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PINUS STROBUS L. IN PROTECTED AREAS OF THE UKRAINIAN POLISSYA

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Abstract

The paper considers the introduction of *Pinus strobus* L. to the Ukrainian Polissya for 200 years. The purpose of the study was to conduct an inventory of *P. strobus* in protected territories of the Ukrainian Polissya and to analyze its distribution, stand age structure, regeneration patterns, and application in different types of plantings. The study covers 26 protected man-made objects and natural areas and objects (botanical garden, 3 dendrological parks, 6 parks-monuments of landscape art, 8 natural monuments, 3 national natural parks, regional landscape park, 3 reserves, protected tract) in Ukrainian Polissya (Volyn, Rivne, Zhytomyr, Chernihiv, Khmelnytsky regions). The age of *Pinus strobus* ranges from 35 to more than 200 years. In the protected areas grow 120- to 200-year-old ancient *Pinus strobus* trees, with a number of its specimens ranging from 1 to 16. In 80 % of protected entities, *Pinus strobus* was represented by one specimen as a solitary or in groups mainly mixed with *Pinus sylvestris* L.; in 5 objects *Pinus strobus* grows in pure and mixed plantations of natural monuments. The condition of plants in 19 objects is good, in 5 – satisfactory, in two – unsatisfactory (harmed by the pest *Pineus strobi* Htg.). By self-seeding, *P. strobus* regenerated on 24 % of the territories of nature-protection entities; in one entity it has naturalized. It is proposed to use the best specimens of *Pinus strobus* as genetic material for further application in forestry and park gardening.

Key words: biodiversity conservation, eastern white pine, introduction, man-made objects.

Introduction

Conservation of biodiversity is currently a hot topic discussed on both global and national levels, including Ukraine (Prots et al. 2011). Particular attention is paid to endangered and vulnerable species, protection of which requires combined efforts of several countries. For their protection, the state of endangered species is monitored and controlled (Verkhovna Rada of Ukraine 1996).

Among the top 5 global risks identified for the next ten years are the significant loss of biodiversity and the destruction of terrestrial and aquatic ecosystems with irreversible consequences for the environment (WWF Ukraine 2020). Therefore, the preservation and protection of rare species of woody plants to be enjoyed by future generations represent important tasks for current natural resources scien-

tists and managers. Over the last few decades, significant efforts have been made by European countries to preserve a genetic diversity of woody plants. According to EUFGIS1, there are more than 3200 genetic conservation units that represent more than 4000 populations of about 100 tree species (de Vries et al. 2015).

White pine (*Pinus strobus* L.) is on the International Red List of Nature Conservation and belongs to the LC (low risk) category (Farjon 2013). Historically, the species dominated the eastern and western parts of North America and was an important commercial tree species (OECD 2006, Thompson et al. 2006, Mehes et al. 2009). *P. strobus* populations significantly declined since the 1600s following the white settlement of eastern North America. White pine felling in eastern Ontario, Canada, began in the late 1700s. During the 18th century, the number of *P. strobus* plantations within the natural range of the United States decreased (Thompson et al. 2006), yet owing to species' high growth rate they were eventually restored (Mandák et al. 2013). In the 19th and 20th centuries, within Canada's natural range, *P. strobus* underwent sharp decline due to excessive logging, fires, and the introduction of a pathogen *Cronartium ribicola* J.C.Fisch., which played an important role in forming the genetic structure of *P. strobus* populations (Mehes et al. 2009). First appearing in Europe in early 1865 in Estonia, *C. ribicola* eventually spread to France and Germany, and few years later to New England (1909) and Canada (1914) (Radu 2008). In North America in the early 20th century, the mortality from *C. ribicola* in mature pine groves was often 50–80 % (Ling 2003).

The rate of growth, high wood quality, ability to adapt to various climatic and growing conditions, and highly ornamental appearance were the main reasons for *P. strobus* introduction into the plantations of Europe. The species was first introduced to Europe in 1705 in Great Britain (Radu 2008, Krumm and Vítková 2016, Adamenko et al. 2020). During the 18–19th centuries, *P. strobus* was introduced in the following European countries: Germany (1770), the area currently occupied by the Czech Republic and Slovakia (1773), Switzerland (1850), Romania (1861), Poland (1876), Austria (1886) and Bulgaria (1903). In Germany, *P. strobus* was one of the species used for reforestation in the early 20th century (until 1927, when it was banned due to *C. ribicola*) (Radu 2008).

Mandák et al. (2013) reported that *P. strobus* had naturalized in the Outer Western Carpathians subdivision of the Carpathian Mountains in the Czech Republic and southern Poland. However, in Central Europe mainly in sandstone areas of the Czech Republic *P. strobus* is an invasive tree species (Hadincová et al. 2008, Mandák et al. 2013).

On the territory of Ukraine, *P. strobus* was first planted between 1796 and1800 in the dendrological park 'Sofiyivka' (Lypa 1952). At the beginning of the 19th century, Czartoryska (1805) (who owned estates in the Polish-Lithuanian Commonwealth, now Ukraine), recommended creating in gardens mixed groups of domestic and exotic trees and shrubs, including *P. strobus*. Nowadays in Ukraine, the area of plantations where *P. strobus* predominates, amounts to 165.6 ha, whereas the area of plantations where *P. strobus* is not the dominant species is 2542.0 ha (Musiienko 2015). The share of *P. strobus* in mixed plantations ranges from 10 to 90 %. Lukash (2008) indicated that within the areas of the Desniansko-Starohudskyi NNP (Eastern Polissya) the group of the class Viccinio-Piceetea Br.-Bl 1939

and Pulsatillo-Pinetea sylvestris Oberd 1992 is a place of growth of *P. strobus*, which is self-healing. To improve the aesthetics and increase the dendrodiversity of ancient parks in the Zhytomyr region, Markov et al. (2020) recommended the introduction of white pine in the plantations of four PMLA (Yulino, Miklouho-Maclay, Korostyshivskyi, Vilkhivskyi), which are concentrated in the Ukrainian Polissya. Anisimova (2020) noted that *P. strobus* pollen has low allergic potential (allergenicity level 3–4 out of 10 with 10 being the most severe). Therefore, based on the allergenicity of pollen, there is no reason to restrict further creation of *P. strobus* plantations in Ukraine.

The purpose of the study was to conduct an inventory of *P. strobus* in protected territories of the Ukrainian Polissya and to analyze its distribution, stand age structure, regeneration patterns, and application in different types of plantings.

Materials and Methods

The study was conducted in several stages. The first stage included work in archives and examination of tree stand inventory materials in order to identify *P. strobus* in the protected areas of Ukrainian Polissya. The next stage was inventory of *P. strobus* by detailed route method depending on size, landscape features and structure of plantings. During the study, the condition of *P. strobus* was evaluated (good – trees are healthy and well developed, have no presence of pathogens or pests, wounds, or signs of physical damage to the trunk or skeletal branches, and no hollows, the needles are dense, evenly distributed on the branches, of regular size and colour; satisfactory – trees are healthy, but with signs of slow growth, with unevenly developed crown, have small needles on branches, there is a presence of minor mechanical damages and small hollows; unsatisfactory – trees are very weak, trunks are crooked, crowns are poorly developed, with dry branches, and insignificant growth of annual shoots, trunks are mechanically damaged, with hollows) (State Committee … 2014). During field studies, the diameter was measured with a measuring fork 1.3 m up the bole from the ground surface (DBH). Tree length was measured with an altimeter Suunto PM-5/1250. In some trees, the circumference of the trunk was measured with a measuring tape. The age of these trees was determined by the formula for ancient trees of at least 100 years: $L = C \cdot K \cdot 100$, where L is the age of the tree, C is the tree bole circumference length (girth) at DBH, and K is the coefficient for *P. strobus* (0.7 – for moist fertile soils, 1.5 – for dry rocky soils) (Boreiko 2001). To determine the natural regeneration of *P. strobus*, plots of 1×1 m^2 (for seedlings of 1–5-years-old) and 5×5 m^2 (for saplings of 6–10 years, 11–15 years, 15–20 years, and more) were laid at 0,5 % of the total area of the stands. The total number (pcs/ha) was determined by the formula $N = 10000 \cdot n/P$, where n is the number of seedlings and saplings on all accounted plots, P is the area of all accounted plots, m^2 (Hirs et al. 2004). For the information obtained from the literature, we applied a systematic approach and comparative analysis. We assessed if *P. strobus* was on the International Union for Conservation of Nature Red List (Farjon 2013).

Study Area

We examined 26 entities representing protected territories in five regions of Ukrainian Polissya (Volyn, Rivne, Zhyto-

myr, Chernihiv, and Khmelnytsky). Among them were 8 nature protection areas (three National Natural Parks (NNP), a regional landscape park (RLP), a botanical reserve (BR), two landscape reserves (LR), a protected tract (PT)), and 18 man-made entities (a botanical garden (BG), 3 dendrological parks (DP), 6 park-monuments of landscape art (PMLA), six botanical monuments of nature (BNM), and 2 complex monuments of nature (CNM)) (Fig. 1).

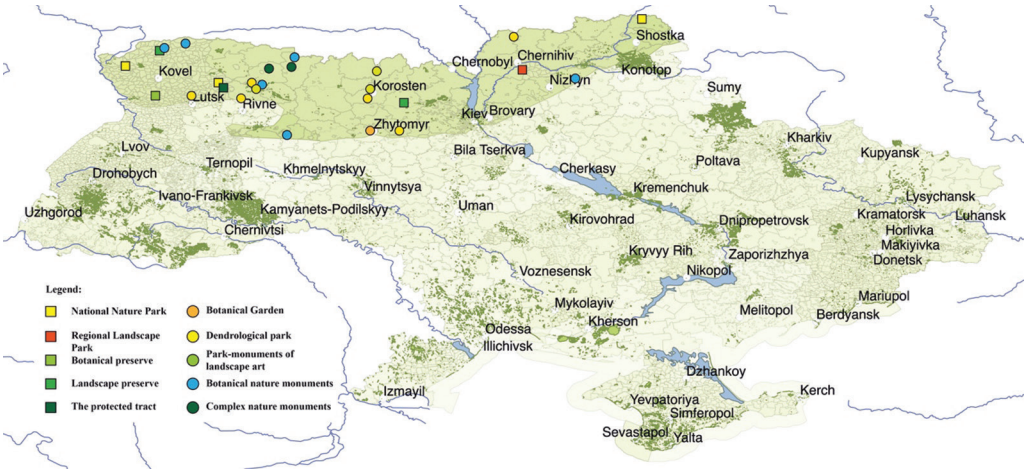

Fig. 1. Nature protection entities of Ukrainian Polissya containing *Pinus strobus*.

Results and Discussion

The introduction of *P. strobus* in Ukrainian Polissya took place in three stages with the first stage encompassing a period from the second half of the 19th century to the beginning of the 20th century; the second stage encompassing a period from the beginning of the 20th century until 1941, and the third stage encompassing a period between the second half of the 20th century and the beginning of the 21st century (Fig. 2).

Within the area of 26 nature protection entities of Ukrainian Polissya, *P. strobus* grows in different types of plantings, namely: as a solitary specimen, in pure and mixed groups, and in pure and mixed plantations (Fig. 3). In 80 % of protected entities, *P. strobus* is represented by a sol-

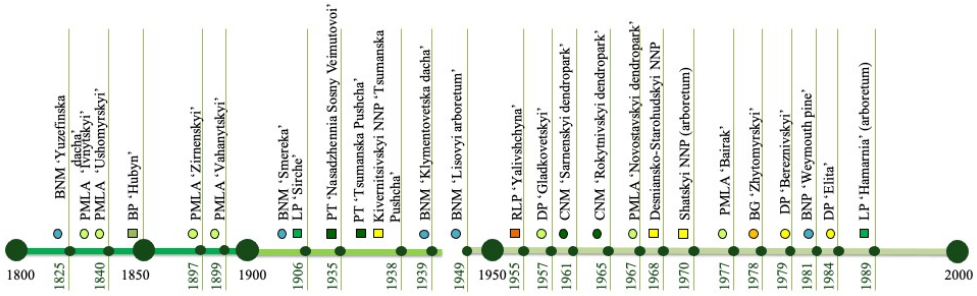

Fig. 2. Stages of the introduction of *P. strobus* in Ukrainian Polissya.

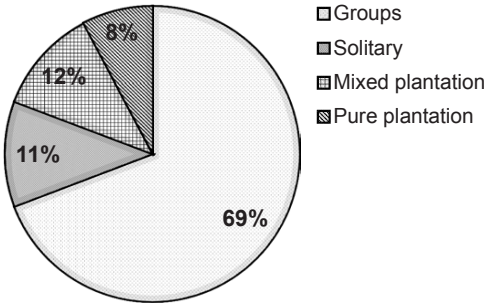

Fig. 3. Types of plantings with *Pinus strobus*.

itary specimen or in groups mainly mixed with *Pinus sylvestris* L. As a solitary specimen *P. strobus*, aged 120 to 180 years and in good condition, was found in three PMLAs: 'Ushomyrskyi'; 'Ivnytskyi' (Zhytomyr region); 'Vahanytskyi' (Chernihiv region) (figs 4–6; Table 1).

In 18 objects, *P. strobus* was represented in pure and mixed groups by one to 16 specimens. One 120-year-old specimen of *P. strobus* (good condition) grew in a group with *Larix decidua* Mill. in LNZ 'Sirche' BNM 'Smereka' (Volyn region) (Fig. 7, Table 1). In BP 'Hubyn' (Volyn region) two 170-year-old specimens of *P. strobus* were found. The first one was in good condition, whereas the second one had a bifurcation of the trunk located at a height of 2 m and was in an unsatisfactory condition (broken top). Sixteen 120-year-old *P. strobus* grew in groups of 3–5 specimens (Table 1) in a mixed plantation in PMLA 'Zirnenskyi' (Rivne region) (Fig. 8). Fourteen trees of them were in good con-

Table 1. Characteristics *Pinus strobus* L. in protected areas of the Ukranian Polissya.

Protected areas	Number of specimens/ area, ha	Age, years	Height /HT, m	Diameter (DBH), cm
'Ushomyrskyi' PMLA	1	180	30.0	81.0
'Ivnytskyi' PMLA	1	180	33.5	82.0
'Vahanytskyi' PMLA	1	120	26.0	64.0
LNZ 'Sirche' BNM 'Smereka'	1	120	23.5	70.0
BP 'Hubyn'	2	170	28.0, 22.0	83.0, 60.0
PMLA 'Zirnenskyi'	16	120	26.4 ±0.5	55.7 ±4.3
BNM 'Nasadzhennia Sosny Veimutovoi'	14	85	24.3 ±0.6	39.4 ±2.8
PMLA 'Bairak'	3	46	16.0, 11.5, 15.0	53.0, 39.0, 32.0
LP 'Hamarnia' (arboretum)	1	36	13.0	21.0
DP 'Elita'	1	35	18.0	22.0
DP 'Hladkovytskyi'	7	65	23.2 ±0.9	51.0 ±2.6
DP 'Beresnivskyi'	11	41	19.0 ±0.6	43.5 ±3.0
Botanical garden of Poliskyi National University	7	43	22,3 ± 0,5	41,5 ± 2,4
Shatskyi NNP (arboretum)	2	45	12.0, 14.0	22.0, 23.0
PMLA 'Novostavsky dendropark'	1	55	24.0	32.0
BNM 'Forest Arboretum'	1	70	26.0	49.0
CNM 'Sarnenskyi dendropark'	3	60	16.5, 23.0, 16.0	40.0, 46.0, 34.0
BNM 'Weymouth pine'	> 30/0,5	41	19.4 ±0.3	21.2 ±1.0

Fig. 4. *P. strobus*, PMLA 'Ushomyrskyi' (Zhytomyr region).

Fig. 5. *P. strobus*, PMLA 'Ivnytskyi' (Zhytomyr region).

Fig. 6. *P. strobus*, PMLA 'Vahanytskyi' (Chernihiv region).

Fig. 7. *P. strobus*, BNM 'Smereka' (Volyn region).

Fig. 8. *P. strobus*, PMLA 'Zirnenskyi' (Rivne region).

Fig. 9. *P. strobus*, BNM 'Nasadzhennia Sosny Veimutovoi' (Rivne region).

dition, whereas two were in satisfactory condition. The trees were fruiting, however, self-seeding was not observed. The optimal age of fruiting was from 50 to 150 years (Wilson and McQuilckin 1963).

A *Pinus strobus* plantation in BNM 'Nasadzhennia Sosny Veimutovoi' (Rivne region) was established in 1935. In 1993, 32 specimens were still growing. In 2015, some trees were felled because they were drying, leaving 14 specimens (satisfactory condition) (Fig. 9, Table 1). *P. strobus,* aged 36 to 70 years, grew by one to 7 specimens in pure and mixed groups. In PMLA 'Bairak' (Volyn region) (Fig. 10), the botanical garden of Poliskyi National University, and DP 'Elita' (Zhytomyr region) plants were in good condition, whereas in LP 'Hamarnia' (arboretum) (Zhytomyr region), Shatskyi NNP (arboretum) (Volyn

region), and BNM 'Forest Arboretum' (Chernihiv region) the condition of the plants was satisfactory. Characteristics of *P. strobus* in the above-protected areas of the Ukrainian Polissya are shown in Table 1.

A group of 13 *P. strobus* trees was created at the CNM 'Sarnenskyi dendropark' (Rivne region) in 1961. Currently, from that group, there are 3 trees remaining (Fig. 11, Table 1): two of them have satisfactory conditions; one tree affected by *Pineus strobi* has an unsatisfactory condition.

In BNM 'Weymouth pine' (Volyn region), a 41-year-old pure plantation of *P. strobus* was found to grow in the area of 0.5 ha (Table 1). This plantation is damaged by *Pissodes strobi* W. D. Peck. (Fig. 12), with tree condition being unsatisfactory. According to research on *Pineus strobi* (Fora and Lauer 2008) the pathogen begins to attack trees when they are 25–30-years-old, especially when their sensitivity to pathogen increases due to urban pollution. Past the age of 30 years, the trees exhibit high sensitivity to the pathogen and are subject to moderate and high intensity of infestation.

P. strobus was found to grow in pure and mixed stands in DP 'Hladkovytskyi', 'Bereznivskyi', RLP 'Yalivshchyna', in protected tracts 'Tsumanska Pushcha' Kivertsivskyi NNP 'Tsumanska Pushcha', BNM 'Juzefinska dacha', 'Weymouth pine', and 'Klymentovetska dacha'. Regeneration of *P. strobus* in Ukrainian Polissya was observed in six nature protection areas ('Tsumanska Pushcha' tract Kivertsivskyi NNP 'Tsumanska Pushcha' (Partizanske forest management enterprise (FME) (Fig. 13), quarter 21, stand 6, Berestyanske FME, quarter 29, stand 2, Desnyansko-Starogudskyi NNP, DP 'Bereznivsky', DP 'Hladkovytskyi' (Fig. 14), BNM 'Yuzefinska dacha' (Fig. 15).

'Tsumanska Pushcha' tract Kivertsivskyi NNP 'Tsumanska Pushcha' (Berestyanske FME, quarter 29, stand 2) in Volyn Region is characterized by western and north-western winds. Several 80-year-old *P. strobus* (n = 29, mean diameter at breast height (DBH = 39.6 ±2.0 cm), mean total tree height (HT = 27.9 ±0.4 m)

Fig. 10. *P. strobus*, PMLA 'Bairak' (Volyn region).

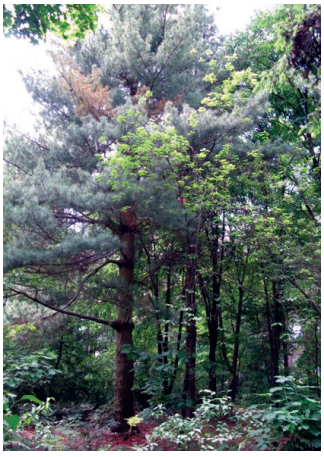

Fig. 11. *P. strobus*, CNM 'Sarnenskyi dendropark' (Rivne region).

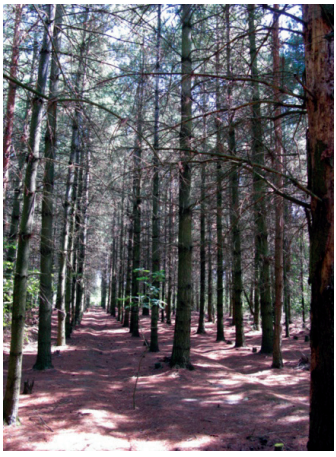

Fig. 12. *P. strobus*, BNM 'Weymouth pine' (Volyn region).

Fig. 13. *P. strobus*, Kivertsivskyi NPP 'Tsumanska Pushcha', PT 'Tsumanska Pushcha' (Volyn region).

Fig. 14. *P. strobus*, DP 'Hladkovytskyi' (Zhytomyr region).

Fig. 15. *P. strobus*, BNM 'Yuzefinska dacha' (Rivne region).

were found to grow in a stand mixed with *P. sylvestris*, *Picea abies* (L.) Karst., *Quercus robur* L., occupying an area of 0.3 ha. Trees are naturally regenerating. In the study area, the natural regeneration was absent, however, it was present 100–150 m west and north-west from the seed trees, within a 4-m wide strip running along the road. Natural regeneration is viable. Two-three-year-old seedlings are 20 cm in height (3 seedlings). Six-year-old saplings are 6 cm in diameter and 6.0 m in height. Thirteen-year-old saplings are 6.0 and 8.0 cm in diameter and 3.0 and 4.0 m in height. Fifteen and twenty-year-old trees are 8 cm and 16 cm in diameter and 7.0 m and 10.0 m in height, respectively.

Wilson and McQuilckin (1963) indicated that seed dispersal is dependent on growing conditions and a dominant wind direction. Maximum distance for seed dispersal could be up to 60 m and 200 m in closed and open stands, respectively. According to Hadincová et al. (2008), *P. strobus* seeds could be dispersed up to 752 m from the source.

In Partyzansky FME (quadrant 21, stand 6, area 2.1 ha) in a mixed stand with *P. sylvestris*, *Picea abies*, *Quercus robur* and *Alnus glutinosa* (L.) Gaertn., 80-year-old *P. strobus* (n = 36, mean diameter at breast height (DBH = 39.9 ±1.9 cm), mean total tree height (HT = 27.5 ±0,3 m) regenerate naturally (Fig. 13). Natural regener-

ation is concentrated in a 3 m^2 gap, created by a fallen tree. Ten young pines range in age from 1 to 7 years. The majority of seeds are distributed within a distance equivalent to the height of the seed tree (Horton and Bedell 1960). In pure stands, *P. strobus* forms twice as many cones as in stands where it is a co-dominant species (Wilson and McQuilckin 1963).

DP 'Hladkovytskyi' (Zhytomyr region) was created in 1957 (Hladkivske FME, quadrant 38, area 4.0 ha). A mixed stand of *P. strobus* (12 specimens) and *Juglans cinerea* L. (5 specimens) was created in the western section of the park. Seven 65-year-old *P. strobus* from that stand still exist today (n = 7, mean diameter at breast height (DBH = 51.0 ±2.6 cm), mean total tree height (HT = 23.2 ±0.9 m)). All trees are in good condition. Species can regenerate via self-seeding in the north-eastern and western sections of the park within 10–12 m from the seed trees. Thirteen viable *P. strobus* specimens were found with an age ranging between 1 and 15 years (Fig. 14).

In 1979, 41 *P. strobus* seedlings were planted in DP 'Beresnivskyi' (Rivne region). By 2017, eleven 41-year-old trees remain (n = 11, mean diameter at breast height (DBH = 43.5 ±3.0 cm), mean total tree height (HT = 19.0 ±0.6 m). A total of four trees are damaged by pathogens, two by *Cronartium ribicola* and two by *Pineus strobi*. The trees are in good and satisfactory condition. Ten 2–7-year-old *P. strobus* seedlings and saplings were located within 12–18 m from the seed trees, with three from ten succumbed to mortality.

BNM 'Yuzefinska dacha' (Rivne region) covers an area of 100 ha (Hlynnivske FME quadrants 14 (except for stands 5, 7, 8, 10, 12, 12.1, 13, 14, 33, 35, 36, 63)). The nature preserve was created to protect old oak stands (Andryenko and Sheliah-Sosonko 1983). *P. strobus* (mean diameter at breast height (DBH = 63.3 ±6.4 cm), mean total tree height (HT = 28.9 ±0.8 m)) grows here in mixed stands with *Pinus sylvestris* L., *Picea abies* (L.) Karst., *Quercus robur* L., *Alnus glutinosa* (L.) Gaertn., *Betula pendula* Roth., *Populus tremula* L., with an understory of *Corylus avellana* (L.) H.Karst., *Rhododendron luteum* Sweet., *Euonymus europaeus* L. and *Frangula alnus* Mill. The oldest *P. strobus* trees are found in Hlynnivske FME, quadrant 14, stand 47 (Fig. 15) and have the following characteristics: DBH 131, 86, and 90 cm; height 37, 31, and 30 m, respectively. In

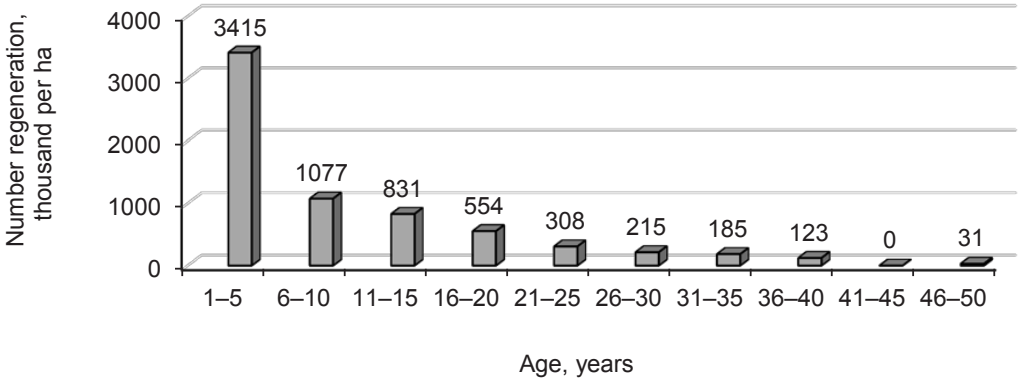

Fig. 16. Regeneration *P. strobus* in BNM 'Yuzefinska dacha', Hlynnivske FME quadrants 14.

1975, the proportion of *P. strobus* in a stand was 0.5 %. After 40 years, its distribution extended in north-eastern, eastern, and western directions (which corresponds with the prevalent wind direction). Regeneration is via self-seeding, in good condition, and of high density in quadrant 14, stands 45 (11.2 thousand per ha), 46 (4.1 thousand per ha), 47 (6.6 thousand per ha), 48 (4.0 thousand per ha), and 49 (2.2 thousand per ha), whereas in stands 21, 22, 23, 24, 25, 26 it is relatively sparse. Natural regeneration is viable ranging in age between 1 and 40 years (sometimes older) (Fig. 16) and dispersed at a distance of over 100 m from seed trees. *P. strobus* trees in these stands are in good condition.

Conclusions

Lasted for the past 200 years, the introduction of *Pinus strobus* to the forest plantations and parks in Ukrainian Polissya occurred in three stages. It became most widespread in the second half of the 20th century. *P. strobus* grows in 26 protected areas and in 19 areas (73.1 %) it is in good condition; 7 locations contain ancient trees aged 120 to 200 years. In 80% of protected areas, *P. strobus* is represented as a solitary or in groups with *Pinus sylvestris*.

In 6 protected areas (located between 51 and 52 degrees northern latitude) *P. strobus* regenerates naturally by self-seeding. Most seeds are dispersed immediately under or within 200 m from the seed tree. The count of natural regeneration varies between 162 and 11.2 thousand seedlings per ha. *P. strobus* has naturalized in stands where it is mixed with *Pinus sylvestris*, *Picea abies*, *Quercus robur*, *Alnus glutinosa*, *Betula pendula* and *Populus tremula*.

The study of *P. strobus* L. in protected areas provides information on its further use in parks and forests of Ukrainian Polissya. Although *P. strobus* is damaged by two pathogens (*Cronartium ribicola* and *P. strobi*), it is a valuable ornamental tree; therefore for creating groups, solitaries, and mixed plantings one should utilize specimens that are resistant to fungal diseases. ‘Tsumanska Pushcha’ tract Kivertsivskyi NNP ‘Tsumanska Pushcha’, BNM ‘Yuzefinska dacha’, DP ‘Hladkovytskyi’, ‘Bereznivskyi’, PMLA ‘Bairak’ can serve as a centre of genetic material for further breeding of trees resistant to fungal diseases. We propose to grant the status of a monument of nature to individual ancient trees as valuable historical, natural, scientific and cultural objects.

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