-Rog.	shrub	seed, vegetative way	colonophyte _c	rare	reproduction
Rosaceae	<i>Rubus macrophyllus</i> Weihe & Nees	shrub	seed, vegetative way	ephemerophyte	unique	records
Rosaceae	<i>R. odoratus</i> L.	shrub	seed, vegetative way	ephemerophyte	controlled	survival
Rosaceae	<i>Spiraea</i> × <i>billardii</i> Hérin	shrub	seed, vegetative way	ephemerophyte	rare	survival
Rosaceae	<i>S. chamaedryfolia</i> L.	shrub	seed, vegetative way	ephemerophyte	rare	survival
Rosaceae	<i>S. douglasii</i> Hook.	shrub	seed, vegetative way	ephemerophyte	rare	survival
Rosaceae	<i>S. salicifolia</i> L.	shrub	seed, vegetative way	colonophyte	rare	survival
Rosaceae	<i>S. × vanhouttei</i> (Briot) Zabel	shrub	seed, vegetative way	ephemerophyte	rare	survival
Ulmaceae	<i>Celtis australis</i> L.	tree	seed	colonophyte _c	rare	survival
Ulmaceae	<i>C. caucasica</i> Willd.	tree/shrub	seed	colonophyte _c	rare	survival
Ulmaceae	<i>C. occidentalis</i> L.	tree	seed	ephemerophyte	rare	survival
Ulmaceae	<i>Zelkova carpinifolia</i> (Pall.) K. Koch	tree	seed	colonophyte _c	rare	survival
Moraceae	<i>Maclura pomifera</i> (Raf.) C. K. Schneid.	tree	seed, vegetative way	colonophyte _c	rare	survival
Moraceae	<i>Morus nigra</i> L.	tree	seed	colonophyte _c	sporadic	establishing
Moraceae	<i>M. rubra</i> L.	tree	seed	colonophyte _c	sporadic	establishing
Fagaceae	<i>Castanea sativa</i> Mill.	tree	seed	colonophyte _c	unique	establishing
Fagaceae	<i>Quercus macranthera</i> Fisch. & C. A. Mey. ex Hohen.	tree	seed	ephemerophyte	controlled	establishing
Fagaceae	<i>Q. palustris</i> Moench	tree	seed	ephemerophyte	rare	reproduction
Juglandaceae	<i>Juglans ailanthifolia</i> Carrière	tree	seed	ergasiophyte	local	establishing
Juglandaceae	<i>J. cinerea</i> L.	tree	seed	ergasiophyte	local	establishing
Juglandaceae	<i>J. mandshurica</i> Maxim.	tree	seed	ergasiophyte	local	establishing
Juglandaceae	<i>J. nigra</i> L.	tree	seed	ergasiophyte	local	establishing
Juglandaceae	<i>J. regia</i> L.	tree	seed	ergasiophyte	sporadic	establishing
Juglandaceae	<i>J. subcordiformis</i> Dode	tree	seed	ergasiophyte	local	establishing
Celastraceae	<i>Celastrus angulata</i> Maxim.	liana	seed, vegetative way	colonophyte	local	survival
Celastraceae	<i>C. flagellaris</i> Rupr.	liana	seed	ephemerophyte	local	survival
Celastraceae	<i>C. orbiculatus</i> Thunb.	liana	seed	ephemerophyte	local	survival
Anacardiaceae	<i>Rhus glabra</i> L.	tree/shrub	seed, vegetative way	colonophyte	rare	survival
Anacardiaceae	<i>R. typhina</i> L.	tree	vegetative way	colonophyte	controlled	survival
Anacardiaceae	<i>R. typhina</i> L. 'Laciniata'	tree	vegetative way	colonophyte	controlled	survival
Anacardiaceae	<i>Toxicodendron pubescens</i> Mill. <i>Acer platanoides</i> L. f. <i>atropurpurea</i> 'Krimson King'	shrub	seed, vegetative way	ephemerophyte	rare	survival
Aceraceae	<i>A. saccharinum</i> L.	tree	seed	ephemerophyte	controlled	survival
Aceraceae	<i>A. saccharinum</i> L.	tree	seed	colonophyte	sporadic	survival
Hippocastanaceae	<i>Aesculus flava</i> Sol.	tree	seed	ephemerophyte	unique	records
Hippocastanaceae	<i>A. hippocastanum</i> L.	tree	seed	ergasiophyte	rare	establishing
Sapindaceae	<i>Koeleruteria paniculata</i> Laxm.	tree	seed	colonophyte _c	rare	survival
Rutaceae	<i>Phellodendron amurense</i> Rupr.	tree	seed	ephemerophyte	unique	records
Tiliaceae	<i>Tilia begoniifolia</i> Steven	tree	seed, vegetative way	ephemerophyte	rare	survival
Cistaceae	<i>Poncirus trifoliata</i> (L.) Raf.	tree/shrub	seed	ephemerophyte	rare	reproduction
Hydrangeaceae	<i>Deutzia scabra</i> Thunb.	shrub	seed, vegetative way	ephemerophyte	rare	survival
Hydrangeaceae	<i>Philadelphus microphyllus</i> A. Gray	shrub	seed, vegetative way	ephemerophyte	rare	reproduction
Ebenaceae	<i>Diospyros lotus</i> L.	tree	seed, vegetative way	colonophyte _c	rare	survival
Eucommiaceae	<i>Eucommia ulmoides</i> Oliver.	tree	seed, vegetative way	ephemerophyte	unique	records
Oleaceae	<i>Olea europaea</i> L.	tree	seed, vegetative way	colonophyte _c	rare	establishing
Scrophulariaceae	<i>Buddleja davidi</i> Franch.	shrub	seed, vegetative way	colonophyte _c	unique	records
Paulowniaceae	<i>Paulownia tomentosa</i> (Thunb.) Steud.	tree	seed	ephemerophyte	unique	records
Bignoniaceae	<i>Catalpa bignonioides</i> Walter	tree	seed, vegetative way	colonophyte _c ephemerophyte	unique	survival
Bignoniaceae	<i>Campsis grandiflora</i> (Thunb.) K. Schum.	liana	vegetative way	colonophyte	controlled	establishing

Family	Taxon	Life-form	Spread	Degree of naturalization	Occurrence	Stage of naturalization
Bignoniaceae	<i>C. radicans</i> (L.) Seem.	liana	vegetative way	colonophyte	controlled	establishing
Aquifoliaceae	<i>Ilex aquifolium</i> L.	tree	seed, vegetative way	ephemerophyte	unique	records
Caprifoliaceae	<i>Lonicera caerulea</i> L.	shrub	seed	ephemerophyte	rare	survival
Caprifoliaceae	<i>L. caprifolium</i> L.	shrub	seed	colonophyte	rare	survival
Caprifoliaceae	<i>L. standishii</i> Jacques	shrub	seed	colonophyte	rare	survival
Caprifoliaceae	<i>Weigela florida</i> (Bunge) A. DC.	shrub	seed, vegetative way	ephemerophyte	rare	survival
Aracaceae	<i>Aralia elata</i> (Miq.) Seem.	shrub	seed, vegetative way	ephemerophyte	controlled	survival

A general overview of the course of invasion of woody species into the spontaneous flora of Ukraine

According to the results of our determination and analysis of the group of non-native woody species, this component of the spontaneous flora of Ukraine has a rather diverse taxonomy: 182 species, belonging to 95 genera and 45 families. These include 71 alien species, which have completely naturalized. Let us compare: the global database of invasive trees and shrubs contains 751 alien species (434 trees and 317 shrubs); the flora of Europe has 134 of them (Rejmánek & Richardson, 2013). It is evident that it has no significant relevance for the course of invasion whether the life-form is a tree or a shrub. The involvement of trees in the total list slightly exceeds the involvement of shrubs, and as for alien species – they are even (Table 7). The most intense distribution has been noted mainly for the species remarkable both for seed dispersal and vegetative reproduction, though most non-naturalized species have only seed dispersal. Mostly common and rare species are noted in the total list in terms of occurrence and distribution, which is explained by high involvement of these very species among alien and non-naturalized ones.

The course of invasion of non-native woody species, which are at the initial stages of migration – introduction, acclimatization, survival, adaptation of reproductive sphere and establishment (Blackburn et al., 2011) – and have not naturalized yet, takes place after overcoming the geographical barrier as a result of human activity. Continuing their introduction, they cross the barriers of controlled cultivation, a barrier to survival and adaptation of reproductive sphere, and start the formation and establishment of populations. According to our observations, only 30 of them have established local populations, have cryptic (hidden) invasion risk, and the rest of the non-naturalized species do not manifest any invasive activity. First of all, noteworthy are vegetatively mobile shrubs of *Rhus typhina*, *R. typhina* 'Laciniata', *Rubus odoratus* and lianas *Ampelopsis aconitifolia*, *A. delavayana* var. *glabra*, *A. bodinieri*, *A. glandulosa* var. *brevipedunculata*, *Campsis grandiflora*, *C. radicans*, *Clematis gowriana*, *C. jackmanii*, *C. ligusticifolia*, *C. tangutica*, *C. viticella* and *Vitis coignetiae*. The global pattern of plant invasions demonstrates that under favourable conditions the species of these life-forms invade a territory fast and retain there hold on it. The studies on the naturalization in forests and parks of Kyiv demonstrated that 6 species of the genus *Juglans* (*J. ailanthifolia*, *J. cinerea*, *J. mandshurica*, *J. nigra*, *J. regia*, *J. subcordiformis*) (Burda & Koniakin, 2018) and *Aesculus hippocastanum* establish self-reproductive local populations. As for further successful or failing seed dispersal of trees (*Acer platanoides* f. *atropurpurea* 'Krimson King', *Celtis australis*, *Larix decidua*, *Quercus macranthera*), it is too early to forecast anything. The mentioned ornamental form of *Acer platanoides* is present in some parks of Kyiv, but there were no reports about self-dispersal. Non-naturalized and not high trees or shrubs (*Aralia elata*, *Parrotia subaequalis*, *Thuja occidentalis*) are still undergoing the processes of acclimatization and adaptation of reproductive sphere. Such shrubs as *Berberis thunbergii* and *Ribes americanum* do not have abundant seed dispersal. Thus, the group of non-native woody species combines the species with hidden or non-expressed invasive activity. At first sight, they are completely undynamic, almost invisible in flora, plant communities, ecosystems and landscape. However, at the impact of some factors, for instance, factors of time, favourable conditions of reproduction, sharp change in environment, etc., their activity may be revealed. Most species, which have not naturalized, have not acquired sufficient vegetative development for at least some invasive activity, so they remain passive in terms of this feature for some time.

The picture of invasive activity of alien species is quite different. The species, which have formed secondary ranges within Ukraine, are known as invasively active species, at least within Europe and Northern Asia. Transformer species in the spontaneous flora of Ukraine are revealed as the most wide spread in almost 40 regions of Europe: *Robinia pseudoacacia* (42 regions), *Ailanthus altissima* (40), *Acer negundo* (38) (Lambdon et al., 2008). Some of our non-native plant species are among the more than "100 worst" alien species in Europe (Nentwig et al., 2018). There are *Pueraria lobata* var. *montana* (rank 10 and total impact sum 29), *Robinia pseudoacacia* (13 and 28), *Prunus serotina* (59 and 17), *Elaeagnus angustifolia* (67 and 16), *Rosa rugosa* (76 and 13) and *Buddleja davidii* (80 and 11 respectively).

Table 7

The diversity of non-native woody species in spontaneous flora of Ukraine

Feature	Number of species		
	total	alien	on-naturalized
<i>Taxonomic diversity</i>			
of species	182	71	111
of genera	95	47	65
of families	45	28	35
<i>Life-form</i>			
tree	75	30	45
shrub	64	26	38
tree or shrub	16	7	9
liana	27	8	19
<i>Spreading</i>			
seed dispersal	77	15	62
vegetative way	4	0	4
both way	101	56	45
<i>Occurrence</i>			
common species	44	44	0
local species	34	17	17
sporadic species	11	4	7
rare species	57	6	51
unique species	13	0	13
controlled species	23	0	23
<i>*Degree of naturalization</i>			
agriophyte	35	35	0
hemagriophyte	5	5	0
epoecophyte	16	16	0
ergasiophyte	23	15	8
colonophyte	42	0	42
ephemerophyte	61	0	61
<i>*Invasive activity</i>			
transformer species	12	12	0
invasive species proper	8	8	0
potentially invasive species	29	29	0
naturalized species with no manifested invasive activity	22	22	0
<i>*Non-naturalized species, such stages of naturalization continue</i>			
introduction	10	0	10
survival	40	0	40
adaptation of reproduction sphere	31	0	31
establishment	30	0	30

Note: * – the highest level has been accepted for species, which is quite different by the degree features at the local level.

The expansion of *Amorpha fruticosa* is observed in neighbouring countries. In the flood plain of Kuban near the town of Temriuk *A. fruticosa* formed compact clumps, pushing out native plant communities of hygro- and hydrophytes. There were cases when the traditional shrub life-form of *A. fruticosa* was changed to the tree life-form. The height of trees was 6 m with the trunk diameter of 15 cm (Shvydkaya & Kudinova, 2013). About two dozen alien woody species of the spontaneous

flora of Ukraine have spread in 25 and more regions as the most common alien species of Europe: *Prunus cerasus* (34), *Quercus rubra* (34), *Rosa rugosa* (34), *Prunus domestica* (31), *P. cerasifera* (30), *Aesculus hippocastanum* (30), *Pyrus communis* (30), *Syringa vulgaris* (30), *Malus domestica* (29), *Berberis aquifolia* (28), *Parthenocissus quinquefolia* (27), *Symphoricarpos albus* (27), *Juglans regia* (26), *Populus × canadensis* (26), *Vitis vinifera* (26) (Lambdon et al., 2008).

Thus, coming back to the issue on the source of diaspores in the course of woody plant invasions in Ukraine, we would like to highlight a probable role of interstate migrations of invasive woody species. It is also possible that some migrations go both ways. At present, Ukraine's botanical gardens and arboreta have abundant and rather old collections. Some introduction centers own over 2,000 species of trees and shrubs. During their history (from 1793 till 2019), these institutions have passed on many woody exotic species for creation of forest cultures, use by communal services, to private amateurs, etc. In our country, woody species, used in gardening by the botanical gardens and arboreta after initial introductory testing, are planted to create current greenery of the cities along with the local species. They ensure comfortable life of local residents, promote optimization of microclimate in agriophytocoecosystems, protect railways and highways from unfavourable weather effects, resist water and wind erosion of soils, etc. In this situation, reports about immediate facts of woody species escaping the botanical gardens and arboreta which have introduced them, and establishing spontaneous plantings, are almost absent. We have managed to find only one abovementioned case of the "escape" of *Clematis vitalba* from the Donetsk Botanical Garden of NAS of Ukraine, on the mainland. This species is usually estimated by specialists as an unstable element of flora (colonophyte), remarkable for potential invasive activity, conditioned by the ability of both fast vegetative reproduction, and easy dispersal of seeds in the wind. As for the Crimean Peninsula, there is a registered fact of native penetration of *Bupleurum fruticosum* and *Fraxinus ornus* into the nature reserve "Mys Martian" from the adjacent territory of the Nikitsky Botanical Garden, where both species were naturalized long time ago (Bagrikova et al., 2014). However, the question about the nature of *Fraxinus ornus* in the Crimea is still under discussion. P. S. Pallas considered *F. ornus* on the South Coast of Crimea, in particular, in the plant communities on Mys Martian, to be an aboriginal East Mediterranean species, even 18 years prior to the establishment of the Nikitsky Botanical Garden. This thought coincides quite well with the opinions of some modern botanists. However, taking into consideration successful seed dispersal of *F. ornus* in modern plant community complexes, it seems reasonable to accept it as a transformer species on the South Coast of Crimea (Kish et al., 2009; Protopopova et al., 2012). The consequences of invasions of woody trees from the introduction centers seem to be negligible on the background of the events in domestic spontaneous flora. This conclusion is in agreement with the status of naturalization for woody plants from collections and expositions of the N. V. Tsytsyn Main Botanical Garden, RAS. Its specialists have not observed any fact of an introduced woody species escaping the garden in 70 years of introduction tests (Yatsenko & Vinogradova, 2018). They have described the following course of migration: 2,400 species have been involved in the introduction experiment; 1,317 species (55%) have overcome the ecological barrier and adjusted to new natural and climatic conditions; 66 species have overcome the reproductive barrier (5%); 12 species have actually "left the arboretum" and invaded natural forest cenoses within the territory of the Garden (8%). It should be noted that among 66 species, which have spread beyond the limits of cultivation, 10 species are aboriginal in the flora of Ukraine, and the rest are mostly mentioned in Tables 5 and 6.

Thus, the botanical gardens and arboreta of Ukraine as centers of plant introduction are neither direct sources of naturalization nor sources of spontaneous distribution of non-native woody species. The assumption about these institutions being the centers of initial introduction is surely reasonable.

In addition, the fact of seed dispersal, made by this or that species within the collection or under conditions, approximated to natural ones, is not a guarantee of its invasion in the nearest future. The way in which a plant migrates within a new territory is rather complicated, there may

be "boom" and "bust" situations, or other occasions (Blackburn et al., 2011). There have been many situations when the invasion of some species started with seed dispersal and ended with it. For instance, *Parrotia subaequalis* was introduced into the arboretum of the M. M. Hryshko National Botanical Garden in 1950, the plants first blossomed in 1975 and the mature seeds had 98% germination. Abundant seed dispersal was observed the following year, however, the seedlings were soon eliminated. In the following years the plants of *P. subaequalis* blossomed, had seeds, but there was no seed dispersal (Doroshenko et al., 2013). In this respect, noteworthy are observations of the spreading of woody trees in the arboretum of the Donetsk Botanical Garden (Eremenko & Ostapko, 2011). Three tendencies of distribution were noted under the controlled conditions of the arboretum during 10 years of observations. As expected, the species with the positive tendency include most invasive species: *Acer negundo*, *Ailanthus altissima*, *Parthenocissus quinquefolia*, potentially invasive: *Morus alba*, *Ribes uva-crispa*, and naturalized *Gleditsia triacanthos*, *Berberis vulgaris* and *Juglans regia*. The latter species sometimes establishes separate local self-reproducing populations in Donetsk on the background of abundant cultivation on private land. Decreasing dispersion was demonstrated by *Berberis aquifolia*, while *Caragana arborescens*, *Ptelea trifoliata*, *Robinia pseudoacacia* had a stable tempo of spreading.

In 55 years of observations, 227 alien woody species out of 73 genera and 31 families with seed dispersal were revealed in green plantings of Saint Petersburg. Among these, only about 10 species have become invasive and even threats to aboriginal plant communities (Firsov & Byalt, 2015). For instance, these are species: *Cornus saricea*, *Aronia mitschurinii* A. Scvorts. et Maitull., *Acer negundo*, *Amelanchier spicata*.

262 species of vascular plants, which escaped the collections and expositions, were determined in the Tsytsyn Main Botanical Garden, RAS and the Botanical Garden of Lomonosov of the Moscow State University (Mayorov et al., 2013). *Aralia elata* and *Symphoricarpos albus*, capable of independent distribution in botanical gardens of Ukraine, are among them. Contrary to the abovementioned, in the arboretum of the Tsytsyn Main Botanical Garden, natural forest communities of the Garden were invaded from the outside greenery of the city by *Acer negundo*, *Cotoneaster lucidus*, *Malus domestica* (Yatsenko & Vinogradova, 2018).

The phenomenon of naturalization of non-native species near collections and expositions of the botanical gardens and arboreta is of global character. Let us supplement the description of the experience of botanical gardens of Ukraine, Moscow and Saint Petersburg with the facts of *Caragana arborescens*, going out of cultivation within the Yakutsk Botanical Garden of the Institute of Biological Problems of Cryolithozone, the Siberian Division, RAS (on dry coastal shores of a lake, sometimes), which belongs to hemiagrophytes in Ukraine, and *Sorbaria sorbifolia* (in a birch forest, near collection plots), which is an epocophyte in our flora (Nikolaeva & Danilova, 2019).

Thus, important sources of naturalization of non-native woody species are green areas of cities, forest cultures, protective plantings of different intended purposes, private households, etc. The management of woody species invasion, the pragmatic unified framework for biological invasions (Blackburn et al., 2011), should be based on the global strategy on invasive alien species. The course of invasion of non-native woody species in the domestic flora dictates the following scheme of actions: preventing invasions, eradication – at the stages of survival and adaptation of the reproductive sphere, containment – after the species has overcome the barrier of reproduction and dispersal, and mitigation – on the final stages of invasion.

Conclusion

This is the first and preliminary determination and evaluation of non-native woody species in Ukraine's spontaneous flora. The data, presented in the article, demonstrate the active course of naturalization of non-native woody species and invasion of alien species in the spontaneous flora. The tendencies towards global increase of involvement and invasive activity of alien woody species in the spontaneous domestic flora have been confirmed.

The analysis of the occurrence, naturalization, distribution and the estimation of invasive activity of non-native species of trees, shrubs, and lianas in floras of 5 regions, 5 urban floras, over 30 floras of protected areas demonstrated as follows: there are 182 species from 95 genera and 45 families (75 trees, 16 trees or shrubs, 64 shrubs, and 27 lianas) are at different stages of naturalization in the spontaneous flora.

71 species have completely naturalized, 20 of which are invasive and pose the highest threat to local diversity (12 transformer species and 8 invasive proper ones). The rest of the naturalized species are potentially invasive (29 species) or do not demonstrate invasive activity (22 species).

111 species have overcome the geographical barrier due to human activity. These are undergoing the initial stages of invasion: survival, acclimatization, adaptation of reproductive sphere, establishment and formation of local populations.

In Ukraine, there are about 50 botanical gardens and arboreta – centers of initial introduction of plants, 2 of them have been working since the end of the 18th century, and 8 – since the 19th century. The collections of 1 arboretum exceed 2,000, 2 botanical gardens have about 2,000 species, and the number of woody species in 4 botanical gardens and 1 arboretum exceeds 1,000 species. There is information about controlled spreading of 23 woody species beyond collections and expositions of the introduction centers. There was only one described case of spontaneous escape of 2 invasive woody species beyond the introduction center (*Bupleurum fruticosum* and *Fraxinus ornus*) from the Nikitsky Botanical Garden to the adjacent nature reserve "Mys Martian".

The mitigation of the effects of invasive alien woody species on local biodiversity requires restoration of local natural plant community complexes, organization of land use and culture of taking care of woody plantings. Our conclusions are relevant for employees of introduction centers, nature protection bodies, communal services, and state quarantine while elaborating the system of preventive, radical (eradication, limitation of assortment), containment and mitigation of impacts of plant invasions.

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