JOURNAL OF FOREST SCIENCE, *64*, 2018 (9): 387–393

https://doi.org/10.17221/4/2018-JFS

Growth and formation patterns of pine-larch saplings in conditions of Eastern Siberia

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Abstract

Runova E.M., Garus I.A., Serkov D.V. (2018): Growth and formation patterns of pine-larch saplings in conditions of Eastern Siberia. J. For. Sci., 64: 387–393.

Researches and generalizations of information on basic patterns of formation, growth, and structure of Irkutsk region forest stands and plantations enabled to study dynamics of formation and productivity of mixed pine forests, being naturally developed under various economic impacts. Such parameters as diameter-, height-, and volume-wise pine and larch increment in mixed forest stands were studied. The obtained results were accurate due to a wealth of experimental material, statistical and mathematical processing using MS Excel application software, graphic methods of processing the materials. The following conclusions can be made based on the materials collected: areas and yields of larch in Irkutsk region have been sharply reduced, since there are processes of intense deforestation and weak natural regeneration of larch here. Mixed forest plantations of pine and larch grow rather successfully, however, such areas are few, since there is no commercial procurement of larch seeds in Irkutsk region, no larch seedlings are cultivated in nursery forests; larch saplings occupy a much smaller area than Scots pine saplings do; basic taxation parameters and structure of mixed pine-larch forest plantations are formed at the young age; saplings have mean productivity, equivalent to the 3rd yield class; mixed forest stands are of high practical and industrial value that depends on conditions of domestic and foreign market.

Keywords: productivity; formation; dynamics; mean diameter; height

The main goal of developing forest sciences nowadays is to design a technology for growing mixed forest stands that facilitates more rational use of natural resources, preservation of biological diversity, stability in utilizing and processing the forests, and enables to respond to changes in the timber market demand and supply in a more flexible way. Many authors examined mixed and multistoried pine forest stands: Voropanov (1954), Vipper (1973), Buzykin and Pshenichnikova (1980), Varaksin et al. (2002), and Gvozdev et al. (2003). Patterns of structure and growth, formation and composition of the Eastern-Siberian taiga mixed forest stands are poorly studied to properly satisfy the demands of forest sector and husbandry in regulatory and reference materials, recommendations for forest use and regeneration. Forest stands with coniferous species predominant are of the highest economic and ecological value. Mixed pine-larch forest stands are highly efficient. Proper management of forests requires development of forestry technologies, which fully take into account the fact that light-loving types of Scots pine (*Pinus sylvestris* Linnaeus) and Siberian larch grow together, and their silvicultural and biological features as well. The most important and primary task, in conditions of commercial forest exploitation, is to preserve biological diversity within natural objects. Planning of forest regeneration activities shall be focused on cultivating highly productive mixed forest stands, thus, basic patterns of their formation, growth, and structure should be known. The

following tasks shall be carried out to achieve the specified goal:

(*i*) to study the processes of forming, growing, and maintaining productivity of mixed forest stands under the age of 40;

(*ii*) to study the patterns of structure, growth, and interdependence between taxation indicators in the mixed forest stands;

(*iii*) to study dynamics/behaviour patterns of certain elements of the mixed forest stand.

Geographically, the Irkutsk region North territory is located in the Angara flatland forest-growing province of the Southern taiga and sub-taiga pine and larch forests. Climate of the studied area is sharply continental, characterized by a long, little snowy, cold winter and a short summer. The duration of vegetation period is 120 days. An average annual precipitation is 374.3 mm. The prevailing wind direction is western and south-eastern. An average wind speed is 2 $m \cdot s^{-1}$. An average multi-annual temperature per a year is 2.4°C, an absolute value of air temperature: minimum –43.1°C, and maximum +31.4°C. The latest frost was on July 1. The first autumn frosts were on August 1. An average date of the rivers' freezing is on November 10. The average dates for the beginning and end of the flood are on May 10–June 1. The depth of soil freezing: the average depth is 100 cm, the maximum depth is 200 cm. The snow cover depth is 35–50 cm.

A stable snow cover appears on October 25 on the average, there are 180 days with snow. An average date of the snow cover loss is on April 15. The following negative climatic factors should be noted: (*i*) little snow, cold winter with deep soil freezing (up to 2 m), (*ii*) prolonged duration of dry periods in summer (up to 20 days), (*iii*) low relative air humidity, (*iv*) insufficient precipitation, (*v*) a long period of strong winds.

In general, climate of the region is favourable for successful growth of cedar, pine, larch, spruce, fir, birch, aspen, and shrubs (Polikarpov 1962; Pobedinsky 1965; Levin 1966; Leopold, Gunar 1968; Melekhov 1980; Luganskiy et al. 2010; Paramonov, Klyuchnikov 2010). An assessment of mixed pine and larch saplings' state was carried out according to the data collected in the Irkutsk region.

MATERIAL AND METHODS

A comparative assessment was carried out of *P. sylvestris* and Siberian larch (*Larix sibirica* von Ledebour) saplings' growth and development. The Irkutsk region plantations were taken as an example.

The main method of gathering experimental data involved a field survey of plantations on permanent and temporary sample plots. Sample plots were laid using a standard procedure (Biging, Dobbertin 1992) and detailed methods indicated in the literature (Polikarpov 1962; Pobedinsky 1965). Silvicultural and geobotanical descriptions were made for each sample plot, indicating the features of stand, undergrowth, living soil cover and relief. Then there was a complete enumeration by two-centimeter diameter classes. Height was measured for each tree. The tree enumeration data was processed by statistical methods. The studies were carried out on permanent and temporary sample plots in the territory of the Irkutsk region (number of sample plots: 27). An analysis of the taxation description within 1,287,923 ha was analysed. Pine and larch saplings under the age of 30 years were subject to analysis. Only the saplings of natural and artificial origin were examined.

RESULTS

According to taxation description, areas with mixed composition of pine and larch were selected, and the main taxation indicators and distribution by prevailing species and areas were analysed. The data were systematized and processed using computer programs. Based on the research results, a distribution pattern of pine and larch stands by age and area classes was obtained.

Fig. 1a shows distribution of pine forests by age classes. As can be seen from Fig. 1a, among the pine plantations, the first and second age class saplings predominate, which indicates a fairly successful natural and artificial reforestation of pine forests. Larch is regenerated much worse naturally, the forest plantations of larch are practically not created.

Fig. 1b shows larch distribution by age classes. From Fig. 1b it can be seen that mature and overmature stands of larch predominate, and there are few plantations of 1–3 age classes, which indicates that deforestation of large larch stands' areas and weak natural larch regeneration. Thus, from the Irkutsk region predominant species, larch gradually moves to the second place after pine.

Fig. 2 shows dynamics of the areas occupied by pine and larch saplings of different ages. In the case of pine, the largest area is occupied by 11–30 years old saplings, while, in the case of larch, the largest area is occupied by the 21–30 years old age group of larch saplings and very small areas are occupied by saplings under the age of 30. This fact confirms

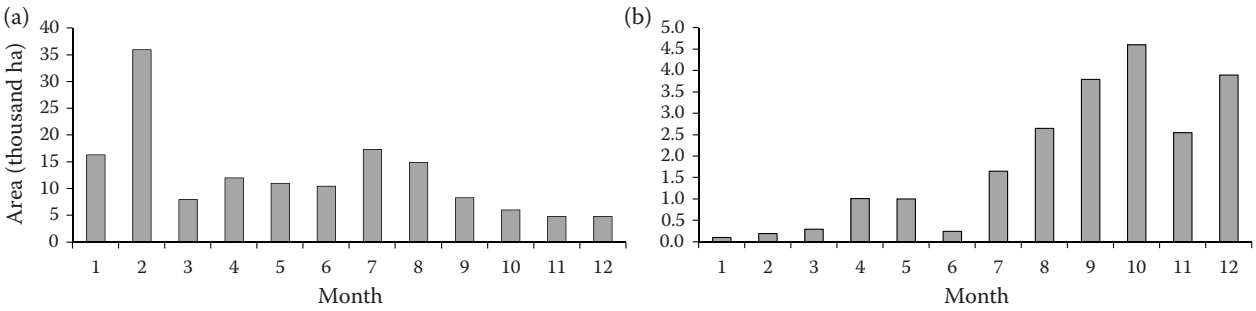

Fig. 1. Distribution of pine (a), larch (b) forests by age classes

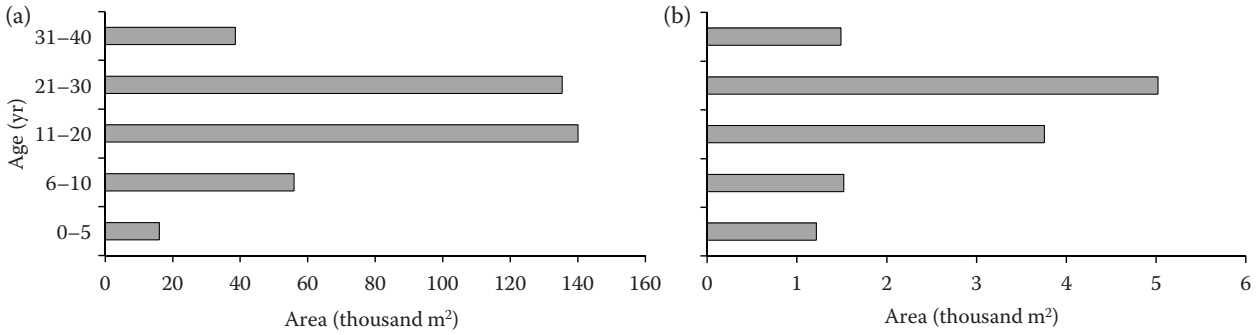

Fig. 2. Dynamics of pine (a), larch (b) saplings' areas by age periods

once again that in the last 20–30 years regeneration of larch is unsatisfactory. This is due to large volumes of larch timber harvested and changes in the forest growing conditions, which does not contribute to abundant larch seeding, as well as a weak natural regeneration of clean larch stands. According to review of literature, larch grows most successfully in mixed plantations with pine, while pine and larch do not oppress each other. To study growth of saplings and development of technology for creating mixed pine-larch forest plantations, it is necessary to study conditions of cultivating these stands under the age of 40.

Based on processing the collected experimental materials, the following results were obtained (Fig. 3). The following types of forests are indicated in the legend: *Ledum* Linnaeus, cowberry, cowberry-moss, cowberry-forb, blueberry, moss, Kamchatka bilberry, lichen, alder, forb, forb-moss, forb-sedge, bilberry, bilberry-moss.

As can be seen from Fig. 3, cowberry-forb and cowberry-moss forest types prevail on the sample plots. These types of forests are quite favourable for growth of Scots pine and Siberian larch. It should be noted that forb forest type is also favourable for forest-forming species, but there were few sample

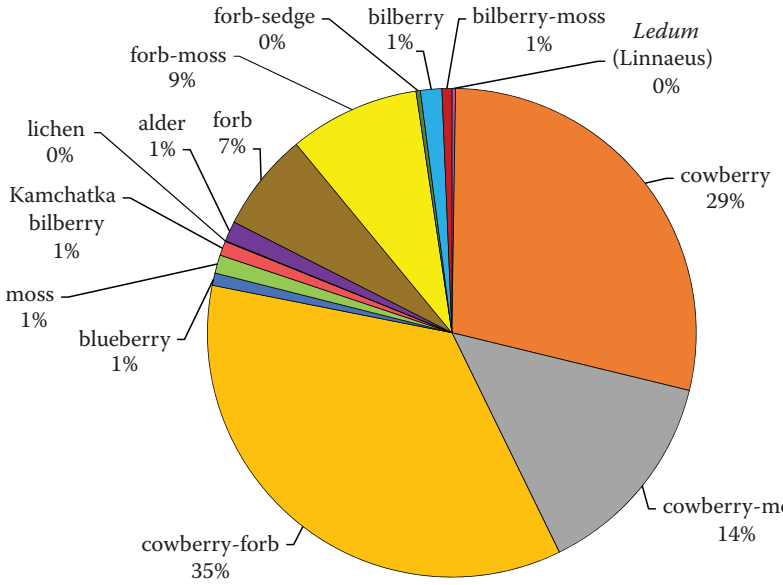

Fig. 3. Relationship between pine and larch stands (rounded to the nearest percent)

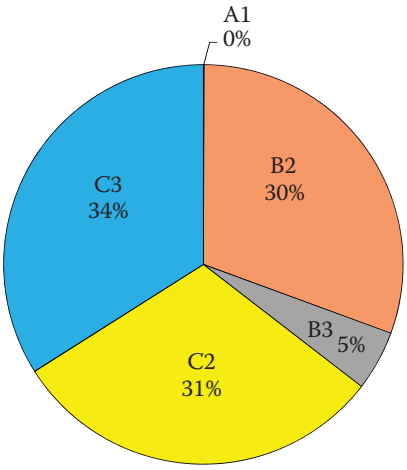

Fig. 4. Histogram of pine and larch areas' distribution by types of forest-growing conditions (rounded to the nearest percent)

A1 – dry pinewood forest, B2 – fresh subor, B3 – moist fresh subor, C2 – fresh suramen, C3 – wet suramen

plots in this forest type. The forb forest type gives a higher productivity class for growth of pine-larch saplings up to class 2.

Fig. 4 represents a histogram of pine and larch areas' distribution according to the types of forest-growing conditions. It shows that the largest percentage of areas occupied by displaced plantations grow on rather fresh and fertile plots.

Sample plots in various forest types were laid for a more detailed study of the basic taxation indicators of saplings with pine and larch predominating.

Table 1 shows average taxation indicators of sample plots with 5–30 years old Scots pine predominating (number of sample plots: 12).

Based on the data from Table 1, it can be concluded that Scots pine is a predominant species, and larch stock does not exceed 3 units in composition, while larch in mature stands is a predominant tree species (5–7 units of composition).

Fig. 5a presents the dynamics of age-wise changes in average height of pine saplings. As can be seen from Fig. 5a, height of saplings grows, as age increases, while the most intense increase in height occurs from 21 to 40 years. Maximum height of pine at the age of 40 years is approximately 10 m, which corresponds to the third class of productivity.

Fig. 5b shows the dynamics of age-wise changes in mean diameter of pine saplings. From the graph in Fig. 5b, dynamics of increasing mean diameter from 0.3 to 9.6 cm at the age of 40 can be traced.

Fig. 5c shows the dynamics of age-wise changes in mean yield class of pine saplings. In the 6–10 years' period, productivity of saplings is the smallest, which corresponds to yield class of 3.1. The greatest productivity is within 21–30 years and corresponds to yield class of 3.0. However, it should be noted that productivity of pine saplings is low, and it does not exceed the 3rd yield class, which corresponds to the natural and climatic conditions of the Irkutsk region (Lavrinenko 1965; Kravchenko 1972; Pisarenko 1990; Plaksiva et al. 2003; Klyuchnikov, Paramonov 2008).

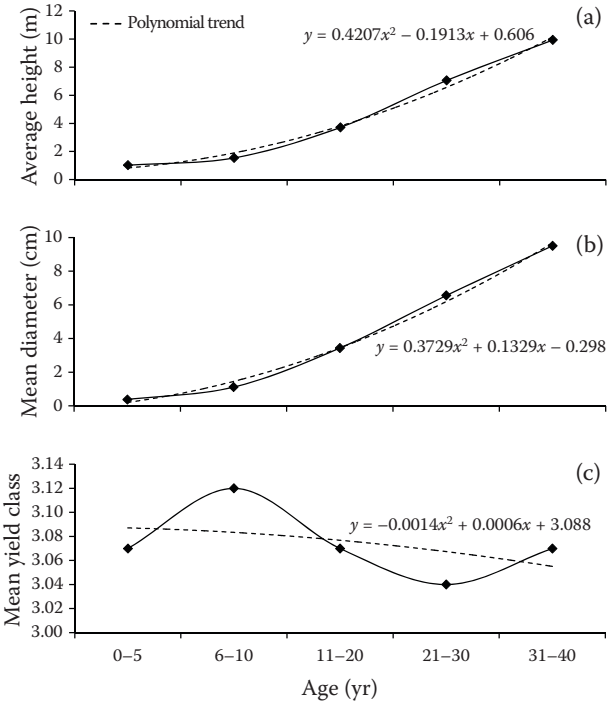

Fig. 5. Dynamics of age-wise changes in average height (a), mean diameter (b), mean yield class (c) of pine saplings

Table 1. Average taxation indicators of permanent and temporary sample plots with pine predominance (pine proportion: 7–10 units)

Plantation age (yr)	Predominant forest and forest-growing conditions' type	Height (m)	Diameter (cm)	Yield class	Relative stand density	Stock per hectare (m^3)
1–5	cowberry-forb/B_2	1.03	0.37	3.07	0.53	5.95
6–10	forb, cowberry, cowberry-forb/B_2, C_2	1.55	1.12	3.12	0.59	9.81
11–20		3.75	3.44	3.07	0.69	31.45
21–30		7.06	6.56	3.04	0.75	75.57
31–40		9.94	9.51	3.07	0.76	115.92

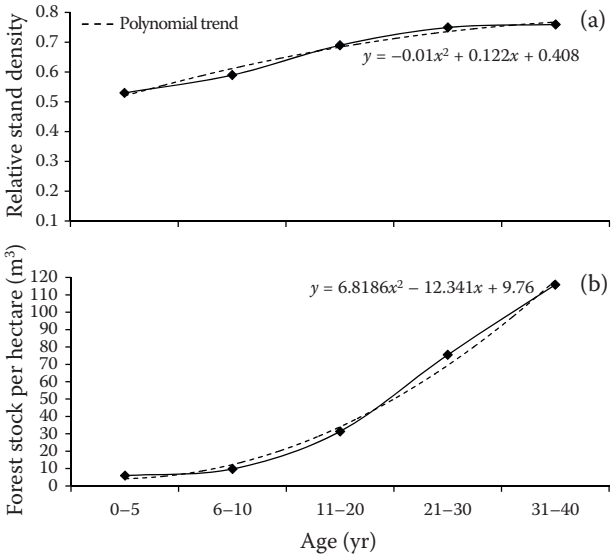

Fig. 6. Dynamics of age-wise changes in relative stand density (a), forest stock per hectare (b) of pine saplings

Fig. 6a shows the dynamics of age-wise changes in relative stand density of pine saplings. It is interesting that average density of mixed stands from 1 to 10 years is relatively small (0.5 to 0.55), by the age of 40 years density reaches a value of 0.76. Such saplings can belong to the category of high-density plantations.

Fig. 6b shows the dynamics of age-wise changes in forest stock per hectare of pine saplings. Under the age of 10 years, it is impossible to determine the forest stock, since there are no large tables for such small-dimension stems. There is a significant increase in the mean forest stock on 1 ha within the 21–40 years' period. It reaches a value of up to 120 $m^3 \cdot ha^{-1}$. Table 2 summarizes the results of research carried out on larch forests for different age periods (the number of sample plots: 11). Materials are obtained on sample plots, statistically processed and summarized.

As can be seen from Table 2, taxation indicators are slightly different from those of pine saplings. The difference in taxation indicators is more obvious in Figs 7a–c and 8a, b.

Fig. 7a shows the dynamics of age-wise changes in average height of larch saplings. The change in height can be described by a polynomial curve with some sufficient degree of accuracy. Maximum height at the age of 31–40 years is 10 m, which exactly corresponds to the height of pine at the same age.

Fig. 7b shows the dynamics of age-wise changes in mean diameter of larch saplings. The dynamics is also described by a polynomial curve, with a maximum diameter value of 9.5 m, which also corresponds to pine data. This coincidence indicates that there is a good compatibility of pine and larch as light-loving and fast-growing tree species. Fig. 7c shows the dynamics of age-wise changes in mean yield class of larch saplings. The yield class shows productivity of forests, and potential largest forest stock by the age of clearing plantations.

As can be seen from Fig. 7c, the highest yield class of larch at the age of 11–20 years is 2.85, by the age of 31–40 years yield is reduced and becomes equal to 3.2. This means that larch can achieve higher productivity than pine. Fig. 8a shows the dynam-

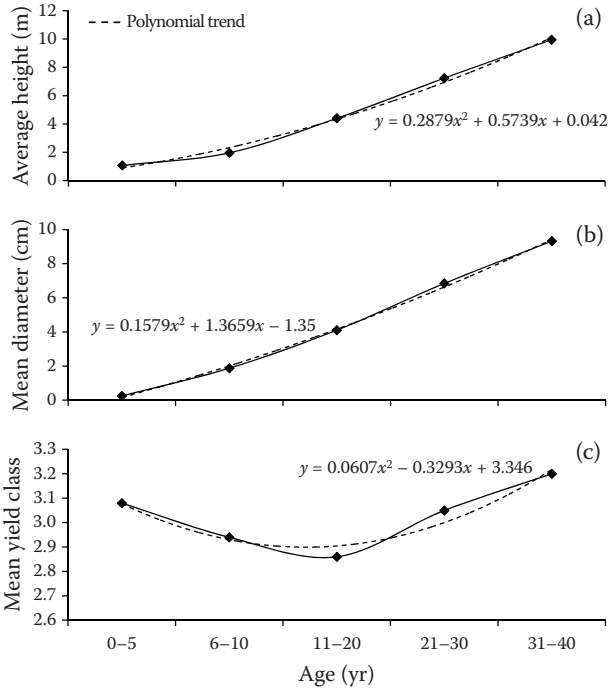

Fig. 7. Dynamics of age-wise changes in average height (a), mean diameter (b), mean yield class (c) of larch saplings

Table 2. Average taxation indicators of permanent and temporary sample plots for larch stands (larch composition: 7–10 units)

Plantation age (yr)	Predominant forest and forest-growing conditions' type	Height (m)	Diameter (cm)	Yield class	Relative stand density	Stock per hectare (m^3)
1–5	forb, cowberry, cowberry-forb/B_2, C_2	1.08	0.25	3.08	0.51	5.69
6–10		1.97	1.88	3.94	0.61	13.54
11–20		4.44	4.11	2.86	0.63	31.35
21–30		4.24	6.85	3.05	0.66	57.92
31–40	forb, cowberry, cowberry-forb/B_2	9.95	9.30	3.20	0.67	94.44

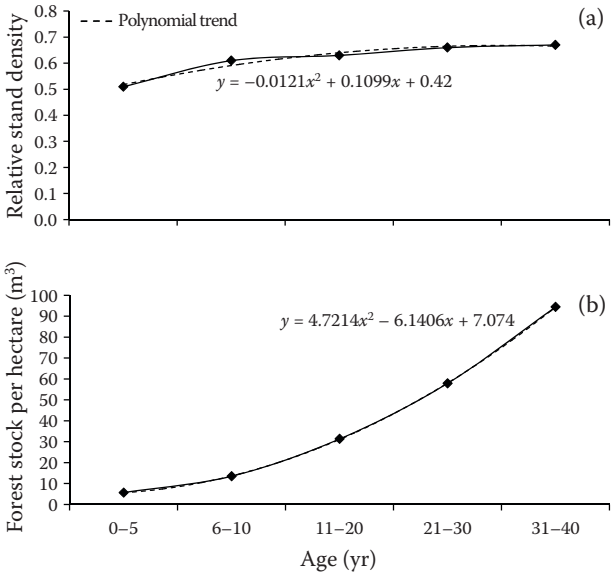

Fig. 8. Dynamics of age-wise changes in relative stand density (a), forest stock per hectare (b) of larch saplings

ics of age-wise changes in relative stand density of larch saplings. Stand density is relatively low, it varies from 0.5 to 0.67, which is lower than that of Scots pine.

Fig. 8b shows the dynamics of age-wise changes in forest stock per hectare of larch saplings. This dependence is relatively described by a highly accurate polynomial curve. The forest stock on 1 ha is small and reaches 95–100 $m^3 \cdot ha^{-1}$, which is lower than that of young Scots pine.

DISCUSSION

Studies on a similar topic were conducted by Polikarpov (1962), Pobedinsky (1965, 1966), Vipper (1973), Buzykin and Pshenichnikova (1980), Varaksin et al. (2002), Runova and Serkov (2014), as well as by a number of foreign researchers (Vanninen et al. 1966; Hegyi 1974; Mälkönen 1974; Giertych 1979; Murcia 1995; Vanninen et al. 1996; Muukkonen et al. 2006; Repola 2006; Hunt et al. 2010; Fritz et al. 2012). Studies of mixed pine-larch plantations have practically not been carried out at present, and as studies show, it is the mixed stands that are most resistant to various unfavourable environmental factors. They preserve biological diversity and provide maximum stock of valuable timber by the age of clearing (TsBNTI Gosleskhoza SSSR 1983; Runova, Savchenkova 2007, 2014; Runova, Vedernikov 2012; Runova et al. 2013).

Some scientists note that global warming of climate in the last few decades is particularly noticeable on the phytocenoses of Siberia and its species composition. In this connection, a decrease in the energy of germination of Siberian larch seeds in natural conditions is identified. The amount of precipitations does not significantly affect the energy of seed germination. The authors believe that the reason for weak natural regeneration of Siberian larch is in damaging seedlings due to early frosts or presence of seed pathogens. In any case, the species composition of mixed pine and larch stands of the Irkutsk region shows a tendency to formation of pure pine plantations, which greatly impoverishes the species diversity of taiga ecosystems.

At the same time, mixed pine-larch stands are most favourable for joint growth, since they do not interfere with growth and development of each other, and even supplement and increase the degree of filling spatial distribution of trees and root systems. Larch increases the degree of soil fertility due to formation of soft humus. One of the global research problems is the assumption that the Siberian larch had lost its leading role as the main forest forming tree species. From the point of view of the authors, it is necessary to significantly reduce removal of mixed pine and larch forest plantations in the appropriate forest soil and subsoil conditions by sowing quality-tested pine and larch seeds.

The carried out studies are significantly different from those of other authors, who consider growth and development patterns of either pure plantations, or certain tree species.

CONCLUSIONS

The following conclusions may be drawn based on the studies carried out:

(*i*) Areas and stocks of larch in Irkutsk region have been sharply reduced due to its intense deforestation and weak natural regeneration. Mixed forest plantations of pine and larch grow rather successfully, however, such areas are few, since there is no commercial procurement of larch seeds in Irkutsk region, no larch seedlings are cultivated in nursery forests;

(*ii*) Larch saplings occupy a much smaller area than Scots pine saplings do;

(*iii*) Basic taxation parameters and structure of mixed pine-larch forest plantations are formed at the young age;

(*iv*) Saplings have mean productivity, equivalent to the 3rd yield class;

(*v*) Mixed forest stands are of high practical and industrial value that depends on conditions of domestic and foreign market.

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Received for publication January 29, 2018
Accepted after corrections September 23, 2018