

GEOGRAPHY OF CONSERVATION *EX SITU* OF RARE TAXA OF ANCIENT EXOTIC TREES *Pinophyta* IN UKRAINE

Serhii POPOVYCH, Anzhela DZYBA

National University of Life and Environmental Sciences of Ukraine,
19 St. General Rodimtsev, 03041, Kyiv, Ukraine

Corresponding author email: orhideya_onycidium@ukr.net

Abstract

In the article was analyzed the representativeness of rare taxa of protected ancient exotic tree species *Pinophyta* in physiographical zones and mountainous countries of Ukraine. Sixtyone species, one subspecies, and one plant variety of this genus were identified in the nature reserves of Ukraine. Among these, most species were found in forest-steppe zone (32), Mountainous Crimea zone (31), and deciduous forest zone (22) suggesting that these three regions could potentially be most favorable for the introduction and acclimatization of foreign *Pinophyta* species. In ecological structure of the region, dominant are taxa of the mesophytes ecological group, containing frost and winter resistant tree species. Within the geographic range, predominant are native plant species of circumboreal and Atlantic - Pacific Northwest (total of 27 species), Madrean (12) and Western-Asian (11) floristic zones. All 63 taxa are on the IUCN Red List (LC-42, VU-4, NT-7, EN-9, and CR-1 categories). At the same time, *Abies nordmanniana* (Steve) Spach. subspec. *equi-trojani* (Asch. & Sint.) Code & Cull. (R) and *Abies pinsapo* Boiss. (VU) are on the European Red List. These two species together with *Abies numidica* (CR) represent the rarest taxa among the century-old exotic *Pinophyta* trees in Ukraine.

Key words: physiographic regions, floral analysis, protected localities, coniferous introduced species, protected trees.

INTRODUCTION

Nature-protection research projects of ancient trees are an important and urgent scientific task that is being solved comprehensively and in various parts of the world (Huckaby et al., 2003; Pelt, 2008; Lindemayer et al., 2012; Lindemayer & Laurance, 2016; Li & Zhang, 2017). For many years the identification and inventory of the old-growth forests and century-old trees have been important in the neighboring with Ukraine countries: Moldova (The most famous..., 2017), Romania (Schickhofer & Schwarz, 2019), Hungary (The thickest, tallest..., n.d.), Slovenia (The oldest trees..., n.d.), Poland (Siewniak, 2007), Belarus (Is the myth..., 2016) and Russia (Trees are monuments..., n.d.).

In Ukraine, the protection practices of the century-old trees began in the late nineteenth century. However, active discussion of these practices in the scientific community started only in the 1960s (Ivchenko, 1967; Rubtsov & Laptev, 1971; Lypa, 1977; Boreiko, 2001; Galkin et al., 2014; Karpenko & Pototska, 2017).

Several attempts to inventory century-old trees at the national level were made in the last 30

years. In 1991, the program "Famous and Historic Trees of Ukraine" was initiated (Kushnir et al., 1995). In 2009, a contest for prominent trees over 1000 years of age was held at the national level. Currently, about 30% of century-old trees in Ukraine hold status of botanical nature monuments. During the 20th century, Ukraine lost six *Quercus robur* L. trees with the tree age ranging between 1000 and 1500 years (Hrynyk et al., 2010; Schneider et al., 2011).

The goal of our study was to determine quantitatively and qualitatively the species composition of century-old rare *Pinophyta* trees introduced in nature reserves of Ukraine. Within the nature reserves, there are 11 categories of territories and entities approved by the national legislation of Ukraine. Among these, the most researched taxa are introduced in botanical gardens, dendrological parks, park-monuments of landscape art (PMLA), and man-made botanical nature monuments.

Introduced in Ukraine species of woody plants present on red lists are called exotic woody plants. The degree of rarity of plant species was determined by their presence on the following official international red lists: IUCN Red List,

European Red List, Appendix I Bern Convention, CITES (The convention..., 1979; European..., 1992; Information..., 2002; The IUCN Red List, 2018).

MATERIALS AND METHODS

To achieve the goal of the study, we composed the summary of the taxa of century-old (100 years of age and older) exotic *Pinophyta* trees introduced in nature reserves of Ukraine. This work required a review of considerable number of literary sources published in the last 20 years. Simultaneously with the literature review, we conducted the field inventory. This approach made it possible to obtain data for the individual physiographic zones of Ukraine (Marynych et al., 2003): forest-steppe (Popovych et al., 2011b), steppe (Popovych et al., 2014), mixed forest (Popovych et al., 2017b), and broad-leaved forest zone (Popovych et al., 2020). The published in this manuscript information on the researched taxa, present in mountainous countries and territory of Ukraine, appears in the literature for the first time.

The compiled summary of taxa of century-old exotic *Pinophyta* trees has been a subject to a rigorously tested research method of structural floristic analysis (Popovych et al., 2010, 2013, 2017a; 2019; Stepanenko & Popovych, 2015; Vlasenko & Popovych, 2016; Savoskina & Popovych, 2019; Miskevych & Popovych, 2019). We used published by Takhtajan (1978) methods to determine how the plant species were associated with the floristic regions of the Eart.

A methodology associated with calculating an acclimatization value was utilized to determine the success rate of the introduction of century-old exotic *Pinophyta* trees (Kohno & Kurdyuk, 2010). The highest degree of acclimatization success was assigned to the plant species with the highest acclimatization value ($A = 100$). The ranking of plant wellbeing was determined using Alekseev's scale (1989).

Determined from publications tree age was used as basis for ranking. Indicated in the relevant publications, the age of the woody plants was taken as the basis with the oldest objects being specified by tested methods (Kushnir et al., 1995; Boreyko, 2001; Hrynyk et al., 2010; Schneider et al., 2011).

The taxonomic status and plant Latin names were verified against the checklist of exotic trees of Ukraine (Popovych et al., 2016) and the IUCN Red List and The Plant List databases. The complete binary taxa names with corresponding author names were only provided in Table 1.

RESULTS AND DISCUSSIONS

The obtained data are presented separately for each physiographic region and for the entire area of Ukraine (Table 1).

Mixed forests zone (Ukrainian Polissia). All nine studied tree species are listed on the IUCN Red List predominantly in the Least Concern (LC) category. The only species allocated to the Endangered (EN) category is *Ginkgo biloba* because it is the rarest one in the region. An analysis of species geographical distribution of century-old exotic *Pinophyta* trees revealed that five species originated from the circumboreal region, some of which also originated from the American North-Atlantic Floral Regions, whereas two species are representative of the Rocky Mountains Region. Century-old *Larix decidua* trees are the most widespread. They have been identified in 22 nature reserves distributed among five administrative regions. Among five species of the genus *Pinus* L., *Pinus strobus* occurs most frequently (seven localities).

Tree ages range between a 100 and 203 years. The oldest trees are *Larix decidua* (203 years, Vahanytskyi PMLA, the Chernihiv region) and *Pinus strobus* (203 years, a botanical nature monument "Yuzefinska dacha", the Rivne region). A lonely *Pinus sibirica* is 153 years old. Century-old trees most often were found in PMLAs, especially those in the Zhytomyr region.

Presence of century-old exotic trees, particularly those over 150 years of age, is the evidence of their full acclimatization in all physiographic zones of the region ($A = 100$). Plants usually retain growth rates, have a pronounced frost and good drought resistance, have an average adaptation level (score III), form uniform seeds. Among the species, *Larix decidua* stands out for its particularly high vitality and prolific seed production.

Table 1. Representation of rare species of protected century-old *Pinophyta* woody plants in physiographic regions of Ukraine

Latin species names of woody plants	Physiographic zones and mountainous regions						Total for Ukraine
	MFZ ¹	BLFZ ²	FSZ ³	SZ ⁴	UCM ⁵	MC ⁶	
<i>Abies balsamea</i> (L.) Mill.			2				2
			110				110
<i>Abies cephalonica</i> Loud.				2		1	3
				112		175	175
<i>Abies concolor</i> Lindl. et Gord.		2	7	1			9
		105	130	120			130
<i>Abies nordmanniana</i> (Stev.) Spach.		1	1	2	2		6
		110	140	112	120		140
<i>Abies nordmanniana</i> (Steve) Spach. subsp. <i>equi-trojani</i> (Asch. & Sint.) Code & Cull.			1			1	2
			110			125	125
<i>Abies numidica</i> de Lannoy ex Carrière						2	2
						105	105
<i>Abies pinsapo</i> Boiss.						2	2
						175	175
<i>Abies sibirica</i> Ledeb.		1	1				2
		105	110				110
<i>Calocedrus decurrens</i> (Torr.) Florin				1		2	3
				105		165	165
<i>Cedrus atlantica</i> (Endl.) Manetti ex Carrière						5	5
						165	165
<i>Cedrus deodara</i> (D. Don) G. Don. f.						3	3
						178	180
<i>Cedrus libani</i> Harr. var. <i>libani</i>						5	5
						155	155
<i>Cephalotaxus harringtonia</i> (Knight ex. J. Forbes) C. Koch						1	1
						165	165
<i>Chamaecyparis lausoniana</i> (Andr.) Parl.				2		1	3
				125		110	125
<i>Chamaecyparis pisifera</i> (Sieb. et Zucc.) Endl.		2	2		2		6
		125	145		130		145
<i>Cryptomeria japonica</i> (L. f.) D. Don						1	1
						110	110
<i>Cupressus arizonica</i> Greene		1				1	2
		105				175	105
<i>Cupressus goveniana</i> Gordon						1	1
						105	105
<i>Cupressus guadalupensis</i> Wats.						2	2
						105	105
<i>Cupressus lusitanica</i> Mill.						1	1
						178	178
<i>Cupressus macrocarpa</i> Hartw.						2	2
						175	175
<i>Cupressus sempervirens</i> L.						8	8
						203	200
<i>Cupressus torulosa</i> D. Don						1	1
						175	175
<i>Ginkgo biloba</i> L.	1	13	7	2	6	1	30
	163	250	210	130	120	205	250
<i>Juniperus pseudosabina</i> F. et M.			1				1
			110				110
<i>Juniperus virginiana</i> L.		6	7	2		1	16
		125	200	115		105	200
<i>Larix decidua</i> Mill.	22	24	45	1	5		98
	203	200	410	135	200		410
<i>Larix kaempferi</i> (Lamb.) Carrière		2	1		2		5
		105	120		150		150
<i>Larix sibirica</i> Ledeb.		1	3				4
		105	210				210
<i>Metasequoia glyptostroboides</i> Hu & W. C. Cheng		1					1
		105					105
<i>Picea engelmannii</i> Parry ex Engelm.			3				3
			110				110
<i>Picea glauca</i> (Moench.) Voss.		2	3	2			7
		105	110	105			110
<i>Picea jezoensis</i> (Sieb. et Zucc.) Carr.			1				1
			115				115
<i>Picea mariana</i> (Mill.) Britton, Sterns & Poggenb.			1				1
			110				110
<i>Picea pungens</i> Engelm.	3	9	14	2	3		31
	103	200	140	107	120		200

<i>Picea rubens</i> Sarg.		1	1				2
		105	145				145
<i>Pinus banksiana</i> Lamb.			1				1
			110				110
<i>Pinus coulteri</i> D. Don						1	1
						105	105
<i>Pinus gerardiana</i> Wall. ex D. Don						1	1
						175	175
<i>Pinus halepensis</i> Mill.						1	1
						185	185
<i>Pinus montezumae</i> Lamb.						1	1
						105	105
<i>Pinus nigra</i> J. F. Arnold	2	21	23	5	2		53
	153	200	310	125	160		310
<i>Pinus peuce</i> Griseb.		1			1		2
		110			150		150
<i>Pinus pinaster</i> Aiton						2	2
						303	303
<i>Pinus pinea</i> L.						6	6
						203	203
<i>Pinus ponderosa</i> Douglas ex C. Lawson	1		1				2
	103		110				110
<i>Pinus rigida</i> Mill.	1						1
	103						103
<i>Pinus sibirica</i> DuRoi	1	2	7				10
	153	105	210				210
<i>Pinus strobus</i> L.	7	22	26		6		61
	203	300	230		150		300
<i>Pinus teocote</i> Schied. ex Schltdl. & Cham.						1	1
						165	165
<i>Pinus virginiana</i> Mill.			1				1
			110				110
<i>Platycladus orientalis</i> (L.) Franco		3	1	2			6
		150	110	125			150
<i>Pseudotsuga menziesii</i> (Mirb.) Franco		5	7		6	1	19
		200	130		130	105	200
<i>Sequoiadendron giganteum</i> (Lindl.) J. Buchholz						2	2
						175	175
<i>Sequoia sempervirens</i> (D. Don) Endl.					1	2	3
					140	175	175
<i>Taxodium distychem</i> (L.) Rich			1		3		4
			110		220		220
<i>Taxus cuspidata</i> Siebold & Zucc.			1				1
			110				110
<i>Thuja occidentalis</i> L.	1	9	6	2	4		22
	113	150	130	118	150		150
<i>Thuja plicata</i> Donn ex D. Don			3		1		4
			110		105		110
<i>Thuja standishii</i> Carr.				2			2
				110			110
<i>Torreya grandis</i> Fortune ex Lindl.						1	1
						110	110
<i>Tsuga canadensis</i> (L.) Carrière		4	2		4		10
		135	110		150		150
<i>Xanthocyparis nootkatensis</i> (D. Don) Spach			1				1
			110				110

¹MC - Mountainous Crimea, ²MFZ - mixed forests zone, ³BLFZ - broad-leaved forests zone, ⁴FSZ - forest-steppe zone, ⁵SZ - steppe zone, ⁶UCM - Ukrainian Carpathian Mountains. The numerator contains the number of protected localities; the denominator provides the approximate maximum age of the trees.

In contrast, a 160-year-old *Ginkgo biloba* tree growing in PMLA “Yuri Gagarin” (Zhytomyr) does not form seeds. In general, majority of trees are healthy without external crown and bole damage.

In relation to moisture level, the eco-group contains five mesophytes, one mesoxyrophyte, two xerophytes, and one hygrophyte. All examined plant species withstand freezing temperatures to -20°C .

Broad-leaved forests zone. Among 22 taxa, 17 were on the IUCN Red List with the predominance of LC category. Only *Tsuga canadensis* and *Platycladus orientalis* belong to the Near Threatened (NT) category, whereas *Ginkgo biloba*, *Pinus peuce*, and *Metasequoia glyptostroboides* belong to the EN category, that is they are the rarest in this zone. In total, 12 plant species originated from the circumboreal region (some of which also

originated from the American North-Atlantic region), five came from the East Asian Floral Areas, and three represented the Rocky Mountains. The rest of the plant species were introduced from the Iran-Turan and Madrean floral regions. *Larix decidua* (24 sites), *Pinus nigra* (21) and *Ginkgo biloba* (13) have the most extensive distribution in the region. Commonly studied plant species occur in PMLAs, mainly in the Lviv and Khmelnytsky regions.

The oldest tree group includes: *Pinus strobus* (300 years old, Raivskyi PMLA of the Ternopil region); *Ginkgo biloba* (250 y.o., PMLAs: “The park of the seventeenth-century Great Lubin” in the Lviv region and Viknianskyi park in the Chernivtsi region); *Larix decidua* (200 y.o., five localities); *Pseudotsuga menziesii* and *Picea pungens* (there are 200 of each one in the Kremenets Botanical Garden of Ternopil region); *Pinus nigra* (200 y.o., Kremenets Botanical Gardens and PMLA Maliyivkyi in the Khmelnytsky region).

Winter hardiness of plants is one of the main indicators of their successful introduction ($A = 100$). Except for the oldest by tree age, tree species *Thuja occidentalis* (150 years), *Tsuga canadensis* (135), *Chamaecyparis pisifera* (125) and *Juniperus virginiana* (125) belong to a group of frost-resistant and winter-hardy plants. The least cold-hardy appeared to be plants of *Cupressus arizonica* ($A = 85$). In relation to moisture, the mesophytic eco-group (mesophytes, xeromesophytes and hygromesophytes) prevails. Hygrophytes and xerophytes eco-groups contain six and five plant species, respectively.

Forest-steppe zone. Allocated to this zone, there are 31 protected plant species and one subspecies. Among them, 28 species are on the IUCN Red List with the predominance of a LC category, two species (*Tsuga canadensis* and *Platycladus orientalis*) belong to the NT category, whereas *Ginkgo biloba*, *Pinus peuce*, and *Abies nordmanniana* subsp. *equi-trojani* belong to the EN category. *Abies nordmanniana* subsp. *equi-trojani* is the rarest in this zone. Besides IUCN Red List it is on the European Red List due to its rarity (category R) (European ..., 1992). Among century-old protected exotic tree species not on the IUCd N

Red List, two taxa (*Abies lowiana* Murr and *Larix × eurolepis* A. Henry) were found in this zone. Majority of the taxa in the region are from the circumboreal (seven), Rocky Mountains (seven), East Asian (six), and North Atlantic (four) floral regions. Some species took origin from the areas allocated to as many as two floral zones, while others could have come from a different set of areas, i.e. Iran-Turan, Madrean, and Caribbean floral regions. One taxon was introduced from each the Iran-Turan and Mediterranean floral regions. The geography of the researched plant species in this region is quite representative. *Larix decidua* (45 entities), *Pinus strobus* (26), *Pinus nigra* (23), *Picea pungens* (14) have the highest rate of occurrence.

By the age structure, the oldest are: *Larix decidua* (410 years old, dendrological park “Trostyanets”, the Chernihiv region); *Pinus nigra* (310, PMLA “Little Sofiyivka”, the Vinnytsia Region); *Pinus strobus* (230, “Alexandria” dendrological park, the Kyiv region); *Pinus sibirica* (230, two botanical nature monuments “The Siberian Cedar”, the Sumy and the Vinnytsia regions); *Ginkgo biloba* (210, PMLA Krasnokutsky, the Kharkiv region); *Larix sibirica* (210, “Alexandria” dendrological park); *Juniperus virginiana* (200, “Alexandria” dendrological park). The majority of researched plant species are protected in dendrological parks and in Chernihiv and Poltava regions.

In relation of plants to moisture in the environment, mesophytic and hygrophytic eco-groups dominate (12 taxa each), whereas the xerophytic eco-group consists of the remaining (eight) species. Some of the species form intermediate eco-groups (xeromesophytes, mesohygrophytes). Altogether, dominant are winter-hardy plants (4 points) from the Circumboreal and Atlantic - Pacific Northwest floristic regions ($A = 100$: *Picea glauca*, *Larix kaempferi*, *Pinus banksiana*, *Abies concolor*, and others). In contrast, the most frost-resistant plants can withstand temperatures of -25° to -35° C ($A=100$: *Picea engelmannii*, *Xanthocyparis nootkatensis*, and others), while yet others could survive in temperatures below -35° C (*Taxus cuspidata*, *Abies balsamea* and others). A significant proportion is occupied by the eco-group of moderately frost-resistant

plants (A=85-90: *Tsuga canadensis*, *Abies nordmanniana*, and others).

Steppe zone. Allocated to this zone, there are 14 protected century-old tree species. Among them, 10 species that are listed on the IUCN Red List with the predominance of a LC category. One species (*Chamaecyparis lausoniana*) belongs to the Vulnerable (VU) category, two (*Platycladus orientalis*, *Thuja standishii*) belong to the NT category, whereas the rarest one in this zone (*Ginkgo biloba*) belongs to the EN category. Half of all species have originated from the Circumboreal region. Home range of others besides Circumboreal includes the American North-Atlantic and Mediterranean Floral Regions. Three species came from the Rocky Mountains Region, three others take origin from the Western-Asian Region (including one with home range distribution also including Iran-Turan floral region). One species was introduced from the Madrean floral region. *Pinus nigra* (five localities) has the highest distribution frequency. Most species appear in two localities. Only three species including *Larix decidua*, *Abies concolor*, and *Calocedrus decurrens* were found in a single locality. Most of the century-old trees were found in protected entities and dendrological parks of the Kherson region, primarily in one of the oldest biosphere reserves "Askania-Nova" (The Kherson region).

In general, introduced trees found in the region have a narrow age range between 100 and 133 years. The oldest trees are *Larix decidua* (135 years old, Velykoanadolskyi forest preserve, the Donetsk region); *Ginkgo biloba* (130 y.o., Odessa Botanical Garden); *Pinus nigra* (125 y.o., dendrological park "Veseli Bokovenky", the Kirovograd region), *Chamaecyparis lausoniana* (125 y.o., dendrological park "Askania-Nova"), *Platycladus orientalis* (125 y.o., dendrological park "Askania-Nova"), and *Abies concolor* (120 y.o., dendrological park "Veseli Bokovenky").

By distribution in the environment in relation to environmental moisture conditions, among the century-old exotic trees mesophytes ranked the highest (seven species), followed by xerophytes (four species), followed by hygrophytes (three species). In relation to

adaptation to low air temperatures, majority of existing species are either frost resistant (eight species: *Picea pungens*, *Juniperus virginiana*, *Thuja occidentalis*, and 5 other species with A = 100) or moderately frost-resistant (six species: *Chamaecyparis lawsoniana*, *Abies nordmanniana*, and four more with A = 100).

Carpathian Mountains of Ukraine. There are 15 protected plant species fl located to this zone. Among them, 12 species are on IUCN Red List with the predominance of a LC category, one species (*Tsuga Canadensis*) belongs to the NT category, whereas the rarest species in this mountainous region (*Ginkgo biloba* and *Sequoia semperviren*) belong to the EN category. Among century-old protected exotic tree species that are not on the IUCN Red List, we identified one taxon (*Larix × eurolepis* - 150 years, PMLA "Arboretum", the Ivano-Frankivsk region). In general, majority of taxa are from either one of four zones, the Circumboreal (four), East-Asian (three), Rocky Mountains (two), and Madrean (one) floral zones. The distribution of other plant species covers the territory of two floral zones, namely, the Circumboreal and Atlantic - Pacific Northwest (three), Rocky Mountains and Atlantic - Pacific Northwest (one), Caribbean and Atlantic - Pacific Northwest (one). The highest occurrence rate in the region have *Ginkgo biloba*, *Pseudotsuga menziesii*, *Pinus strobus* (each of them occurs in six localities), *Larix decidua* (occurs in five localities), *Tsuga canadensis* and *Thuja occidentalis* (each occurs in four localities).

In relation of plants to environmental moisture level, hygrophytes (seven species) and mesophytes (six species) ecological groups dominate, with xerophytes ecological group being represented by remaining two species. In general, the majority (13 species) is represented by frost-resistant plants (4 scores, A = 100). Two moderately frost resistant species (*Sequoia sempervirens* and *Taxodium distychem*) were able to naturalize only in the Zakarpattia Lowland and foothills of the Carpathians (A = 90).

Mountainous Crimea. Allocated to this zone, there are 29 protected species, one subspecies, and one plant variety. Among them, 16 species

are on the IUCN Red List with the predominance of a LC category, three species (*Cryptomeria japonica*, *Pinus gerardiana*, *Pinus coulteri*) belong to the NT category, two species and one plant variety (*Chamaecyparis lausoniana*, *Cupressus macrocarpa*, *Cedrus libani* var. *libani*) belong to the VU category, seven species and one subspecies (*Abies pinsapo*, *Cedrus atlantica*, *Cupressus goveniana*, *Cupressus guadalupensis*, *Ginkgo biloba*, *Sequoiadendron giganteum*, *Sequoia sempervirens*, *Abies nordmanniana* subsp. *equi-trojani*) belong to the EN category, whereas the rarest species in the region (*Abies numidica*) belongs to the Critically Endangered (CR) category. Simultaneously, *Abies nordmanniana* subsp. *equi-trojani* (R) and *Abies pinsapo* (VU) are on the European Red List (European ..., 1992). By the geography of origin, majority of taxa came from the Madrean (ten), Mediterranean (eight), East-Asian (four), Iran-Turan (three), or Rocky Mountains (two) floral zones. One species originated from each pair of the floral zones: Madrean and Atlantic - Pacific Northwest, Madrean and Caribbean, Mediterranean and Circumboreal, and Atlantic - Pacific Northwest and Circumboreal. The extent of species distribution in the region is quite representative. Century-old *Cupressus sempervirens* (seven localities), *Pinus pinea* (six), as well as *Cedrus atlantica* (five) and *Cedrus libani* var. *libani* (five) have the highest occurrence rate.

The tree age ranges between 100 and 205 years. The oldest trees are *Ginkgo biloba* (205 years old); *Cupressus sempervirens* and *Pinus pinea* (203 y.o. each); *Pinus halepensis* (185 y.o.); *Cedrus deodara* and *Cupressus lusitanica* (178 y.o. each); *Abies cephalonica*, *Abies pinsapo*, *Cupressus macrocarpa*, *Cupressus torulosa*, *Pinus gerardiana*, *Sequoiadendron giganteum* and *Sequoia sempervirens* (175 y.o. each). All of them are under protection in Nikitsky Botanical Garden, however, a significant part of century-old exotic trees is present in ancient PMLAs (Isikov, 2017a; 2017b).

In relation to environmental moisture levels, the species distribution by ecological groups is as follows: mesophytes and mesoxerophytes (20 taxa), xerophytes (nine) and hygromesophytes (two). Undoubtedly,

moderately frost resistant and thermophilic plants (2-3 scores) dominate in this zone, whereas frost-resistant plants occur significantly less often, that is, the majority of *Pinophyta* plants in Mountainous Crimea have a subtropical origin (A = 100).

The climatic conditions of the physiographic regions of Ukraine are very diverse and each condition individually determines the ability of the introduction of taxa of woody plants (Kotsun & Pylypchuk, 1999; Kalinichenko, 2003). Taking into consideration the urgency and importance of the above-mentioned problem, first time at the scale of the entire country we composed a summary of the species of century-old *Pinophyta* trees found in nature reserves of Ukraine (Table 1). A comparative quantitative and qualitative assessment of its taxa composition revealed some regional features.

Among the regions represented by the planes, the mixed forest zone of Ukraine appeared to be the least suitable for the introduction and acclimatization of exotic *Pinophyta* plants due to its harsh climatic and oligotrophic edaphic conditions. Under further shift of conditions toward xerophytic, species of woody plants of boreal and montane origin, xeromesophytes and frost-resistant species could be introduced more extensively in this region, whereas mesophytes and mesohygrophytes could be introduced in river valleys. Since the broad-leaved forests zone is an extension of the Ukrainian forest-steppe zone to the west, natural conditions of both zones are quite similar as evidenced by the similarity of species composition of the researched exotic trees. Therefore, as climate keeps changing, it would be worthwhile to introduce xerophytes of montane and oceanic origin more extensively in the western reaches of this latitude, and in the coming decades conduct trials of subtropical *Pinophyta* exotic trees in the region. In this regard, V.P. Kucheriavyyi (1981) noted that *Larix kaempferi* (100 years) is a species that in the city of Lviv is fast-growing, winter-hardy, and frost-resistant. Comparing results of success rates of introduction of all rare exotic trees in Forest-steppe of Ukraine (Stepanenko & Popovych, 2015) with the acclimatization values of exotic trees in the broad-leaved forest zone of Ukraine

(Miskevych & Popovych, 2019), it is worth noting that the indicators for both regions are approximate. In particular, exotic trees, completely acclimatized in the forest-steppe zone, constitute a significant proportion of species (42.2%). Therefore, it can be concluded that the natural conditions, especially temperature and moisture levels, of the Ukrainian Forest-Steppe zone are optimal for the introduction and acclimatization of exotic *Pinophyta* species. This is evidenced by the highest values of tree age. It is also natural that the oldest trees are preserved mainly in ancient parks and farmsteads, which were designed mostly by Polish landscape architects (Popovych et al., 2012; Galkin et al., 2013). Under changing climate, it is worthwhile to introduce xerophytes more extensively, and in the long run conduct trials of some subtropical trees, especially in the right-bank section of the region. A distinctive feature of the Steppe zone of Ukraine in comparison to other physiographic regions is a significant proportion of moderately frost-resistant species. In the future, with a gradual increase in average annual air temperature, their participation in the dendroflora of the region will be higher. Therefore, it is advisable to gradually acclimatize subtropical *Pinophyta* plants.

The Ukrainian Carpathians have an extremely wide climatic range from the lowlands (Zakarpattia, i.e. the region west of the Carpathian range and Peredkarpattia, i.e. the region east of Carpathian range) with subtropical climate supporting subtropical forests to the mountain tops with temperate climate supporting boreal coniferous forests (Terletsky et al., 1985; Popovych et al., 2011a; Pop et al., 2011; Chorny et al., 2017). In the future it is likely to have an ability to do test trials in the mountainous regions of exotic *Pinophyta* species adapted to warmer climates. Instead, the southern coast of the Crimea has the ecological conditions most suitable for the introduction of subtropical plants (Popovych et al., 2011a; Plugatar et al., 2014; Sakhno, 2015; Koba et al., 2018).

By life longevity, trees in Ukraine are usually divided into three groups: short, medium and long lifespan (Rubtsov & Laptev, 1971). Kolesnikov (1974) cited four, whereas

Zayachuk (2014) cited five tree lifespan groups. Since exotic trees have a shorter lifespan in comparison to native species, the most successful approach for grouping belongs to Kolesnikov (1974). According to this approach, we identified four groups of trees by age: 1) 100-200 years; 2) 201-300, 3) 301-400, 4) 401 and older. Based on this approach, 54 taxa belong to the first group, six taxa to the second, two taxa to the third, and one taxon to the fourth. Also, to find out the rarity range, we grouped the plant species by the number of protected localities where plants grow. Four groups were identified: 1) 1-25, 2) 26-50, 3) 51-75, and 4) 76-100 localities. As a result, the first group contains 58 taxa, the second contains two, the third contains two, and the fourth contains one taxa. Based on these two approaches, *Larix decidua* and *Pinus nigra* are the oldest and most common in the nature reserves of Ukraine.

CONCLUSIONS

The oldest exotic trees in Ukraine are *Larix decidua* Mill. (410 years old), *Pinus nigra* J. F. Arnold (310 y.o.) and *Pinus pinaster* Aiton (303 y.o.), whereas the most extensively distributed trees belong to taxa *Larix decidua* Mill. (98 localities), *Pinus strobus* L. (61 localities) and *Pinus nigra* J. F. Arnold (61 localities). *Ginkgo biloba* L. trees with the age range between 100 and 250 represent the only species distributed among all six physiographic regions of Ukraine.

Century-old trees of *Larix decidua* have successfully acclimated in five physiographic regions, whereas *Pinus nigra* J. F. Arnold, *Picea pungens* Engelm. and *Thuja occidentalis* L. have somewhat narrower special distribution.

Owing to ability to survive in wide range of ecological zones and multiple flexible survival strategies, *Larix decidua* and *Pinus nigra* are at the top of the list in maximum age and highest level of distribution categories.

Given the current trends of global climate warming, researched *Pinophyta* species could be recommended for the creation of the scientific species collections and for more extensive implementation in forest and landscape-park management of Ukraine.

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