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Features of natural renewal in pine-linden and larch-linden forest stands in Moscow

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Abstract. Problems of natural renewal of tree species (pine-linden and larch-linden stands) were studied in the territory of Forest experimental station, Moscow Timiryazev Agricultural Academy. Natural regeneration of tree species is one of the most urgent problems of forestry and forest park management in urban areas. Reforestation refers to complex natural processes that affect all components of biogeocenoses. The purpose of the research was to study natural regeneration in mixed stands in Moscow. Methods and results of field surveys of forest stands in permanent trial plots were described. The forest stands of permanent trial plots are mature and overmature, therefore at present there is a loss of large-sized pine and larch trees. Due to greater durability, larch falls off more slowly compared to pine. Further growth of pine-linden and larch-linden plantations depends on quantity and quality of undergrowth, its viability and growing conditions. In Forest experimental station, natural renewal prevails, represented mainly by the following species: maple and linden. Saplings of pine, larch, oak, and birch appear on some permanent test plots, but soon die due to unfavorable conditions. Oak undergrowth is also unreliable due to powdery mildew infection. The greatest loss of growth occurs in unfavorable growing conditions due to increased recreational loads.

Keywords: Forest experimental station, mixed stands, forest phytocenosis, urban forests

Conflicts of interest. The authors declared no conflicts of interest.

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the data, formulated conclusions; T.A. Fedorova — analyzed the data, reviewed scientific literature, wrote the paper; O.V. Kanadin, V.R. Areshchenko — reviewed scientific literature, performed the experiments.

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Introduction

In order to increase efficiency of forests performing ecosystem functions, it is necessary to comply with the basic ecological and forestry requirements in organization and management of forestry [1–4]. Structure of future forests, their commodity potential, productivity, and their environment-forming functions depend on forest growing process [5]. Reforestation refers to complex natural processes that affect all components of biogeocenoses. Therefore, issues of reforestation must be studied considering environmental, social and economic factors. Important criteria include the proportion of natural forests in the forest fund, which are considered more sustainable and productive compared to forest crops [6, 7]. Therefore, special attention should be paid to natural reforestation.

The experimental forest station of Moscow Timiryazev Agricultural Academy is considered one of the first training and research sites in Russia, its forest plantations perform important environmental and recreational functions, described in the article of V.D. Naumova, B.S. Rodionova, A.V. Gemonov [6]. Since the beginning of the 1970s, the forest area of this unique complex has been considered as an important element of Moscow's landscaping, and every year this role is rising. However, plantings in urban conditions are currently experiencing a) consequences of global climate change, which can lead to increase in productivity and accelerate stages of life cycle, and b) air and soil pollution, high recreational loads, which lead to deterioration of sanitary condition of plants and decrease in performance of their useful functions and other negative consequences, which is confirmed in the article of N.N. Dubenok, A.V. Lebedev, V.V. Kuzmichev [8].

The purpose of the research was to study natural regeneration of pine-linden, larch-linden stands, changes in their species composition and amount of saplings of all tree species.

Materials and methods

The object of the study was mixed pine-linden and linden-larch plantations of permanent trial plots (4/A, 4/B, 4/V, 4/G, 4/D, 4/E, 4/Sh, 4/Sch, 4/Ъ, 4/Ь, 4/Ѣ, 4/Z, 4/ Yu, 4/2) of Forest experimental station, Russian State Agrarian University — Moscow Timiryazev Agricultural Academy, located in the north-eastern part of Moscow (Fig.). The area is 249 hectares, including forested part — more than 95 %. The forest fund is dominated by mature and overmature plantations of pine, larch, oak and birch. According to Naumova V.D., Rodionova B.S., Gemonov A.V. [6], the soil is soddy-podzolic with different intensity of soddy and podzolic processes.

Location of the study sites in Moscow
(dominant species on the trial plots: orange — pine, blue — birch, dark orange — larch)

Source: compiled by the authors of the article Lebedev A.V., Gemonov A.V., Volkov S.N., Fedorova T.A., Kalmykova E.S., Kanadin O.V., Areshchenko V.R. using Google Maps

Taxation indicators of plantations were determined according to the results of a tree-by-tree enumeration on permanent trial plots. For growing trees, the taxation diameters of trunks were determined with an accuracy of 0.1 cm (Halghof mechanical measuring fork), heights — with an accuracy of 0.1 m (Vertex VI altimeter). Density of the forest canopy was determined by eye. Volume of growing stock and completeness of forest stands were calculated according to the generally accepted method using standard tables of sums of cross-sectional areas and tables of stem volumes. When describing the living ground cover on the test plots, plots 1×1 m were laid, on which species of vascular plants were identified, and the abundance was estimated according to Brown-Blanque method described by I.G. Krinitsyn, A.V. Lebedev [9].

Natural renewal was measured by the enumerative method by laying out accounting plots 1×1 m^2 in size in parallel rows at the same distance from each other and along the diagonals of each permanent trial plot [9, 10]. In the complete enumeration of saplings, the species, age, height, and number of plants were taken into account. According to the results of enumeration, all plants were divided into 3 groups depending on their quality (condition): viable, questionable and unviable according to methodology proposed by D.V. Lezhnev [11]. Plants with dense foliation, green or dark green needles (foliage), markedly pronounced whorliness, with an increase in height over the past 3–5 years, straight intact stems, smooth or finely scaly bark, were classified as viable. The questionable category included trees that had transitional signs of quality; plants with obvious signs of unsatisfactory quality were classified as unviable saplings [10]. By height, the plants were divided into 3 groups: up to 0.5 m — small, from 0.51 to 1.5 m — medium, from 1.51 m and more — large.

Results and Discussion

The data of tree-by-tree enumeration and evaluation of saplings on permanent sample plots (Table 1) serve as the basis for analyzing ability of various tree species to natural regeneration. Scots pine (*Pinus sylvestris*) dominates in most of the permanent test plots. In addition, small-leaved linden (*Tilia cordata*), silver birch (*Betula pendula*), pedunculate oak (*Quercus robur*), and Siberian larch (*Larix sibirica*) were found in composition of forest stands on permanent test plots.

Table 1

Taxation characteristics of stands on permanent trial plots

Plot	Year of laying	Area. ha	Measurement year	Age. years	Average height. m	Average diameter. cm	Number of trees							
							Species							
							Lr	Ln	P	O	B	S	M	E
4/Ь	1911	0.1853	2022	139	25.9	34.8	19	-	-	2	7	-	3	-
			2009	126	33.1	34.6	19	-	1	2	5	-	3	1
			2005	122	32.0	34.4	30	-	-	2	8	-	-	-
			1998	115	31.8	32.9	30	-	-	-	-	-	-	-
			1993	110	31.3	44.8	31	-	-	-	-	-	-	-
			1986	103	24.3	22.52	34	1	7	5	10	-	-	-
			1964	81	24.0	22.7	34	1	10	5	-	-	-	-
			1959	76	23.3	21.1	34	1	15	5	-	-	-	-
			1954	71	22.0	23.5	45	-	22	5	-	-	-	-
			1949	66	21.8	21.8	45	-	27	6	-	-	-	-
			1924	41	14.5	10.9	90	-	120	77	-	334	-	-
			1911	28	—	9.8	93	-	138	106	-	354	-	-
4/Yu	1887	0.0630	2022	157	22.6	27.9	-	27	16	-	-	-	30	5
			2009	144	24.2	30.3	-	33	17	-	-	-	3	-
			2001	136	25.7	32.0	-	28	18	1	-	-	-	-
			1991	126	25.0	30.2	-	38	23	1	-	-	-	-
			1969	104	19.4	21.8	-	36	25	2	-	-	-	-
			1954	89	18.4	17.9	-	55	48	2	-	-	-	-
			1944	79	14.2	14.1	-	57	64	1	-	-	1	-
			1915	50	14.0	5.4	-	181	113	15	-	-	248	-
			1901	36	9.0	12.5	-	-	187	-	-	-	-	-
			1887	22	—	8.5	-	-	329	-	-	-	-	-
4/Z	1887	0.0630	2022	158	21.7	29.4	-	-	14	2	2	-	7	-
			2009	145	22.8	30.0	-	-	18	4	3	-	8	-
			2001	135	25.0	29.5	-	-	21	4	5	-	8	-
			1991	126	22.0	25.2	-	-	23	5	6	-	10	-
			1969	104	20.5	25.0	-	-	26	12	-	-	-	-
			1959	94	18.0	22.6	-	-	31	12	-	-	-	-
			1949	84	16.5	21.0	-	-	49	8	-	-	-	-
			1938	73	12.5	11.6	-	-	71	19	-	-	8	-
			1911	46	12.0	15.2	-	-	129	-	-	-	-	-
			1887	22	—	8.1	-	-	355	-	-	-	-	-

Continuation of table 1

Plot	Year of laying	Area. ha	Measurement year	Age. years	Average height. m	Average diameter. cm	Number of trees							
							Species							
							Lr	Ln	P	O	B	S	M	E
4/Ь	1888	0.2682	2022	169	24.3	33.2	-	1	24	4	2	-	72	13
			2009	156	26.9	35.1	-	3	35	3	3	-	27	19
			1997	144	29.2	25.1	-	8	42	2	4	-	2	48
			1969	122	20.6	27.8	-	10	57	8	5	-	-	33
			1959	112	5.0	27.3	-	12	67	7	5	-	-	5
			1949	102	4.9	23.0	-	12	77	7	6	-	-	5
			1932	85	4.1	15.0	-	14	128	-	11	1	119	13
			1914	67	3.9	8.8	-	22	158	62	73	-	75	5
			1903	56	11.3	23.4	-	-	222	-	2	-	-	-
			1893	46	9.8	19.1	-	-	275	-	2	-	-	-
4/Ъ	1886	0.0819	2022	159	27.6	34.2	-	4	20	3	2	-	7	-
			2009	144	25.9	32.1	-	4	25	2	1	-	3	-
			1986	121	5.5	23.5	-	-	32	-	-	-	-	-
			1969	104	5.9	24.1	-	4	34	5	5	-	-	-
			1959	89	5.8	23.2	-	4	35	4	1	-	-	-
			1949	79	5.6	19.5	-	4	50	4	1	-	-	-
			1939	69	4.3	12.0	-	4	68	8	1	-	48	-
			1924	54	17.5	18.8	-	-	110	-	-	-	-	-
			1909	39	12.0	14.3	-	-	188	-	-	-	-	-
			1896	25	—	9.4	-	-	3365	-	15	-	-	-
4/Sch	1891	0.1571	2022	156	27.2	34.4	-	-	16	1	11	-	-	-
			2009	143	26.6	34.3	-	-	21	2	26	-	2	3
			1981	115	8.2	24.6	-	-	29	30	104	-	-	-
			1966	100	8.2	23.8	-	-	29	-	12	-	-	2
			1956	90	23.5	27.3	-	-	36	-	-	1	-	-
			1941	75	21.5	23.8	-	-	52	-	-	13	-	-
			1930	64	19.8	19.7	-	-	69	-	-	236	-	-
			1914	48	17.3	16.2	-	-	86	-	-	370	-	-
			1904	38	—	10.9	-	-	115	-	-	666	-	-
			1891	25	—	8.3	-	-	132	-	6	850	-	-
4/Sh	1891	0.1740	2022	156	25.2	31.3	-	-	11	-	19	-	54	-
			2012	146	24.3	30.6	-	-	13	-	22	-	21	1
			2000	134	6.8	16.2	-	-	13	-	-	-	-	-
			1981	115	12.8	25.7	-	-	13	1	45	-	-	3
			1961	95	24.0	30.5	-	-	15	-	-	-	-	-
			1951	85	24.0	29.4	-	-	39	-	-	-	-	-
			1941	75	21.3	22.7	-	-	52	-	-	25	-	-
			1930	64	19.0	20.3	-	-	65	-	-	267	-	-
			1904	38	—	13.1	-	-	128	-	-	613	-	-
			1891	25	—	8.6	-	-	150	-	5	933	-	-
4/E	1892	0.1420	2022	132	12.7	29.9	-	3	49	-	-	-	13	2
			2009	119	5.4	29.3	-	3	56	1	1	-	9	1
			1993	103	24.3	24.6	-	5	73	-	-	-	7	-
			1975	85	19.7	21.6	-	3	85	2	2	-	-	-
			1960	70	16.1	18.9	-	2	128	2	-	-	-	-
			1950	60	17.0	17.5	-	-	153	2	-	-	-	-
			1941	51	13.0	15.3	-	-	226	2	-	-	-	-
			1930	40	8.5	10.3	-	-	446	4	-	-	-	-
			1923	33	7.3	8.0	-	-	610	11	-	-	-	-
			1910	20	—	5.3	-	-	1042	11	13	-	-	-

Continuation of table 1

Plot	Year of laying	Area. ha	Measurement year	Age. years	Average height. m	Average diameter. cm	Number of trees							
							Species							
							Lr	Ln	P	O	B	S	M	E
4/D	1892	0.1420	2022	132	11.1	18.3	-	12	54	-	-	-	32	-
			2009	119	22.4	24.8	-	11	64	-	2	-	75	-
			2005	115	8.8	21.5	-	-	69	-	-	-	-	-
			1999	109	25.7	26.1	-	6	88	-	4	-	-	-
			1975	85	—	7.2	-	-	103	-	-	-	-	-
			1970	80	—	6.7	-	-	108	-	-	-	-	-
			1965	75	—	6.4	-	-	112	-	-	-	-	-
			1950	60	13.0	16.4	-	-	193	4	3	-	-	-
			1935	45	4.9	16.1	-	-	428	4	-	1	-	-
			1910	19	—	4.3	-	-	1842	10	18	-	-	-
4/2	1962	0.1600	2022	124	29.8	35.2	45	26	6	11	-	-	18	-
			2015	117	29.6	34.7	45	9	14	11	-	-	0	-
			2009	111	27.8	39.0	47	1	14	11	-	-	-	-
			1997	99	13.3	24.0	48	-	-	11	-	-	-	-
			1987	89	7.0	7.8	48	-	-	-	-	-	-	-
			1962	64	3.6	19.9	56	2	22	27	3	1	-	-
4/A	1892	0.1357	2022	132	10.2	25.7	-	12	53	-	-	-	-	-
			2016	126	9.5	26.9	-	10	56	-	-	-	-	-
			2005	115	13.7	28.5	-	-	63	-	14	-	-	-
			1993	103	13.4	21.7	-	-	65	-	34	-	-	-
			1988	98	13.3	20.9	-	-	66	-	-	-	-	-
			1970	80	3.7	19.1	-	1	78	5	3	1	-	2
			1960	70	3.5	16.3	-	1	83	1	2	3	-	2
			1950	60	3.1	11.5	-	1	152	1	1	14	-	1
			1935	45	6.5	10.6	-	-	336	-	1	-	-	-
			1912	22	—	4.4	-	-	1502	9	4	472	-	-
4/B	1892	0.1410	2022	132	25.6	19.5	-	14	64	-	-	-	-	-
			2005	115	27.9	29.4	-	10	74	-	-	-	-	-
			1993	103	23.4	24.4	-	10	84	1	-	-	1	-
			1988	98	12.8	12.7	-	13	85	-	-	-	-	-
			1975	85	13.0	19.8	-	8	91	6	-	-	-	-
			1960	70	18.0	19.0	-	4	97	-	-	-	-	-
			1947	57	18.0	17.4	-	-	165	-	-	-	-	-
			1941	51	17.9	17.0	-	-	251	-	-	-	-	-
			1935	45	16.8	17.0	-	-	356	-	3	-	-	-
			1912	21	—	5.4	-	-	1419	17	6	-	-	-

Ending of table 1

Plot	Year of laying	Area. ha	Measurement year	Age. years	Average height. m	Average diameter. cm	Number of trees							
							Species							
							Lr	Ln	P	O	B	S	M	E
4/V	1892	0.1388	2022	132	26.8	29.9	-	1	30	-	-	-	14	-
			2009	119	25.9	27.3	-	10	63	-	-	-	16	-
			1999	109	17.6	17.2	-	9	67	-	-	-	43	-
			1986	96	7.9	8.4	-	-	79	-	-	-	-	-
			1970	80	5.6	5.2	-	-	83	-	-	-	-	-
			1960	70	5.0	17.0	-	5	103	7	1	-	-	-
			1950	60	4.8	14.1	-	4	154	5	1	-	-	-
			1941	51	6.0	14.7	-	-	252	3	1	-	-	-
			1930	39	—	10.0	-	-	509	8	1	-	-	-
			1912	21	—	4.4	-	-	1583	18	8	-	-	-
4/G	1892	0.1466	2022	131	17.9	24.3	-	9	5	4	17	-	-	1
			2009	118	18.6	23.2	-	6	8	8	28	-	-	-
			1975	84	19.9	20.9	-	-	20	11	81	-	-	-
			1965	75	19.3	20.2	-	-	22	11	90	-	-	-
			1960	69	18.6	18.2	-	-	22	11	97	-	-	-
			1955	64	18.7	17.0	-	-	32	11	108	-	-	-
			1950	59	17.5	16.1	-	-	33	20	119	-	-	-
			1944	53	16.6	13.9	-	-	51	23	132	-	-	-
			1931	40	—	8.8	-	-	100	44	214	1	-	-
			1914	23	—	3.5	-	-	119	1093	1332	4	-	-

Note: Lr — larch; Ln— linden; P — pine; O — oak; B — birch; S — spruce; M — maple; E — elm.

Low cover was represented mainly by Norway maple (*Acer platanoides*). Small-leaved linden (*Tilia cordata*), pedunculate oak (*Quercus robur*), Siberian larch (*Larix sibirica*) and European white elm (*Ulmus laevis*) were found in small quantities. The results of undergrowth accounting (Table 2) showed that in the plantations of Forest experimental station, an active process of nemoralization of forest communities was observed due to predominance of broad-leaved species in young generation. According to the works of D.V. Lezhnev, L.V. Stonozhenko, S.A. Korotkov, S.V. Kovalchuk, V.G. Yugay, K.A. Zhirnova, O.Y. Prikhodko, O.R. Fedorov, T.A. Bychkova et al. [10, 12–15], this process was also noted in other forest areas of the Moscow region and nearby regions.

Table 2

Classification of saplings by condition and size

Site	Forest stand composition formula	Tree species	Number of trees per ha	Tree condition			Size category								
							Viable			Questionable			Unviable		
				Viable, trees/ha	Questionable, trees/ha	Unviable, trees/ha	Small, trees/ha	Medium, trees/ha	Large, trees/ha	Small, trees/ha	Medium, trees/ha	Large, trees/ha	Small, trees/ha	Medium, trees/ha	Large, trees/ha
4/Z	5P3M1O1B	Maple	517	372	62	83	368	0	4	62	0	0	82	0	1
4/Yu	3Ln2P4M1E	Maple	607	558	36	13	513	0	12	33	0	1	12	0	0
4/Ъ	6Lr2B1M1O	Maple	101	67	10	24	51	0	16	8	0	2	18	0	6
4/Ь	6M2P1E1O+B sgLn	Maple, Elm	365	274	40	51	257	8	9	38	1	1	48	1	2
4/Ъ	6P2M1Ln1O+B	Maple, Linden	367	249	59	59	244	0	5	58	0	1	58	0	1
4/Sch	6P4B+O	Maple	356	256	50	50	184	2	4	83	0	0	83	0	0
4/Sh	6M2P2B	Maple, Linden	309	232	37	40	218	6	8	35	1	1	38	1	1
4/E	7P2M1Ln+E	Maple, Linden	197	177	12	8	167	5	5	11	0	1	7	0	1
4/D	6P3M1Ln	Maple	243	160	34	49	156	0	4	33	0	1	48	0	1
4/2	4Lr2Ln2M1P1O	Maple, Linden, Larch	93	65	11	17	54	3	8	9	1	1	14	1	2
4/A	8P2Ln	Maple, Elm	202	152	30	20	145	0	7	29	0	1	19	0	1
4/B	8P2Ln	Maple, Linden, Oak	198	134	32	32	128	1	5	30	1	1	30	1	1
4/V	7P3M sgLn	Maple, Elm	250	180	20	50	174	0	6	19	0	1	48	0	2
4/G	5B3Ln1P1O sgE	Maple, Linden	188	151	11	26	142	0	9	10	0	1	25	0	1

Table 2 shows that in all types of forest stands, proportion of healthy undergrowth is more than half of the total amount of undergrowth. On permanent trial plots 4/Yu, 4/E, 4/G, healthy undergrowth accounted for 82 to 90 % of its total amount, while on plots 4/B, 4/Ъ it did not exceed 67 %. The largest number of viable small undergrowth was observed on the test plots 4/Yu, 4/E, 4/G, and medium and large — on the areas 4/B, 4/Ъ. Thus, viable small undergrowth prevails on the territory of Forest experimental station. The condition for successful natural regeneration is the presence of regeneration spaces in the canopy. On most of the considered permanent trial plots, the undergrowth has a group distribution.

Shrub layer in all studied areas was represented by mountain ash (*Sorbus aucuparia*), red raspberry (*Rubus idaeus*), common hazel (*Corylus avellana*), warty spindle (*Euonymus verrucosus*) and alder buckthorn (*Frangula alnus*).

In the living ground cover, 31 species of plants were identified. The following plants prevailed: small balsam (*Impatiens parviflora*), wood sorrel (*Oxalis acetosulla*), lady fern (*Athyrium filix-femina*), common bracken (*Pteridium aquilinum*), male fern (*Dryopteris filixmas*), false lily (*Maianthemum bifolium*), wood avens (*Geum urbanum*), ground elder (*Aegopodium podagraria*), hairy wood-rush (*Luzula pilosa*), lily-of-the-valley (*Convallaria majalis*), wood sedge (*Carex sylvatica*), asarabacca (*Asarum europaeum*).

Conclusion

The forest stands of the permanent trial plots were mature and overmature, therefore at present there is a loss of large-sized pine and larch trees. Due to greater durability, larch falls off more slowly compared to pine. In the Forest experimental station of Moscow Timiryazev Agricultural Academy, natural renewal prevails, represented mainly by such species as maple and linden. Saplings of pine, larch, oak and birch appear on some permanent test plots, but soon die due to unfavorable conditions. Oak undergrowth is also unreliable due to powdery mildew infection. According to the results of the research, maple and linden have the greatest potential among broad-leaved species.

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Особенности естественного возобновления в сосново-липовых и лиственнично-липовых насаждениях города Москвы

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Аннотация. Рассмотрены проблемы естественного возобновления древесных пород на примере сосново-липовых и лиственнично-липовых насаждений Лесной опытной дачи Тимирязевской сельскохозяйственной академии. Естественное возобновление древесных пород — одна из актуальнейших проблем ведения лесного и лесопаркового хозяйства на урбанизированных территориях. Лесовосстановление относится к сложным природным процессам, оказывающим влияние на все компоненты биогеоценозов. Цель исследования — изучение естественного возобновления в смешанных насаждениях в условиях Москвы. Описаны методы и результаты полевых обследований лесных насаждений постоянных пробных площадей. Древостои постоянных пробных площадей относятся к спелым и перестойным, поэтому в настоящее время наблюдается отпад крупномерных деревьев сосны и лиственницы. Ввиду большей долговечности лиственница отпадает медленнее по сравнению с сосной. Дальнейшая динамика сосново-липовых и лиственнично-липовых насаждений зависит от количества и качества подроста, а также показателей его жизнеспособности и условий произрастания. В Лесной опытной даче преобладает естественное возобновление, представленное, главным образом, следующими породами: кленом и липой. Всходы сосны, лиственницы, дуба, березы появляются на некоторых постоянных пробных площадях, но вскоре погибают из-за неблагоприятных условий. Подрост дуба также является неблагонадежным из-за поражения мучнистой росой. Наибольшие потери прироста подроста по высоте происходят в неблагоприятных условиях произрастания, в результате утраты жизнеспособности из-за повышенных рекреационных нагрузок.

Ключевые слова: лесная опытная дача, смешанные древостои, лесной фитоценоз, городские леса

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