JOURNAL OF FOREST SCIENCE, *64*, 2018 (9): 394–401

https://doi.org/10.17221/17/2018-JFS

Results of silvicultural treatments conducted in the beech forests of Azerbaijan

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Abstract

Yakhyaev A.B., Farzaliyev V.S., Seyfullayev F.S. (2018): Results of silvicultural treatments conducted in the beech forests of Azerbaijan. J. For. Sci., 64: 394–401.

In order to increase productivity, sustainability and protection of the 5-year-old beech plantations of the Greater Caucasus northeastern slopes, 10 plots were established in large gaps and glades of four quarters of the Quba and Qusar forestry. Silvicultural treatments which were realized based on sowing and planting methods or applying both of them in a combined form were carried in this region. The sowing operations were carried out on sites of 1 × 1 m and 1 × 2 m in size and using an amount of 120–300 individuals per hectare, located across the slope. The best results in sowing sites in terms of the number of emerging beech seedlings and their survival were obtained in fresh herbage, and the worst in moist herbage forest growing conditions. In the stands created by planting, in fresh herbage forest growing conditions the best results were obtained in the middle mountain belt and satisfactory in the high mountain belt. Cultivated plants 6–8 years after sowing (planting) were transferred to a forest covered area. During this time, in the plants were carried out: with sowing – 10 treatments, with planting – 5 agrotechnical treatments.

Keywords: beech stands; reforestation; plants; sowing; seedlings; forest growing conditions

Beech (*Fagus orientalis* Linnaeus) forests in the northern regions of Azerbaijan are distributed along the northeastern slopes of the Greater Caucasus (700–2,000 m a.s.l.), where they cover about 36% of the forest area (Prilipko 1952). Random cuts in the past, recreational pressure, transfer of wooded lands into farmlands, uncontrolled grazing and forest fires have exerted a significant impact on the beech forest located on the northeastern slopes of the Greater Caucasus. As a result, the productivity and sustainability of plantations decreased with the formation of low-density beech stands (0.2–0.5) in forest areas, and numerous large gaps and glades of different configurations and dimensions were formed. On the other hand, the northeastern slopes of the Greater Caucasus, marked by high steepness, a strongly dissected ravine-beam network and a large amount of annual precipitation (700–1,200 mm), cause intensive erosion processes, which are intensified on treeless plots (Yakhyaev 2011; Yakhyaev, Farzaliev 2014; Yakhyaev et al. 2015).

In the beech forests of this region, spread on the mountain slopes of 11–25°, the beech plantations were created in small sites by a terrace method by planting and proportion of 20% mountain maple in the plantations, which were accompanied by large material and labour costs. On the other hand, this work did not take into account natural factors and technological parameters (Asadov 2008). As a result, the rates of survival and preservation of cultures were low.

The purpose of the present work is the restoration of local beech forests in large gaps and glades by cre-

ating stands of this species without preparation of terraces and partial tillage in mountain conditions.

MATERIAL AND METHODS

The studies were carried out in non-renewing large gaps and glades of beech forests of Qusar and Quba forest districts during 2008–2014. Plots were established on the slopes of mountains at the heights of 935–1,486 m a.s.l., with steepness of 11 to 35°, which are concentrated on the northwestern and northeastern exposures. The climate of the research area is moderately continental and humid. In the composition of the surrounding plantations or groups of trees of selected sites, mainly participated beech (3–10 units), hornbeam, maple whose average height varied within 4–14 m, and density 0.2 to 0.3 units. Here forest growing conditions are classified into fresh herbage, moist herbage and fresh fescue types of forest conditions. Soils are brown (partly shallow) of medium thickness (Table 1).

Establishing a plantation by sowing method. In large gaps of beech forests with a width of up to 30 m, the silvicultural work was carried out by sowing. Methodology was carried out as described in Paramonov (1970). For this purpose, in seven plots (P1–2, P5–9) with an area of 0.076–0.149 ha, in a staggered way across the slope, sites were established: on slopes with steepness of 15° and size of 1 × 2 m, 120–160 individuals per hectare; with steepness more than 15° and size of 1 × 1 m, 250 to 300 individuals per hectare.

We used a simple method – under the shovel, partial preparation of the soil of plots. The choice of this method is mainly dictated by the characteristic relief of this region, danger of the intensification of erosion processes in treeless areas with soil treatment, as well as the poor availability of appropriate equipment on farms and economic consideration (Tishkevich 1976; Oniskiv 1992; Badalov 2012; Kurbanov et al. 2016). The soils of the sites were treated for a crop year, in autumn until the seeds fell as follows: grass cover and litter were removed from the surface of the sites, the soils were loosened to a depth of 6–7 cm and the fine structure of the litter was mixed. Besides this – in establishing of the plantations, during observations, when defining of the number and size of the plants and as well as when discussing results, the results and suggestions of Mirzoyev (1967), Maltsev (1977) and Amirov (2004) were considered.

On the sites of the plots located at a distance of up to 15 m from seed beech trees, it was sown naturally – with a natural fall of seeds, and at a distance

Table 1. Planting site characteristics

Plot No.	District name	District code, area (ha)	Plot size (m)	Altitude (m a.s.l.)	Slope steepness (°)	Exposition	Thin forest composition	Forest type	Density	Forest edge height (m)	Forest regeneration method	Area (ha)	No. of sites	Strips size (m)	Strips No.
1	Quba	41/2, 12	18 × 58	1,384	24	NW	7Be2Hb1Mp	fresh herbage	0.3	13	natural sowing	0.105	32	–	–
2		41/9, 4	24 × 62	1,265	11	NE	10Be + Hb	moist herbage	0.2	4	artificial sowing	0.149	57	–	–
3		41/21, 1.1	58 × 72	1,486	22	NW	7Be2Mp1Ap –6Be3Hb1Mp	fresh herbage	–	–	planting	0.418	–	8 × 30	8
4		43/16, 2.3	54 × 64	1,113	14	NW	6Be3Hb1Mp –8Be2Hb	fresh herbage	–	–	planting	0.346	–	8 × 24	6
5	Qusar	24/2, 15	26 × 40	1,216	19	NE	6Hb3Be1Mp	fresh fescue	0.3	8	natural/artificial sowing	0.104	10/22	–	–
6		24/6, 3.5	21 × 36	935	15	NE	5Be5Hb	fresh fescue	0.3	13	natural sowing	0.076	12	–	–
7		24/11, 2.5	25 × 41	1,144	22	NE	10Be + Hb	fresh fescue	0.3	11	natural sowing	0.103	31	–	–
8		24/8, 7.0	30 × 46	1,052	24	NE	10Be	fresh herbage	0.2	8	natural sowing	0.138	42	–	–
9		25/26, 1.2	17 × 51	1,241	33	NE	10Be	fresh herbage	0.3	14	artificial sowing	0.087	26	–	–
10		25/27, 1.6	52 × 81	1,086	35	NE	10Be – 6Be4Hb	fresh herbage	–	–	natural sowing	0.421	–	8 × 36	6

Be – beech, Hb – hornbeam, Mp – maple, Ap – apple

of more than 15 m – in an artificial way, i.e. beech seeds prepared in farms. Totally 111 natural and 121 artificial sites were sown. In the first decade of December, sites with natural seeding were covered with a thin layer (2–3 cm) of fine-structured litter and areas with artificial sowing, immediately after the sowing operations were completed. Further, to protect the seeds from animals, as well as from trampling, the sown areas were fenced completely or in groups.

Establishing a plantation by planting method. On three plots (P3–4, P10) of beech plantations, glades without regeneration, width of more than 30 m, beech stands were created by planting saplings. For this purpose were allocated 20 strips with the size of 6–8 × 24–36 m and located across the slope with 4–6 m breaks. The distance between the strips was 8–10 m.

Planting on the strips was done in 5–6 main rows and 4–5 in-between rows (at the angles of the formed squares and at the intersection points of the diagonals) with the placement of saplings in the main rows at a distance of 1.5–2.0 m, in the aisles 1.0–1.4 m (3,389–5,667 individuals per hectare). The layout of plantations is shown in Fig. 1.

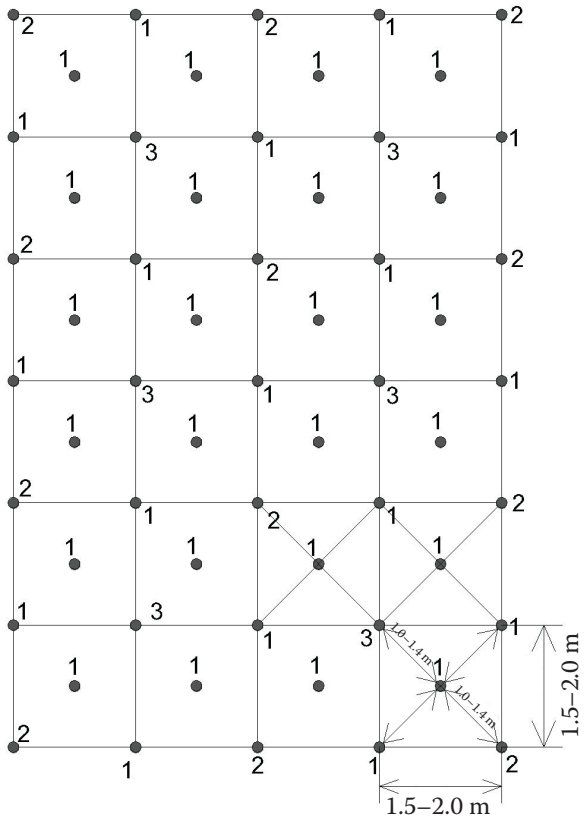

Fig. 1. The scheme of plantation and sequence of woody plants with the target species

1 – Oriental beech, 2 – European hornbeam (Trautvetter's maple, Caucasian pine), 3 – European ash

The soils of the strips were prepared in a simple and accessible way – under the shovel, without the preparation of terraces on these plots. Forest plantations began with the cleaning of the entire area of selected plots from shrubs, while keeping only herbaceous plants, projective coverage of which was 0.3–0.8. Planting places of saplings were prepared with dimensions of 75 × 75 cm, depth 40–50 cm, with backward sloping of 2–3°. Depending on the forest condition of this region beech (Be), oak (O), oriental ash, Caucasian hornbeam (Hb), mountain maple (Mp), mountain bighorn, pine were used, which have silvicultural and economic significance in the beech area (Safarov 1967; Badalov 2012). In this case, oak and maple seedlings were 3 years old, and hornbeam and ash were 2 years old (due to their fast growing ability). Sizes of beech saplings were the following: height 43–51 cm, root collar diameter 7.2–8.1 mm. Depending on the growing conditions, the composition of the created stands in terms of the number in the plots was: P4 and P10 – 7.0Be2.0Hb1.0Ash; P3 – 5.0Be3.2O1.8Mp. The overall design of the experiment can be presented in the following form.

Statistical processing of experimental data and graphic design were carried out using Microsoft Excel software (Version 2007). At the same time, in each site, the mean of the obtained results and the correlation of the number of seedlings and the current growth of beech with age were calculated.

RESULTS AND DISCUSSION

In spring (27–30.5.2009) in all the naturally and artificially sown plots the first observations of the appearance of seedlings were conducted, and at the end of the growing season (27–30.10.) of the same year, their numbers by species were determined, the proportion of beech in the composition by number, its survival and current height growth, the results of which are presented in Table. 2.

In May 2009 in plots P1 and P9 with fresh herbage forest growing conditions it was found that on the plot of the created plantations there appeared from 3.0 to 6.6 individuals of beech, and their total number varied within 5.82–6.75 thousand individuals per hectare. At the end of the first year in these stands, the survival of beech seedlings was only 50–59%. The high mortality of woody plants can be explained by unfavourable conditions of the open terrain of the established plots and the destruction of a part of the sown seeds by animals.

On P5–6 with fresh fescue forest growing conditions at the end of the first year in comparison with

Table 2. Changing number and dynamics of the survival rate and height growth of seedlings

Plot No.	Forest growing conditions	Tree species	No. of seedlings per hectare (thousand individuals)						
			calculation in spring (27–30.5.)	1st year		2nd year		5th year	
				survival rate	height (cm)	survival rate	height (cm)	survival rate	height (cm)
1	beech, fresh herbage	beech	5.82	3.27	10.7 ± 0.2	2.83	34.4 ± 0.6	2.09	83.6 ± 1.8
		hornbeam	3.67	2.53	12.4 ± 0.3	1.72	41.8 ± 1.0	1.17	95.3 ± 2.8
		maple	1.05	0.61	10.9 ± 0.4	0.40	33.5 ± 1.7	0.21	88.6 ± 6.1
		others*	2.56	1.72	14.8 ± 0.4	1.10	37.1 ± 1.1	0.73	92.1 ± 3.4
		all	13.1	8.13		6.05		4.20	
2	beech, moist herbage	beech	4.34	1.57	8.9 ± 0.3	1.17	30.1 ± 0. 9	0.83	62.3 ± 2.2
		hornbeam	1.51	1.12	11.3 ± 0.3	0.71	34.7 ± 1. 3	0.40	78.7 ± 3.9
		others*	2.65	1.84	12.2 ± 0.3	1.28	32.3 ± 0.9	0.69	74.8 ± 2.8
		all	8.20	4.53		3.16		1.92	
5	beech, fresh fescue	beech	2.71	1.27	10.5 ± 0.3	0.92	33.0 ± 1.1	0.63	70.6 ± 2.8
		hornbeam	6.12	3.14	13.6 ± 0.2	2.08	38.2 ± 0.8	1.15	87.7 ± 2.6
		maple	1.07	0.74	11.1 ± 0.4	0.37	30.4 ± 1.6	0.17	77.2 ± 5.9
		others*	1.89	1.28	13.2 ± 0.4	0.83	36.1 ± 1.3	0.41	83.9 ± 4.1
		all	11.79	6.43		4.40		2.36	
6	beech, fresh fescue	beech	3.42	1.53	9.2 ± 0.2	1.26	31.3 ± 0.9	1.04	73.9 ± 2.3
		hornbeam	5.56	3.28	11.4 ± 0.2	2.31	38.2 ± 0.8	1.54	86.7 ± 2.2
		others*	1.29	0.82	15.8 ± 0.5	0.60	34.1 ± 1.4	0.21	78.3 ± 5.4
		all	10.27	5.63		4.17		2.79	
7	beech, fresh fescue	beech	5.11	2.38	9.7 ± 0.2	2.01	32.5 ± 0.7	1.78	71.8 ± 1.7
		others*	2.57	1.14	11.9 ± 0.4	0.98	41.6 ± 1.3	0.86	88.9 ± 3.0
		all	7.68	3.52		2.99		2.64	
8	beech, fresh herbage	beech	6.42	3.79	12.2 ± 0.2	2.95	38.7 ± 0.7	2.44	88.4 ± 1.8
		others*	2.51	2.07	14.4 ± 0.3	1.82	35.2 ± 0.8	1.36	76.3 ± 2.1
		all	8.93	5.86		4.77		3.80	
9	beech, fresh herbage	beech	6.75	3.42	13.6 ± 0.2	2.61	33.2 ± 0.6	2.22	84.3 ± 1.8
		others*	2.64	1.87	15.9 ± 0.4	1.43	26.5 ± 0.7	1.27	69.4 ± 1.9
		all	9.39	5.29		4.04		3.49	

*great sallow (*Salix caprea* Linnaeus), elm (*Ulmus* Linnaeus), poplar (*Populus* Linnaeus), alder (*Alnus* Miller)

the previous sites there was a smaller proportion of beech seedlings, i.e. from 2.0 to 2.7 individuals, which was due to the smaller seedlings of beech trees in the surrounding plantations. On sites of P7 it counted on average 6.8 thousand individuals per hectare. However, in these plots at the end of the first year, out of 2.71–5.11 thousand individuals per hectare only 44.7–46.8% survived. In these forest conditions, the mortality of beech seedlings was due to the unfavourable conditions of the open area and decrease in soil moisture (up to 2–3 times) in the upper horizons, especially in the vegetation period.

On sites of P2 with moist herbage forest growing conditions, the studied indicators were: 4.0 individuals, 4.34 thousand individuals per hectare and 36.2%, respectively. In these conditions, with 64% mortality, the emergence of beech seedlings was prevented in places by wet forest conditions and dense shading cover of high grass with fern participation, which deprived the seedlings of light and dried out the upper horizons of soil.

At the end of the first year in stands established in fresh herbage conditions, beech seedlings had the largest height increment – 10.7–13.6 cm, the smallest in moist herbage – 8.9 cm, but the number of beech seedlings was twice higher than in the plots with the moist herbage conditions. The results of observations of 3-year-old seedlings are presented in Table 3, which are characterized as follows: in the fresh herbage growing conditions – the number of beech seedlings was 3.27–3.79 thousand individuals per hectare, current height increment was 33.2–38.7 cm; in the fresh fescue conditions – 0.92–2.01 thousand individuals per hectare and 31.3–33.0 cm.

The results of investigations of 3-year-old seedlings are presented in Table 3: fresh herbage forest growing conditions – the number of beech seed-

lings is 3.27–3.79 thousand individuals per hectare, current height increment was 33.2–38.7 cm; in the fresh fescue forest growing conditions – 0.92–2.01 thousand individuals per hectare and 31.3–33.0 cm.

The results of the investigation of 5-year-old plants originated by the sowing method in different forest conditions are presented in Table 3.

The data in Table 3 shows that the created stands in the fresh herbage forest growing conditions are restored beech with a mixed composition.

The success of the restoration of beech plantations in sites P1, P8–9, with 2.09–2.44 thousand individuals of beech seedlings per hectare can be assessed as good. In fresh fescue forest growing conditions in P5–6 beech-hornbeam plantations will be formed. Here, the success of the restoration of beech plantations with 0.63–1.04 thousand individuals of beech seedlings was very weak. The success of the restoration of beech plantations in the site P7 with the number of beech seedlings amounting to 1.78 thousand individuals per hectare was estimated as satisfactory. There will be formed beech stands with mixed composition. In the stands of P2 in the moist herbage forest growing conditions, plantings of different composition with beech participation will be formed. The success of the restoration of beech stands is estimated as weak. The number of beech seedlings was 0.83 thousand individuals per hectare (Yakhyaev et al. 2015).

In the established sites, ten cultural treatments were carried out for the plants for 5 years (1st year – 3 treatments, 2nd year – 3 treatments, 3rd year – 2 treatments, 4th year – 1 treatment, 5th year – 1 treatment), during which weeding was done around the site at a distance of 1 m, partial loosening of soil, cutting of secondary wood species of silencing beech. On the sites on the untreated soils, high grass and small shrubs were carefully mown. Wherein, mainly hand tools and special petrol engine mechanisms were used.

The general dynamics of reforestation works can be presented in the following form. In the first three years the beech seedlings from natural and artificial sowing gradually increased in growth. Beginning from the fourth year, there was observed a higher height increment, which continued for the next 3–4 years. Only, depending on the growth conditions at the age of 6–8 years, the growth of young beech decreases, which makes it necessary to conduct thinning in these stands.

According to the results of the restoration of beech plantations with planting, in the plots: P3 – 4,316 individuals per hectare (composition by the number of 5.0Be3.2O1.8Mp), P4 – 4,170 individuals

Table 3. Characteristics of 5-year-old plants established by sowing method

Plot No.	Forest growing condition	Total No. (thousand individuals per hectare)		Proportion of beech in the composition of plantations	Beech seedlings		Correlations		Restoration success
		seedlings	beech seedlings		current growth (cm)	survival rate (%)	r_{tns}	r_{chg}	
1, 8, 9	fresh herbage	3.5–4.2	2.1–2.5	5.0–6.4	83–88	74–85	–0.83 to –0.72	0.76–0.97	good
5, 6	fresh fescue	2.4–2.8	0.6–1.1	2.7–3.7	71–74	69–83	–0.81 to –0.69	0.65–0.83	very weak
7	fresh fescue	2.64	1.78	6.7	72	89	–0.77	0.87	good
2	moist herbage	1.92	0.83	4.3	62	71	–0.56	0.68	very weak

r_{tns} – correlation coefficient of age with the number of seedlings, r_{chg} – correlation coefficient of age with beech current height increment

per hectare (7Be2Hb1Ash), P10 – 4,494 individuals per hectare (7Be2Hb1Ash) it is possible to note the following: 3-year-old seedlings planted in strips finished their first growth by the beginning of June.

At the end of the first year (October), a satisfactory state of plantations created in the fresh herbage forest growing conditions was found on the strips of P4 with a total number of 3.64–3.79 thousand individuals per hectare, the survival of which was 87.2–90.9%. In the composition of the plantations, the number of beech seedlings varied in the range of 2.55–2.66 thousand individuals per hectare, and its height increment varied from 5.7 to 7.1 cm. Relatively high indicators of the plantations of this plot are mainly associated with the most favourable conditions of the site of occurrence, which are created in the beech belt on the slope of 12–15° and the altitude of 1,100–1,150 m a.s.l. Here a significant rate of mortality (9.1–12.8%) of plantings was related with the exposure of plantations to the open terrain of the mountain slope and their damage by rodents.

In the strips of P3 created in the fresh herbage forest growing conditions at the end of the 1st year, the total number of plants ranged within 3.47 to 3.65 thousand individuals per hectare including beech – 1.73–1.83 thousand individuals per hectare. Here the survival of beech was 80.3–84.6%, and its annual height increment was 4.7–6.1 cm.

In the strips of P10 created in the fresh fescue forest growing conditions, at the end of the 1st year the total number of plants was 3.53–3.71 thousand individuals per hectare including beech 2.47 to 2.59 thousand individuals per hectare. Here the survival of beech was 78.6–82.4%, and its annual height increment was 4.6–5.4 cm. In these stands, the mortality of a large number of beech seedlings (17.6–21.4%) is related to the deterioration of soil-climatic growing conditions on the slope of 35° and to relatively dry soil.

Stands created on the site of P4 with the fresh herbage forest growing conditions, taking into account the existing preliminary undergrowth of beech (0.24 thousand individuals per hectare) plantations in the inter band, form beech plantations. The success of reforestation was estimated as good in this area with the number of beech seedlings 1.83–2.15 thousand individuals per hectare and its participation in the composition of plantations 6.6–6.7 units. At the end of the 5th year in the sites of P3 a significant rate of the total mortality of beech seedlings was observed (34.6–43.4%). This is related with deterioration of environmental conditions in the upper mountain belt (with slope steepness 22° and altitude 1,486 m a.s.l.), mostly spring and autumn frosts in open areas. In the inter-strip areas of this plot, an insignificant quantity (0.081 thousand individuals per hectare) of preliminary undergrowth of beech and other valuable species is distributed. By evaluating the results of the obtained data it can be said that in the strips of P3 different forest formations with the participation of beech are formed. The success of reforestation here with the total number of beech seedlings was 1.22–1.41 thousand individuals per hectare and its participation in the composition of plantations 4.6–4.7 units is assessed as satisfactory.

In the site P10, at the end of the 5th year in comparison with beech seedlings, the hornbeam adapts well to the conditions of steep slopes (35°), increasing its share in the composition of stands by 0.2 to 0.3 units during 5 years. Apparently, in these forest growing conditions beech plantations with mixed composition will be created. Here forest restoration which is 1.56–2.02 thousand individuals per hectare with the number of beech seedlings and its proportion in the composition of plants 6.5–6.8 units is estimated as relatively good.

In the established areas, the dynamics of the total number of seedlings for 5 years by species is shown in Fig. 2.

The results of these studies show that the current height increment of beech saplings gradually increases with aging. For the 3rd year after the creation of stands, this indicator varies within the limits of 20.6–32.6 cm, and in the 5th year 42.3–61.3 cm. The total height of the 5-year-old plants in different forest growing conditions ranged from: in fresh herbage 119.0–134.1 cm (P3) and 133.3–152.0 cm (P4), in fresh fescue 110.5–128.2 cm (P10). Beginning from the 6–7 years of age, a reduction of the height increment was observed in these stands, which indicates the necessity of thinning (Fig. 3).

It should be noted that technological parameters had a significant role in the success of establishing beech after planting and the method of partial tillage. Since, during the preparation of planting sites, tillage and loosening of soils were carried out over a sufficiently large area (75 × 75 cm) and depth (40 to 50 cm), which means that the surface runoff on the planting sites prepared with a backward slope (2–30) will be held in large quantities. Later this moisture will penetrate deep into the soil of these places and thereby create a reserve of moisture for intensive growth and establishment of the beech plantation, especially during the growing season. In support of this, it can be said that on the sites of the established plantings, no erosion of forest areas has been detected for six years (Mishnev 1986).

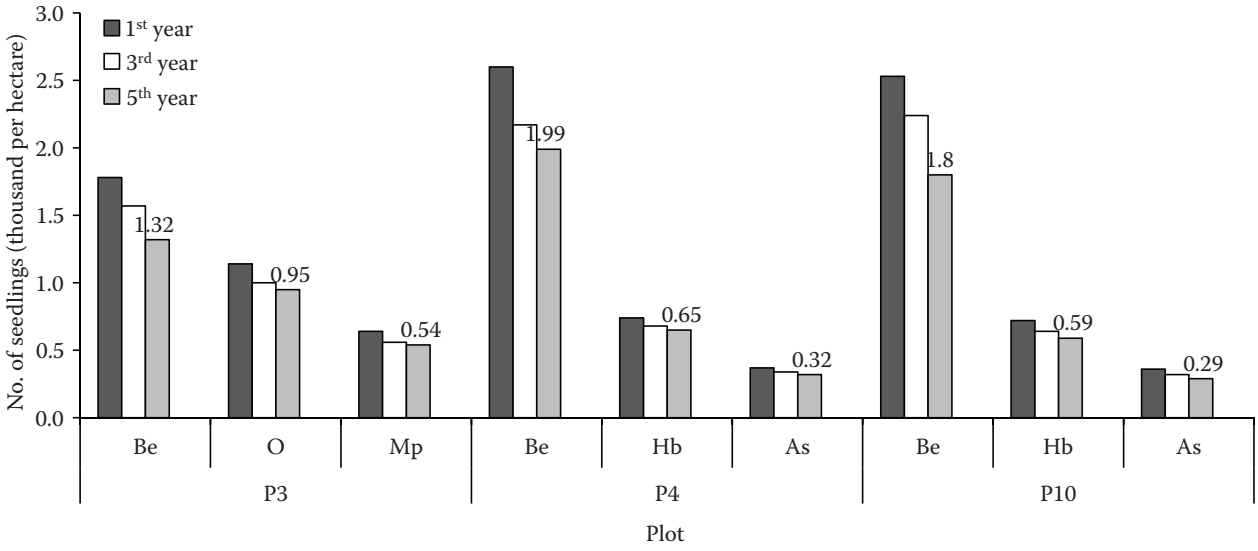

Fig. 2. Dynamics of the number of seedlings on sites by species for 5 years
Be – beech, O – oak, Mp – maple, Hb – hornbeam, As – ash

The beech plants after planting were transferred into the forest covered area at the age of 6–7 years. For the first three years 5 treatments of the plants were carried out (1st year – 2 treatments, 2nd year – 2 treatments, 3rd year – 1 treatment). At the same time, the following works were carried out: on treated soils – weeding, soil loosening and cutting down the secondary species that prevented the planting. On untreated soils – in order to protect the spreading, the tall grass and shrubs were carefully mown in the undergrowth of valuable species. These works were mainly carried out with the help of special manual gasoline mechanisms (Belenko 1975; Mishnev 1986).

Based on the analysis, we can say that indigenous beech forests of this region are undergoing expedient restoration from a silvicultural and economic point of view in the directly permanent place by creating beech plantations. These crops will be resistant to soil and climatic influences, especially on eroded slopes.

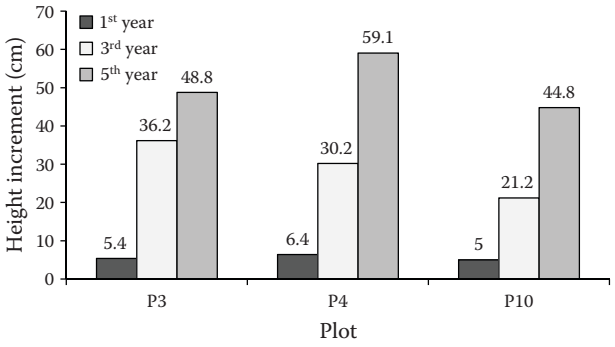

Fig. 3. Current height increment of beech species for 5 years depending on age

CONCLUSIONS

Based on the results of the studies, the following can be noted:

(1) It was revealed that in the 5-year-old plants created by the sowing method, depending on the forest growing conditions, the following conclusions can be drawn:
   (*i*) in the fresh herbage forest growing conditions in the sites P1, P8–9 according to the total number of seedlings and the beech proportion in the composition of stands – assessment of the success of the restoration of beech stands is good;
   (*ii*) in the fresh fescue forest growing conditions in the sites P5–6 this indicator is very weak, in the sites P7 it is satisfactory;
   (*iii*) in the moist herbage forest growing conditions in the sites P2 assessment of the success of the restoration of beech stands is very weak.

(2) In the 5-year-old plants established by the planting method, depending on the forest growing conditions, the following conclusions can be drawn:
   (*i*) in the fresh herbage forest growing conditions in the sites P3 according to the total number of seedlings and the beech proportion in the composition of stands – assessment of the success of the restoration of beech stands is satisfactory and in P4 it is good;
   (*ii*) in the fresh fescue forest growing conditions in the sites P10 this indicator is good.

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Received for publication March 10, 2018
Accepted after corrections September 23, 2018