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State and productivity of mixed stands with silver birch and Scots pine in Ukrainian Polissya

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Abstract: The aim of the study was to assess the current state of silver birch (*Betula pendula* Roth.) stands in Ukrainian Polissya, as well as to identify optimal composition resulting in productive and resilient mixed birch forests. It was found that in forests managed by the State Forest Resources Agency of Ukraine, birch stands grow on an area of 352 800 ha, covering 5.6% of the total area of forests in Ukraine. Within the study region of Ukrainian Polissya, birch stands cover 294 900 ha making 12.3% of the total forest area. Naturally originated birch stands were found to dominate in the study region, with 65.4% of vegetative stands and 25.2% of those grown from seeds. However, planted stands significantly prevail in terms of growing stock as compared to natural ones. In Ukrainian Polissya, silver birch trees grow as a part of mixed pine and birch forests on 632 400 ha. Our study found that mixed pine and birch stands with 80–90% of Scots pine and 20–10% of silver birch in the composition are the most productive.

Keywords: *Betula pendula*; growing stock; *Pinus sylvestris*; stand composition; stand origin

Silver birch (*Betula pendula* Roth.) is one of the most competitive and promising tree species due to its biological and ecological properties, high resistance to pests and forest diseases, as well as high genetic variability and phenotypic plasticity. It is able to adapt well to global climate change and integrate into various mixed stands within its natural range (Dubois et al. 2020; Oksanen 2021). The range of silver birch covers almost the entire territory of Europe. It reaches the central part of Sweden in the north, and the northern part of Greece and the southern part of Italy in the south. Silver birch stands spread from Northern Ireland to Central Siberia (Figure 1).

Being a fast-growing species with low demands on soil fertility, silver birch can well regenerate naturally by seeding and sprouting. It is promising in the increased use of renewable energy sources

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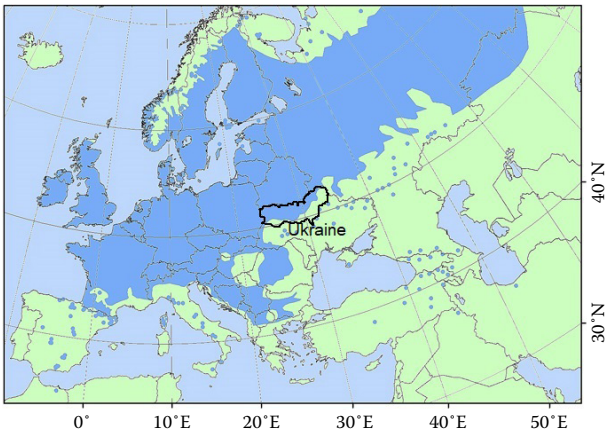

Figure 1. Distribution of silver birch stands (EUFORGEN 2009) including in Ukraine (outlined by a black line)

and in changing climate (Beck et al. 2016; Konôpka et al. 2020). The species is considered indispensable due to its rapid growth, intensive synthesis of organic matter, oxygen production and high carbon concentration. Silver birch, along with such species as common alder (*Alnus glutinosa* L.) and small-leaved lime (*Tilia cordata* Mill.), has the highest carbon-absorbing capacity, which is 60–100 t·ha^{-1} (Moroz et al. 2016). Also, the presence of silver birch in stands contributes to forest biodiversity and increases their productivity and resilience to adverse environmental factors (Dubois et al. 2020; Huuskonen et al. 2021). The presence of silver birch in pine stands reduces soil acidity and increases the soil saturation with metabolic calcium and magnesium (up to 30%) and limits the amount of mobile aluminium in soil composition (Gonchar et al. 2018).

Silver birch and downy birch (*Betula pubescens* Ehrh.) occur in European forests and particularly in the northern part of Ukraine (in Polissya zone), as well as Western Siberia. *B. pubescens* is most common in the north and east of Europe, while *B. pendula* is most prevalent in its southern part (Niemistö et al. 2008; Hynynen et al. 2010; Beck et al. 2016).

Silver birch prefers fresh well-drained sandy or loamy soil, while downy birch grows well on moist, damp and wet soils. Among birch species, silver birch is prevalent in forests within the Ukrainian forest-steppe zone. Downy birch is very rare in this area. Silver birch is one of the most light-loving tree species, which grows in mixed forests, primarily as an additional (associated) species in pine stands, less often in oak ones. Although it is a very common tree species, it does not form large pure stands. The birch tree lifespan is 90–120 years (Gordiyenko, Gordiyenko 2005).

Silver birch trees begin to produce seeds very early; they have a high regenerative capacity and remain fruiting until aging. Birch is one of the pioneer species to grow on burned areas, felling sites and non-forest lands (Hynynen et al. 2010). Birch trees form deep roots contributing to significant wind resistance (Gonchar et al. 2018). Silver birch has a high phytoncide activity and ornamental properties; therefore, it is used in landscaping, forest reclamation and protective afforestation (Gordiyenko, Gordiyenko 2005; Beck et al. 2016).

Silver birch wood can be polished well and is a valuable building material. The furniture industry uses birch wood for plywood, parquet, turnery and joinery products (Niemistö et al. 2008; Dubois et al. 2020). Birch is also a melliferous plant. Its pollen is the most valuable in chemical composition for bee nutrition (Gordiyenko, Gordiyenko 2005). Birch buds and bark are used in medicine (Rastogi et al. 2015).

In Ukraine, the ever-growing demand for energy resources is met mainly by fossil fuels. The volume of energy production from biomass is quite low and is only 0.7–0.8% of total energy consumption in the country. However, like in Sweden, the wood biomass energy share reached about 20% in 2000. Birch firewood has a high calorific value and is an ecologically clean fuel, the consumption of which reduces harmful emissions into the atmosphere, which, in turn, inhibits the processes of global climate change (Matushevich et al. 2009). Therefore, the use of birch wood for energy production in Ukraine is a very topical issue, the solution of which will significantly reduce the dependence on non-renewable fossil fuels.

An optimal composition of mixed silver birch stands will allow increasing their productivity and building forest ecosystem resilience to adverse environmental factors. This will enhance the efficiency of forest site capacity. The management of mixed silver birch forests requires deeper study of their current state and distribution within individual regions as well as the investigation of biological, ecological, forestry, health-improving, aesthetic and other values of the species.

The aim of the study was to assess the current state of silver birch forests in Ukrainian Polissya and to identify the optimal composition to grow productive and resilient mixed silver birch stands.

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MATERIAL AND METHODS

We studied mixed Scots pine and silver birch stands with up to 50% of birch in the composition and pure Scots pine and silver birch stands of different origin within Ukrainian Polissya on the area of 1 747 310 ha comprising 73% of the total forest area in the region.

The distribution and current state of birch stands were investigated in European forests, including Ukraine, based on the analysis of reference materials on the current state of Ukrainian forests

Table 1. Mensuration characteristics of planted pure pine and mixed pine and birch stands

Sample plot No.	Composition (%)	Age (years)	Stand density (trees·ha^{-1})	Average diameter (cm)		Average height (m)		Total stand basal area (m^2·ha^{-1})	Growing stock (m^3·ha^{-1})
				min–max	average ± SD	min–max	average ± SD		
1	100 Sp	40	807	7.7–32.3	19.6 ± 0.98	14.3–22.1	18.2 ± 0.91	24.34	210
	90 Sp		729	7.8–32.5	19.7 ± 0.94	14.2–22.2	18.3 ± 0.92	22.21	193
2	10 Sb	40	88	7.3–30.9	18.7 ± 0.94	14.1–21.7	17.9 ± 0.90	2.42	21
	total		817	–	–	–	–	24.63	214
	82 Sp		617	8.0–33.7	20.4 ± 1.02	14.7–22.6	18.7 ± 0.94	20.16	179
3	18 Sb	40	160	7.4–31.4	19.0 ± 0.95	14.5–22.3	18.3 ± 0.92	4.53	39
	total		777	–	–	–	–	24.69	218
	71 Sp		494	7.6–32.3	19.6 ± 0.98	14.4–22.2	18.3 ± 0.92	14.90	129
4	29 Sb	40	232	7.3–30.7	18.6 ± 0.93	14.1–21.7	17.9 ± 0.90	6.30	53
	total		726	–	–	–	–	21.20	182
	61 Sp		444	7.5–31.7	19.2 ± 0.96	14.2–21.9	18.1 ± 0.91	12.85	110
5	39 Sb	40	307	7.4–30.5	18.5 ± 0.93	14.0–21.5	17.8 ± 0.89	8.25	70
	total		751	–	–	–	–	21.10	180
	52 Sp		382	7.5–31.4	19.1 ± 0.96	14.1–21.8	18.0 ± 0.90	10.94	93
6	48 Sb	40	384	7.2–30.6	18.4 ± 0.92	13.8–21.5	17.7 ± 0.89	10.21	86
	total		766	–	–	–	–	21.15	179
7	100 Sp	60	578	10.7–43.2	26.0 ± 1.30	18.8–27.2	22.7 ± 1.14	30.67	321
	88 Sp		515	10.9–43.7	26.3 ± 1.32	18.9–27.3	22.9 ± 1.15	27.96	295
8	12 Sb	60	86	10.0–40.3	24.1 ± 1.21	17.7–25.6	21.4 ± 1.07	3.92	39
	total		601	–	–	–	–	31.88	334
	82 Sp		482	11.0–44.4	26.6 ± 1.33	19.2–27.8	23.2 ± 1.16	26.77	286
9	18 Sb	60	128	10.1–40.9	24.5 ± 1.23	18.0–26.1	21.8 ± 1.09	6.03	61
	total		610	–	–	–	–	32.80	347
	70 Sp		403	10.6–42.8	25.6 ± 1.28	18.4–26.5	22.3 ± 1.12	20.73	213
10	30 Sb	60	203	10.3–40.3	24.2 ± 1.21	17.8–25.5	21.5 ± 1.08	9.33	92
	total		606	–	–	–	–	30.06	305
	59 Sp		332	10.5–42.4	25.4 ± 1.27	18.3–26.4	22.1 ± 1.11	16.81	171
11	41 Sb	61	271	9.9–39.9	23.9 ± 1.20	17.6–25.3	21.3 ± 1.07	12.15	119
	total		603	–	–	–	–	28.96	290
	50 Sp		279	10.4–42.1	25.2 ± 1.26	18.1–26.2	21.9 ± 1.10	13.91	140
12	50 Sb	59	329	9.8–39.6	23.7 ± 1.19	17.5–25.4	21.2 ± 1.06	14.51	142
	total		608	–	–	–	–	28.42	282

Sp – Scots pine (*Pinus sylvestris* L.); Sb – silver birch (*Betula pendula* Roth.)

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and generalization of European research results. We studied silver birch stands in five Ukrainian administrative regions with the largest birch forest areas, namely Volyn, Rivne, Zhytomyr, Kyiv, and Chernihiv regions.

The research involved the analysis of forest surveying materials (Ukrainian forest fund database) containing qualitative and quantitative characteristics of each forest plot, including mensuration indicators of stands such as species composition, origin, age, diameter, height, type of forest site conditions, etc. Mensuration indicators of the stands were defined by grouping plots by age.

The latest forest surveying data served as a basis for corresponding calculations. We analysed a total of 216 482 subcompartments of pine and birch stands, including 34 354 subcompartments in Volyn region, 59 943 in Rivne region, 67 265 in Zhytomyr region, 22 996 in Kyiv region and 22 567 in Chernihiv region.

In addition, we laid out 36 sample plots in Zhytomyr region in planted 40- and 60-year-old pure pine stands and mixed pine and birch stands with different proportions of birch in the composition: 24 sample plots in Slovechne State Forest Enterprise and 12 sample plots in Radomyshl State Forest and Hunting Enterprise. The sample plots were established in the predominant forest type – fresh oak-pine forest. Table 1 shows the averaged mensuration indicators for groups of sample plots with the same stand composition.

The sizes of the sample plots were determined based on 200 trees at least on a plot. Species were recorded by listing trees by diameter. The tree diameters were measured with a calliper at breast height (1.3 m above ground) to the nearest 0.1 cm. The basal area of the tree stand ($m^2 \cdot ha^{-1}$) being a measure of tree density on a per unit area basis was determined as the sum of the cross-sectional surface areas of each live tree in the stand per unit area (ha). The average diameter was determined by dividing the total basal area of each species by the corresponding total number of trees. Based on the obtained basal area of the average tree, the average diameters for the studied species were determined.

The tree heights were measured in the field conditions with a Haglöf hypsometer (Haglöf Sweden AB, Sweden). The average height of the species was determined graphically by the average diameter of the trees. The heights of 25–30 trees were measured to construct the height curve.

Growing stock was defined as the volume of living trees per unit area. The volume V (m^3) was calculated as the product of the total stand basal area $G_{1.3}$ (m^2) by the stand height H (m) and the form factor f according to Equation (1) (Hrom 2007):

$$V = G_{1.3} \times H \times f \quad (1)$$

Stand density was determined as the number of trees per unit area (Hrom 2007).

Statistical analyses. Normality tests, summary statistics, one-way analysis of variance (ANOVA), Tukey HSD test, Mann-Whitney U test with a significance level of $P < 0.05$ were performed for raw data.

The Box-Cox transformation was used to transform the data to the normal distribution, stabilize group variances and meet the homoscedasticity condition (Hammer et al. 2001). After data transformation, the F-test ANOVA was used to find statistically significant differences between treatments (Hammer et al. 2001).

RESULTS

Birch forests cover 352 800 ha in forests managed by the State Forest Resources Agency of Ukraine, which is 5.6% of the total forest area (Table 2). The largest areas of forests where silver birch is predominant are concentrated in the northern regions of Ukraine, belonging to the Polissya zone (zone of mixed forests in Ukraine). These are Zhytomyr (104 850 ha of birch forests), Rivne (80 550 ha), Volyn (49 550 ha), Chernihiv (36 750 ha), and Kyiv (23 210 ha) regions, and they became the subject of the study. Zaporizhzhia (140 ha), Odesa (70 ha), Mykolaiv (30 ha), and Dnipropetrovsk (30 ha) regions and the Autonomous Republic of Crimea (100 ha) have the smallest areas. There are no birch stands in Kherson region.

Silver birch is the third most common species within the study region (in five administrative regions). The total forest area in Ukrainian Polissya is 2 391 930 ha, the largest part of which are pine stands – 60.7% (1 452 400 ha). Oak stands cover 342 920 ha (14.3%), birch stands occupy 294 910 ha (12.3%), and alder stands 192 530 ha (8.0%). Stands of other species cover 109 170 ha (4.7%) (Table 3).

The largest proportion of birch stands was recorded in Zhytomyr region (15.9% of the region's forest area), while the smallest one was registered in Kyiv region (6.5%). In Rivne region, the birch

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Table 2. The current state of birch stands in Ukrainian forests

Administrative region	Total forest area (ha)	Including birch stands	
		ha	% of the total area
Autonomous Republic of Crimea	227 700	100	< 0.1
Cherkasy region	255 400	2 270	0.9
Chernihiv region	355 500	36 750	10.3
Chernivtsi region	157 300	840	0.5
Dnipropetrovsk region	65 700	30	< 0.1
Donetsk region	92 500	750	0.8
Ivano-Frankivsk region	425 800	4 980	1.2
Kharkiv region	282 300	2 730	1.0
Kherson region	77 300	–	–
Khmelnytsky region	167 400	9 040	5.4
Kyiv region	355 100	23 210	6.5
Kirovohrad region	103 500	80	0.1
Luhansk region	228 200	4 480	2.0
Lviv region	428 200	9 080	2.1
Mykolayiv region	37 400	30	0.1
Odessa region	90 200	70	0.1
Poltava region	157 300	3 670	2.3
Rivne region	584 200	80 550	13.8
Sumy region	255 600	14 110	5.5
Ternopil region	143 600	2 370	1.7
Transcarpathian region	461 200	1 550	0.3
Vinnytsya region	199 700	1 570	0.8
Volyn region	436 800	49 550	11.3
Zaporizhzhya region	34 000	140	0.4
Zhytomyr region	660 300	104 850	15.9
Five target regions together, having the largest areas of birch stands (Volyn, Rivne, Zhytomyr, Kyiv, and Chernihiv regions)	2 391 930	294 910	12.3
Total Ukraine	6 282 200	352 800	5.6

stands comprise 13.8% of the region's forest area. The proportion is 11.3% in Volyn region and 10.3% in Chernihiv region.

Within the large area in Ukrainian Polissya, silver birch occurs as additional (associated) species in pine stands, and its proportion in mixed pine and birch stands varies from 10% to 50%. In total, silver birch trees grow as a component of pine stands on the area of 632 430 ha (43.5%) (Table 4).

Table 3. Distribution of forest area by predominant species in administrative regions within Ukrainian Polissya (ha)

Administrative region	Pine	Oak	Birch	Alder	Others
Chernihiv region	215 230	54 560	36 750	20 690	28 310
Kyiv region	218 980	64 380	23 210	19 700	28 840
Rivne region	381 550	51 920	80 550	53 810	16 350
Volyn region	248 690	56 610	49 550	67 580	14 410
Zhytomyr region	387 950	115 450	104 850	30 750	21 260
Total	1 452 400	342 920	294 910	192 530	109 170

Stands of vegetative and natural seed origin predominate among all birch stands: their proportions are 65.4 and 25.2% of the total area (294 910 ha), respectively. Artificially planted birch stands cover 9.4% of the total area. The largest part of birch stands of vegetative origin is concentrated in Rivne region (69.6%), and the smallest one, in Chernihiv region (58.0%). The largest areas of birch stands of natural seed origin were found in Volyn (33.4%) and Chernihiv (11.1%) regions, and the largest areas of planted birch stands were recorded in Chernihiv (30.9%) and Rivne (2.7%) regions (Table 5). The results show a decrease in the proportion of natural stands when moving from west (Rivne and Volyn regions) to east (Kyiv and Chernihiv regions), which is associated with decreasing rainfall and, accordingly, harsher environment for natural seed regeneration and further growth of birch stands.

Growing stocks of mixed pine and birch stands with various proportions of birch trees in the com-

Table 4. Distribution of pine and mixed pine and birch stands by administrative regions in Ukrainian Polissya

Administrative region	Area of pine stands (ha)	Area of mixed pine and birch stands (ha)	Proportion of mixed pine and birch stands (%)
Chernihiv region	215 230	82 530	38.3
Kyiv region	218 980	62 650	28.6
Rivne region	381 550	178 290	46.7
Volyn region	248 690	102 810	41.3
Zhytomyr region	387 950	206 150	53.1
Total	1 452 400	632 430	43.5

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Table 5. Distribution of the area of silver birch stands by origin in administrative regions within Ukrainian Polissya

Administrative region	Origin of birch stands						Total silver birch stands	
	Vegetative		Naturally seeded		Artificially planted			
	ha	%	ha	%	ha	%	ha	%
Chernihiv region	21 330	58.0	4 080	11.1	11 340	30.9	36 750	100
Kyiv region	14 190	61.2	6 670	28.7	2 350	10.1	23 210	
Rivne region	56 080	69.6	22 290	27.7	2 180	2.7	80 550	
Volyn region	30 210	61.0	16 580	33.4	2 760	5.6	49 550	
Zhytomyr region	71 110	67.8	24 580	23.5	9 160	8.7	104 850	
Total	192 920	65.4	74 200	25.2	27 790	9.4	294 910	

Table 6. Growing stocks of 40-year-old stands depending on the origin and silver birch proportion in the composition ($m^3 \cdot ha^{-1}$)

Stand origin	Silver birch proportion in stand (%)								
	10–20	30	40	50	60	70	80	90	100
Vegetative	210	183	181	173	164	159	155	148	143
Naturally seeded	203	171	168	164	151	148	137	132	135
Artificially planted	236	186	185	187	181	184	179	181	175
F	3.334	0.306	2.044	2.434	1.741	1.344	2.598	2.568	1.744
P	0.234	0.744	0.181	0.138	0.225	0.308	0.125	0.127	0.226

position do not differ statistically depending on the origin (Table 6). However, the growing stocks of 40-year-old mixed pine and birch stands differ significantly depending on the proportions of birch trees in their composition (Figure 2).

Our study showed that planted mixed pine and birch stands with 80–90% of Scots pine and 20–10% of silver birch in the composition are more productive than pure pine stands (100% Scots pine) and mixed pine and birch stands with 50–70% of Scots pine and 50–30% of silver birch (Figure 3). For example, the difference in growing stocks between the mixed stand comprising 80–90% of Scots pine and 20–10% of silver birch, on the one hand, and pure Scots pine stand, on the other hand, is in the range of 0.9–4.6%

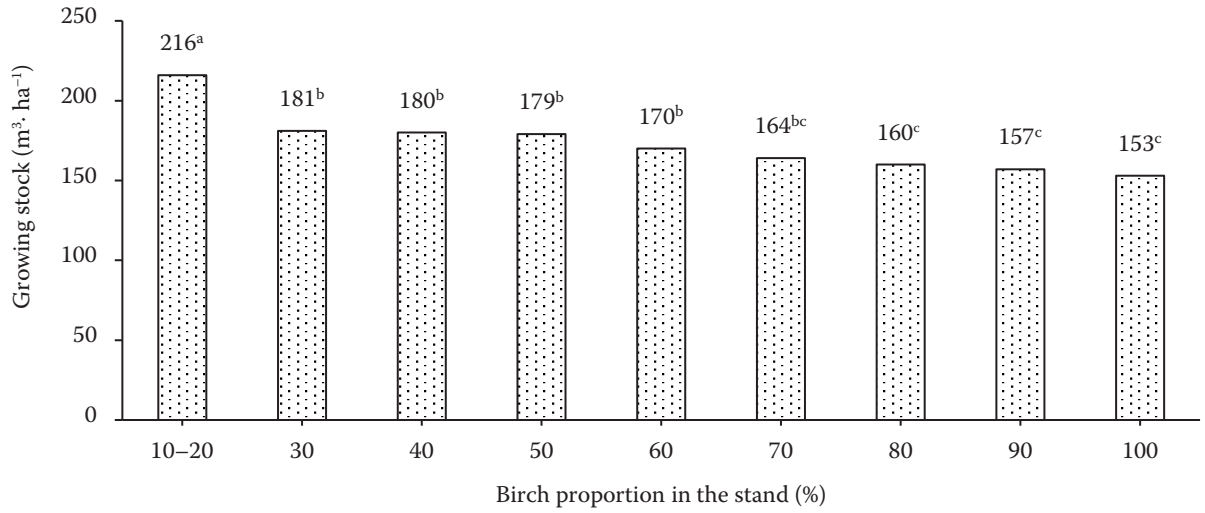

Figure 2. Growing stocks of 40-year-old mixed pine and birch stands depending on the silver birch proportion in the composition ($F = 9.499$, $P < 0.05$); different letters indicate significant difference between treatments ($P < 0.05$, Tukey's pairwise ANOVA)

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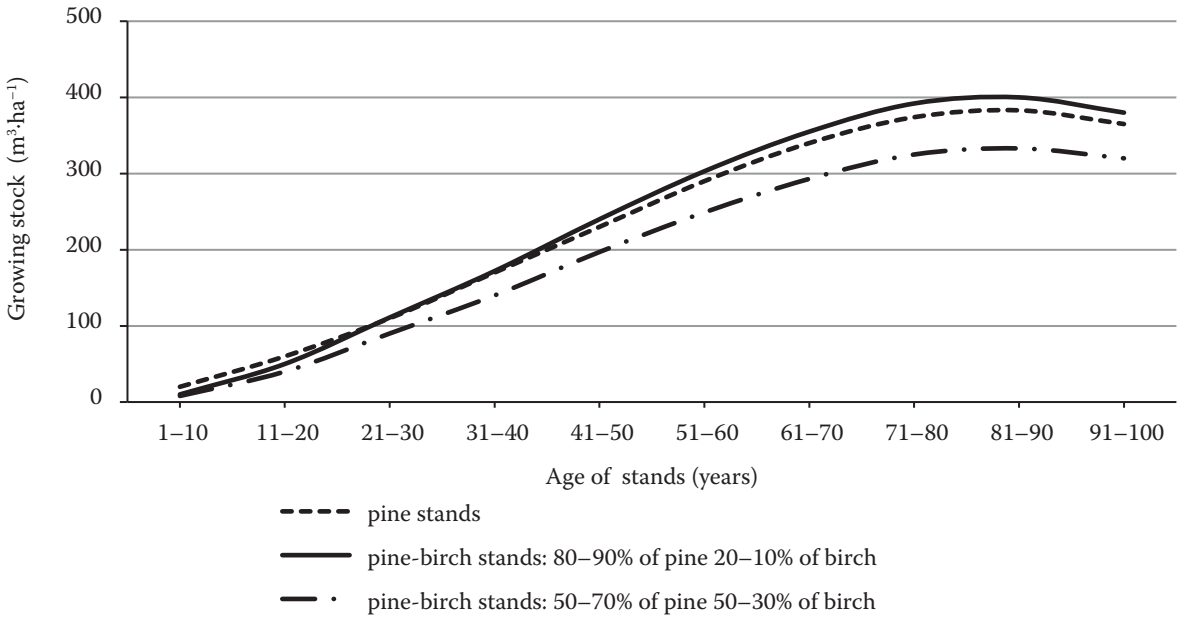

Figure 3. Growing stocks of planted mixed pine and birch and pure pine stands in Ukrainian Polissya

(1–18 $m^3 \cdot ha^{-1}$). The stock difference increases to 15.8–20.0% (10–67 $m^3 \cdot ha^{-1}$) between stands comprising 80–90% of Scots pine and 20–10% of silver birch, on the one hand, and 50–70% of Scots pine and 50–30% of silver birch, on the other hand. This pattern is typical of the stands from 20 years of age to the age of maturity (the age of final harvest). At a younger age (up to 20 years), the maximum growing stock is accumulated by pure pine stands.

A comparison of the growing stocks of planted stands with different proportions of silver birch in their composition on the established sample plots confirms the patterns revealed by the analysis of the forest surveying databases. The most pro-

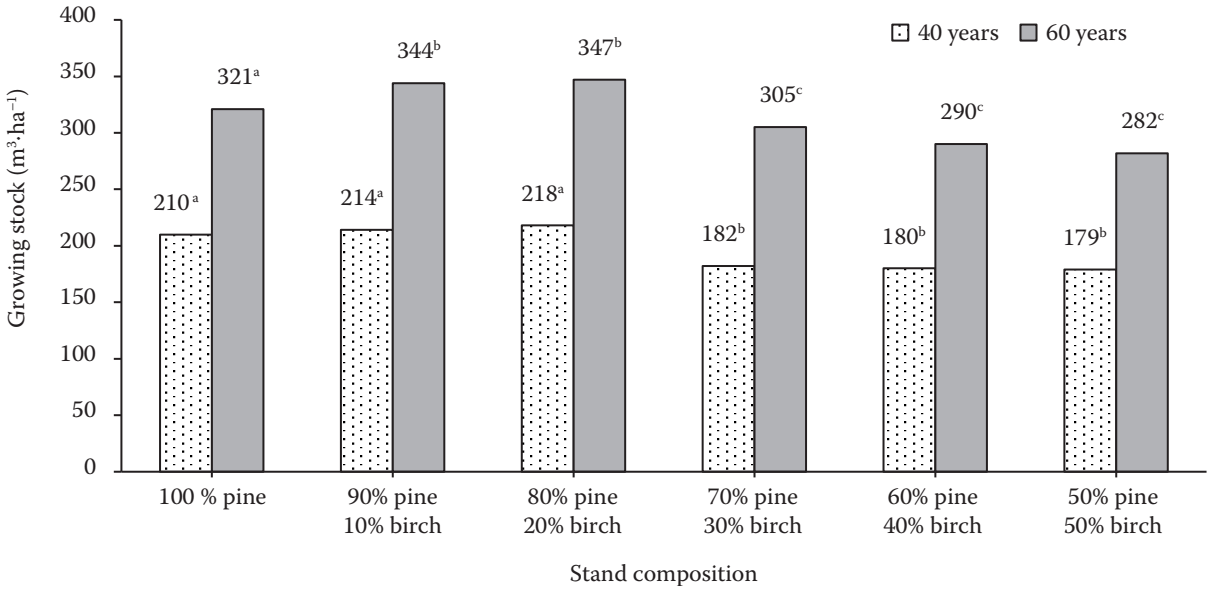

Figure 4. Growing stocks of planted pure pine and mixed pine and birch stands; different letters indicate significant difference between treatments ($P < 0.05$, Tukey's pairwise ANOVA)

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ductive are stands with 80% of Scots pine and 20% of silver birch in the composition. With an increase in the birch proportion to 30% and more, the growing stock decreases, compared to both the stand with 80% Scots pine and 20% silver birch and the stand with 100% of Scots pine (Figure 4).

Stands consisting of 80–90% of Scots pine and 20–10% of silver birch should be formed until the age of maturity through appropriate interventions when tending mixed pine and birch forests in Ukrainian Polissya. The addition of birch to the composition of mixed pine stands accelerates the litter mineralization, increases the supply of nutrients to the soil and promotes the pine growth, which leads to an increase in the productivity of stands and resistance to diseases, pests and adverse environmental factors.

DISCUSSION

Silver birch is not among the main forest-forming species in Ukraine; it is an associated one. The area of birch forests in the last half-century has increased insignificantly. For example, the area of birch stands in Ukraine was 266 500 ha in 1946, 284 000 ha in 1978 and 329 300 ha in 2002 (Krasnov, Kucherenko 2008). According to Meshkova and Koshelyaeva (2015), as of 2011, the area of birch stands was 357 100 ha. Our study showed that the birch forest area decreased slightly during 2011–2016, by 4 300 ha, resulting in 352 800 ha. The proportion of birch stands in the total forest area gradually decreased from 5.9% in 1940 to 4.7% in 1988. The percentage of birch stands in the total forest area was 5.7% in 2011 (Meshkova, Koshelyaeva 2015) and 5.6% in 2016 (according to our study).

The analysis of foreign literature sources shows that in Northern Europe and the Baltics, birch is one of the commercially promising species. The proportion of birch stands in the total forest area ranges from 11% (Sweden) to 16% (Finland and Norway) in the Nordic countries and from 17% (Lithuania) to 28% (Latvia) in the Baltic States (Hynynen et al. 2010). The reference data on Ukrainian forests showed that stands with *B. pendula* in compositions account for 5.6% of the total forest area; by natural zones, the proportion is 10.8% in the forest zone (Polissya) and 2.0% in forest-steppe (Meshkova, Koshelyaeva 2015). According to our research, as of 2016, silver birch stands cover the third largest area in the forests of Ukrainian Polissya (12.3%) after *Pinus sylvestris* L. (60.7%) and *Quercus robur* L. (14.3%). In Polish forestry, silver birch is one of the essential forest-forming deciduous species for the woodworking industry; the birch stands occupy 7.3% of the total forest area (GUS 2016). According to Lachowicz et al. (2016), silver birch ranks third after pine and spruce by volumes of harvested and sold wood and ranks first among deciduous species, followed by beech and oak.

A study in Western Polissya (Gonchar et al. 2018) in pure pine and mixed pine and birch stands at fresh relatively fertile sites showed that pure pine stands prevail in stock over mixed ones under 50 years of age. This can be explained by the lack of competition with deciduous trees. However, pure pine stands of older age (over 50 years) were lower in growing stock than mixed ones due to the presence of deciduous trees in the mixed stands. The latter have a positive effect on the growth and productivity of stands due to replenishing the soil with humic substances with aging. The presence of silver birch in pine stands in relatively fertile conditions was found to contribute to the Scots pine growth increase resulting in the improved forest litter composition and increased humus content in the soil (Gonchar et al. 2018). For example, within the same subcompartment in the same forest type, 47-year-old stands were formed with different silver birch proportions. Here, the average annual radial growth of Scots pine was 2.62 mm in Section 1 with 100% of Scots pine in the composition, while it was 2.75 mm in Section 2 with 90% of Scots pine and 10% of silver birch, and 2.94 mm in Section 3 with 80% of Scots pine and 20% of silver birch (Gonchar et al. 2018).

It has been proved (Felton et al. 2010, 2016; Debryniuk, Myklush 2021; Huuskonen et al. 2021) that adding 20–25% of birch in the composition of Scots pine stands improves soil properties and recreational value as well as increases biodiversity, productivity, and resistance to pests and pathogens. In particular, planted mixed pine and birch stands are more resistant to root rot (*Heterobasidion annosum* /Fr./ Bref.) and fire damage (Lygis et al. 2004; Gonchar et al. 2018; Luk'yanets et al. 2019; Tkach et al. 2020).

In Chernihiv Polissya, the growing stock of mixed pine and birch stands with 10–20% silver birch is 10–35% higher than that of pure pine stands (Bilous et al. 2012). Adding birch in stands activates forest litter decomposition, promotes nutrient ac-

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cumulation in the soil, and, accordingly, improves soil fertility (Hansson et al. 2011; Schua et al. 2015). The study of Bielak et al. (2014) in the northeastern part of Poland showed that the growing stock of mixed pine and birch forests was on average 41% larger than that of pure pine forests.

It is impractical to grow pure pine forests due to their lower resistance to climate change and, as a result, their weakening and susceptibility to pest damage, particularly in the conditions of Polissya (Meshkova, Koshelyaeva 2015; Gonchar et al. 2018; Tkach et al. 2020). Our investigation confirms the results of domestic and European studies regarding the benefit of adding 10–20% of silver birch to pine stands. According to our data, the stands with such composition are superior in mensuration characteristics (tree diameter, height, and growing stock) to pure pine stands and mixed pine and birch stands with a greater proportion of birch in the composition. This will have a positive effect on increasing the overall productivity and resilience of pine and birch forests, as well as on enriching the biodiversity in the study region of Ukrainian Polissya.

CONCLUSION

Birch stands in Ukrainian forests grow on 5.6% of the total forest area. Within the study region (Ukrainian Polissya), birch stands cover 294 900 ha making 12.3% of the total forest area. In the region, silver birch grows as a part of mixed pine stands, ranging from 10% to 50% in the stand composition.

Birch stands of natural origin predominate in the total birch area in Ukrainian Polissya, indicating favourable conditions for their natural regeneration.

It was found that starting from the age of 20 years, mixed pine and birch stands with 80–90% of Scots pine and 20–10% of silver birch in the composition are more productive than pure pine stands (100% Scots pine) and mixed pine and birch stands consisting of 50–70% of Scots pine and 50–30% of silver birch. This pattern must be taken into account when growing forests in Ukrainian Polissya. In particular, the stand composition of 80–90% of Scots pine and 20–10% of silver birch should be achieved by the age of maturity using management interventions such as forming and sanitation forest felling. This will contribute to the better utilisation of forest site capacity of forest lands and allow increasing the resilience of such stands and their ecological importance.

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