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Chapter

Increasing Biodiversity of Russian Taiga Forests by Creating Mixed Forest Cultures of Scots Pine and Siberian Larch

Elena Runova

Abstract

Studies were conducted in the Padunsky forest area of the Bratsk district of the Irkutsk region in order to identify the influence of self-sowing that appears in the young growth of Scots pine, created by sowing or planting due to the self-seeding of Scots pine, which can be proved by the age of test trees that are less than 1–3 years old than the forest cultures. Birch and aspen appear in the composition, Siberian larch and Siberian pine appear in a small amount, and at some test plots, silver birch takes up to six units. Such forest cultures require thinning to avoid changing to soft-leaved species. The parameters of the macroscopic structure of Scots pine wood and the thickness of the bark at the base of the trunks, depending on the age of forest cultures, have been determined. To solve the choice of the most effective method of reforestation and increase the economic value of the young stands formed in various types of forest-growing conditions, the effectiveness of various methods and technologies of reforestation has been evaluated. As a result of the work performed, it was established that regardless of the year when the forest cultures are created, self-seeding always appears in the plantations. The smallest amount of self-sowing appeared on relatively poor fresh soils in the cowberry-grass type of forest. The greatest amount of self-seeding can be seen in the motley grass type forests with relatively rich wet soils.

Keywords: biodiversity, taiga ecosystems, mixed stands, scots pine, Siberian larch

1. Introduction

In the context of modern global climate change, forest ecosystems play an important part in stabilizing the ecological state. According to international standards, mixed, complex forests that have a large biological diversity are of particular importance. In this regard, the forests of the Irkutsk region are mostly of natural origin, often based on pyrogenic factors. Many forests are classified as high conservation value forests according to FSC standards. Basically, the forests of the Irkutsk region belong to light-coniferous taiga. Recently, the content of larch in the total composition of the forests of the Irkutsk region has been decreasing both in percentage terms by area and by age groups. In this regard, a special task is to preserve and multiply mixed pine and larch plantations of natural and artificial origin in the

Angara region on the example of the Irkutsk region. The relevance of the topic lies in the study of the state of mixed pine-larch stands on the example of forests in the Irkutsk region and recommendations for the creation of pine-larch forest crops.

The features of growth of mixed and complex pine stands were studied by many authors: Buzykin and Pshenichnikov [1]; Varaksin et al. [2]; Gvozdev [3]; Klyuchnikov [4]; and Plaksiva et al. [5]. However, the regularities of the composition and growth, formation, and structure of mixed stands of the East Siberian taiga are not fully studied, especially for the Irkutsk region. The author [6–9] studied the growth and formation of pine and larch plantations in the conditions of the Angara taiga region (on the example of the Irkutsk region).

The scientific novelty of the research is that on the basis of the conducted research and generalization of information about the regularities of formation, growth and structure of mixed forest cultures, the dynamics of formation of the main inventory indices, and the quality of the stem wood of artificially grown mixed crops were studied. For the first time, forest management and inventory indices of mixed pine and larch plantations in the Angara region of the Irkutsk region, various age classes, and forest cultures were observed for the study areas. The features of the formation of annual rings of pine and larch in mixed forest cultures were studied.

2. Research methodology and methods

The research methodology was based on a systematic approach to the studied natural objects. The methods of establishing sample plots, which are generally accepted in forest research, were used. Processing of inventory indices was carried out according to generally accepted methods [6, 10–12].

One of the main tasks of the modern development of forest science is to study the dynamics of mixed stands in order to grow more productive and biologically more stable productive stands, which should contribute to a more rational use of natural resources, the preservation of biological diversity. Mixed pine-larch stands often have higher productivity than pure stands. However, in recent years, the area and stocks of Siberian larch are decreasing, and this tree species is losing its predominant function as the main forest-forming species of the taiga forests of Eastern Siberia. The scientific novelty of the work and its significance lies in the study of the growth and development of mixed pine-larch stands and the study of the possibility of creating artificial forest stands of mixed composition, characterized by higher productivity and stability. For proper forest management, it is necessary to study the regularities of changes in inventory indices that take into account the co-growth of light-loving species of Scots pine (*Pinus sylvestris* L.) and Siberian larch (*Larix sibirica* Ldb.) and their silvicultural and biological characteristics.

To achieve this goal, the following tasks are set:

- To study the processes of formation, growth, and productivity of mixed pine-larch stands under the age of 40.

- To study the dynamics of individual inventory indices of mixed stands.

The main method of collecting experimental data was a field survey of plantings at permanent and temporary sample plots. The main method of collecting experimental data was a field survey of plantings at permanent and temporary sample plots. For each sample plot, a forest geobotanical description was made, indicating the features of the stand, young growth, undergrowth, ground cover, and terrain.

Then a continuous list of trees of Scots pine (*Pinus sylvestris* L.) and Siberian larch (*Larix sibirica* Ldb) was carried out at the age of 40 years using conventional measuring devices: altimeters-eclimeters, measuring fork for 1-cm stem diameter. Data of inventory indices was processed using statistical methods. The research program consisted of a comparative assessment of the growth and development of young pine (*Pinus sylvestris* L.) and Siberian larch (*Larix sibirica* Ldb.) in the most widespread types of forest at the sample plots in the Irkutsk region. The areas with 200–250 pine and larch trees were selected, which ensured the determination of the average diameter and other inventory indices with an accuracy of ±2–3%.

The Resistograph 4450 device by RINNTECH, Germany, was used to assess the quality of the wood of test trees. The cuttings of the studied trees were drilled with a thin drill needle. The device allows measuring the relative density of wood and fixing dense (healthy) wood and internal damage rot in the initial stage of development, highly developed rot, and cavities, without causing harm to growing trees or samples. According to the obtained resistogram graphs, the percentage of healthy wood or wood rot damage was determined.

When processing test results, the following characteristics were calculated: a sample arithmetic average, sample square mean deviation, average error S of the sample average, and sample coefficient of variation V as a percentage relative accuracy of determining the sample average.

3. Research result

While processing the collected experimental materials, the following results were obtained, which characterize the average morphometric indicators of the sample plots of Scots pine and Siberian larch at the age of 5 up to 40 years in the cowberry-grass and motley grass type of forest that are the most common ones in the studied region.

In **Figure 1**, the dynamics of the average height of young pine trees of different age groups is presented.

The figure shows the height of trees in meters (axis of ordinates) for age periods up to 5 years, from 6 up to 10 years, from 11 up to 20 years, from 21 up to 30 years, and from 31 up to 40 years. The equation describing the relationship between the height and age periods is also presented. The graphs shown in **Figures 1–8** characterize the average dendrometric indicators of increasing dendrometric indicators for age groups, generalized according to the data from 12 permanent and 45 temporary
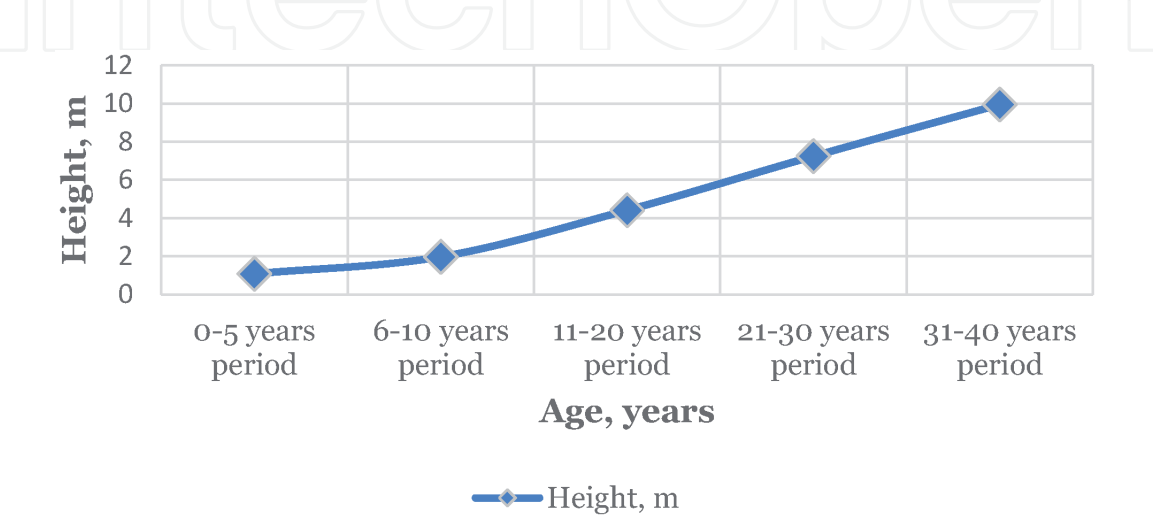

Figure 1.
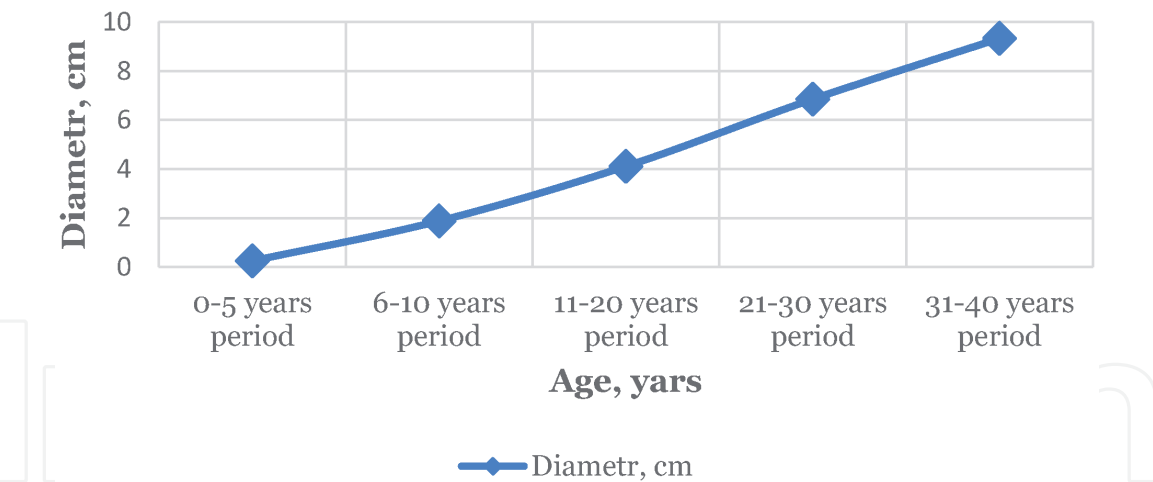*Dynamics of the average height of young pine trees of different age periods.*

Figure 2.
Dynamics of changes in the average diameter of young pine trees by age periods. The figure shows the diameter of trees in centimeters (axis of ordinates) for age periods up to 5 years, from 6 up to 10 years, from 11 up to 20 years, from 21 up to 30 years, and from 31 up to 40 years. The equation describing the relationship between the diameter and age periods is also presented. As it can be seen from the graph in **Figure 2**, *at the age of 40 years, the average diameter of the studied plantings reaches 9.8 cm at the height of 1.3 m.*
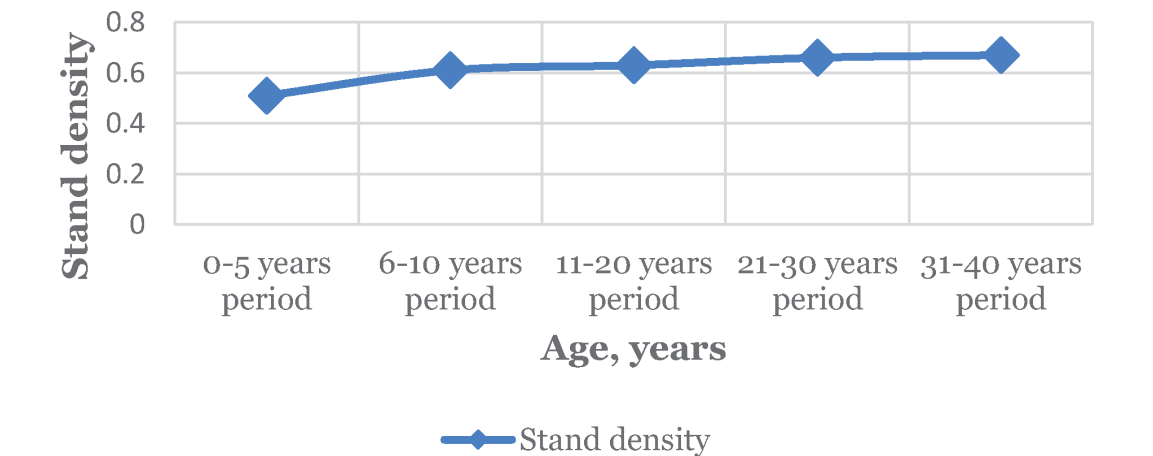

Figure 3.
Dynamics of changes in the relative basal area of young pine growth by age periods. The figure shows the relative basal area of trees (axis of ordinates) by age period up to 5 years, from 6 up to 10 years, from 11 up to 20 years, from 21up to 30 years, and from 31 up to 40 years. The equation describing the relationship between the basal area and age periods is also presented. The density of plantings allows forming quite productive stands.
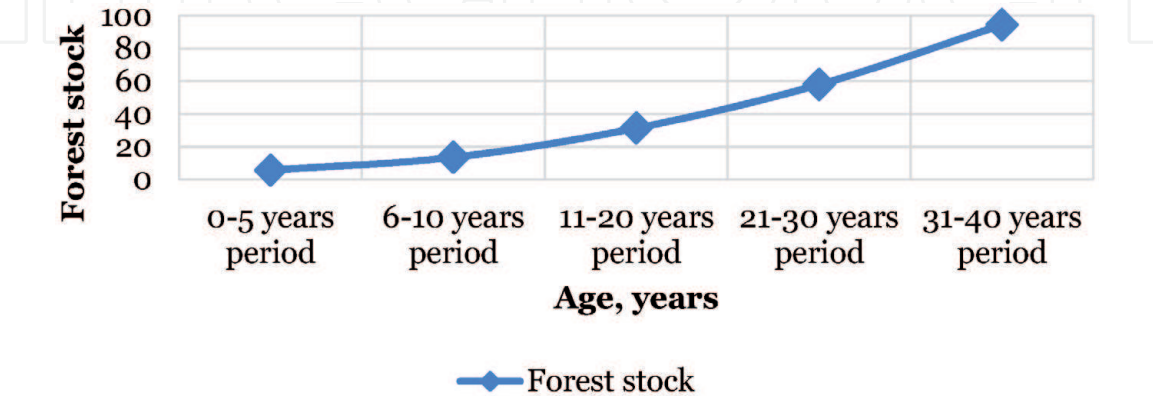

Figure 4.
Dynamics of changes in the growing stock of young pine growth per 1 hectare by age periods. The figure shows the growing stock of stands per 1 hectare in cubic meters (axis of ordinates) for age periods up to 5 years, from 6 up to 10 years, from 11 up to 20 years, from 21 up to 30 years, and from 31 up to 40 years. The equation describing the relationship of the growing stock by age periods is also presented. According to **Figure 4**, *it can be assumed that by the age of logging, the stand can form a fairly good operational reserve.*
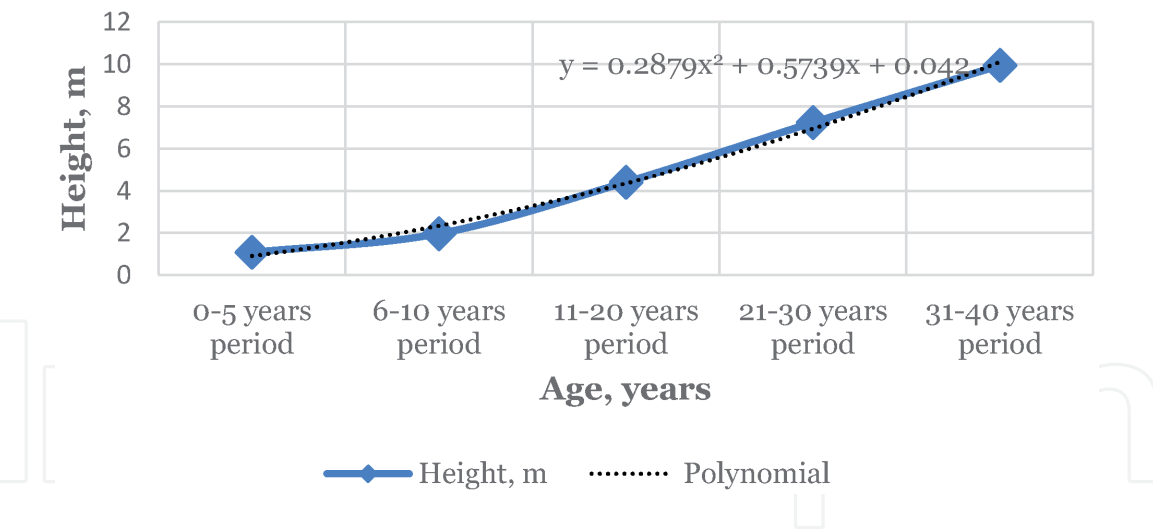
The chart shows Height in meters on the ordinate axis (ranging 0 to 12) versus Age periods. The polynomial equation shown: $y = 0.2879x^2 + 0.5739x + 0.042$

Figure 5.
Dynamics of changes in the height of young larch plants by age periods.

The chart shows Diameter in cm on the ordinate axis (ranging 0 to 10) versus Age periods. The polynomial equation shown: $y = 0.157x^2 + 1.365x - 1.35$
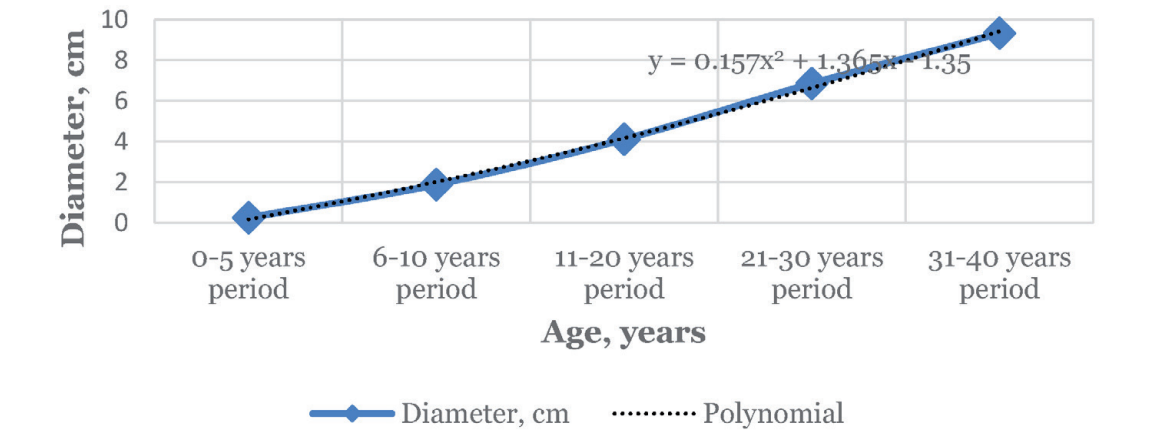
Figure 6.
Dynamics of changes in the average diameter of young larch plants by age periods. The figure shows the diameter of trees in centimeters (axis of ordinates) for age periods up to 5 years, from 6 up to 10 years, from 11 up to 20 years, from 21 up to 30 years, and from 31 up to 40 years. The equation describing the relationship of diameter by age periods is also presented.
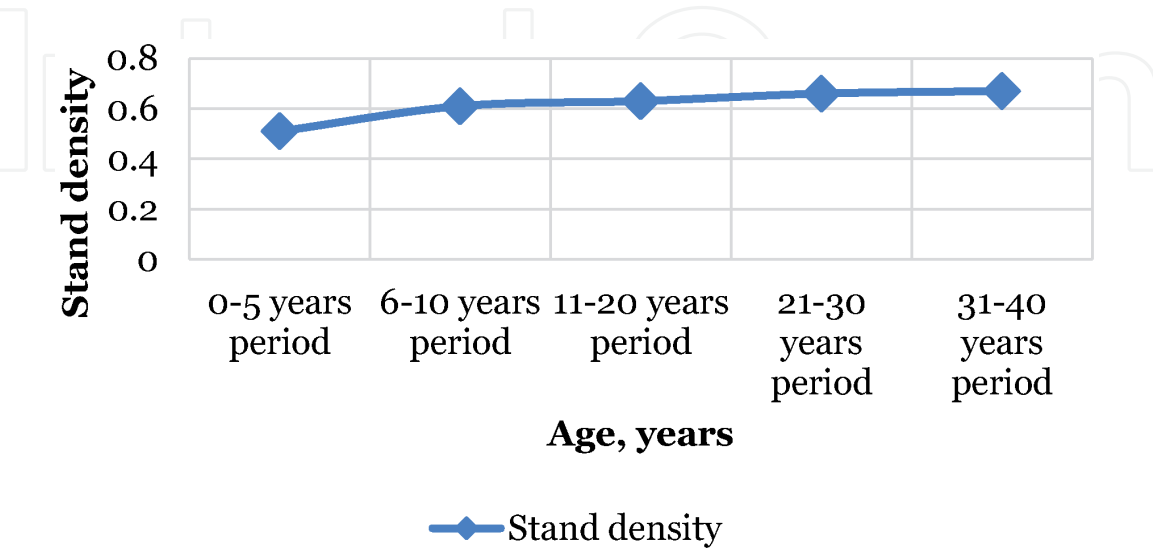

The chart shows Stand density on the ordinate axis (ranging 0 to 0.8) versus Age periods.

Figure 7.
Dynamics of changes in the relative basal area of young larch growth by age periods. The figure shows the relative basal area of trees (axis of ordinates) by age period up to 5 years, from 6 up to 10 years, from 11 up to 20 years, from 21 up to 30 years, and from 31 up to 40 years. The equation describing the relationship of basal area by age periods is also presented.
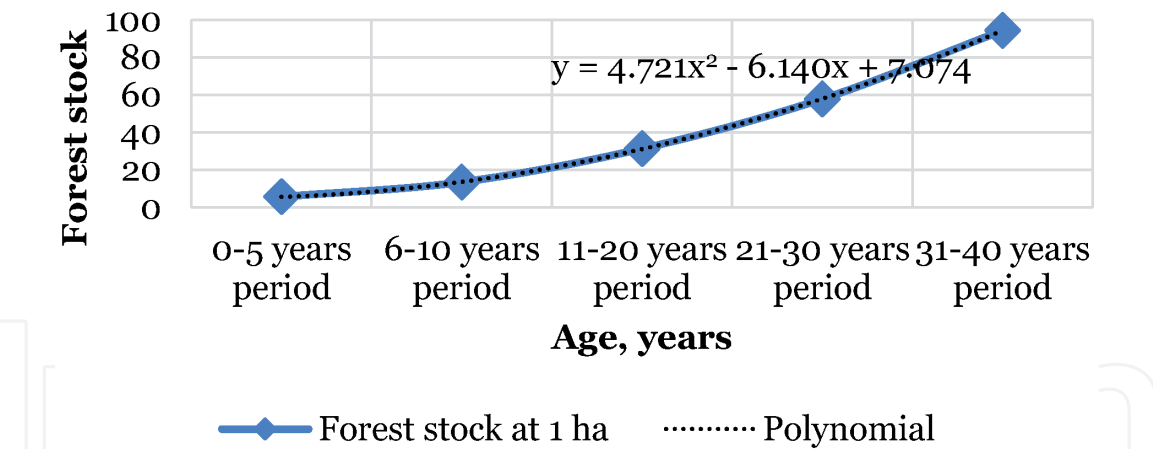
5

$$y = 4.721x^2 - 6.140x + 7.074$$

Figure 8.
Dynamics of changes in the growing stock per 1 hectare of young larch growth by age periods. The figure shows the growing stock of stands per 1 hectare in cubic meters (axis of ordinates) for age periods up to 5 years, from 6 up to 10 years, from 11 up to 20 years, from 21 up to 30 years, and from 31 up to 40 years. The equation describing the relationship of the growing stock by age periods is also presented.

plots with a total area of 14.25 hectares, as well as statistical processing of the taxation description at the plot of 128 hectares, while young growth of natural and artificial origin were studied.

As we can see from **Figure 1**, the height of young growth increases with age, while the most intensive increase in height occurs at the age period from 21 up to 40 years. The maximum height of a pine tree at the age of 40 is approximately 10 m, which corresponds to bonitet class III.

Figure 2 shows the dynamics of changes in the average diameter of young growth of trees by age periods. From the graph in **Figure 2**, it is possible to trace the dynamics of increasing the average diameter from 0.37 to 9.5 cm at the age of 40.

Figure 3 shows the dynamics of relative density and basal area of young pine growth by age periods. It is interesting that the average density of the stand at the age of 1–10 years is relatively small (0.5–0.55), and by the age of 40 years, the basal area reaches a value of 0.76. Such young plants can already be referred to high-density plantings.

Figure 4 shows the dynamics of changes in the growing stock of young pine growth per 1 hectare by age periods. At the age up to 10, it was impossible to determine the growing stock because there are no volume tables for such thin-sized stems. The period from 21 up to 40 years is characterized by a significant increase in the average stock per 1 hectare and reaches a value of up to 115.9 cubic meters per 1 hectare.

Figures 5–**8** show generalized results of studies of young larch growth for different age periods. The materials obtained at the sample plots and as a result of processing the taxational descriptions of the Padunsky forest area of the Irkutsk region are statistically processed and generalized. As it can be seen from the figures, the inventory indices differ somewhat from the inventory indices of young pine growth.

The figure shows the height of trees in meters (axis of ordinates) for age periods up to 5 years, from 6 up to 10 years, from 11 up to 20 years, from 21 up to 30 years, and from 31 up to 40 years. The equation describing the relationship of height and age periods is also presented.

Figure 5 shows the dynamics of changes in the height of young plants by age periods. The change in height can be described by a logarithmic curve with sufficient accuracy (correlation coefficient 0.99). The maximum height at the age of 31–40 years is 10 m, which exactly corresponds to the height of pine trees of the

same area. These results prove the successful co-growth of Scots pine and Siberian larch as light-loving tree species that are biologically well compatible throughout pathogenesis.

Figure 6 shows the change in the average diameter of young larch trees by age periods. The relationship of the dynamics is also described by a polynomial curve, with a maximum diameter of 9.5 m, which also corresponds to the data on pine trees. This coincidence indicates a good compatibility of pine and larch as light-loving and fast-growing tree species.

Figure 7 shows the dynamics of changes in the relative basal area of young larch growth by age periods. The stand density is relatively low and ranges from 0.5 to 0.67, which is lower than that of the Scots pine. This is due to the more powerful root system of the larch which requires more space to accommodate.

Figure 8 shows the dynamics of changes in the growing stock of 1 hectare of young larch growth by age periods. This relationship is relatively well described by a polynomial curve with a high degree of accuracy. The growing stock per 1 hectare is small and reaches 95–100 cubic meters per 1 hectare which is lower than that of young pine trees which can also be explained by the relatively small stand density. However, larch at the age of maturity can reach a large stock (up to 500 m^3), which is higher than that of pure stands of Scots pine at the same age.

A sample plot in the Kuitun forest area of the Irkutsk region was selected as an example of creating mixed forest cultures of Siberian larch and Scots pine. Forest cultures were created at the site of the fire. The area of forest cultures is 214 hectares; forest cultures were created by sowing in 1997. Currently, the age of forest crops is 21 years. When creating forest crops, a partial pre-sowing preparation of the soil was carried out with PLP-135 plow. The distance between the furrows is 2 m, and the width of the plowed furrow is 1.3 m. The scheme for creating forest crops is shown in **Figure 9**.

The plot has the type of forest vegetation conditions B2 with fresh sandy loam soil, the forest is of the cowberry-grass type. The seeds were purchased in the Republic of Tuva (Kyzyl). Pine and larch seeds have the 1 class of quality. Sowing was carried out in spring, when sowing the seeds were evenly mixed in the proportion of 70% larch and 30% pine. Seeding was carried out manually in rows. The seedlings sprouted perfectly, and now we have an excellent example of creating mixed larch-pine forest crops.

Figures 10 and **11** show photos of experienced larch and pine forest crops. The photo shows that the larch is taller than the pine. The trunks are flat and fully wooded. Thinning in rows is required, as overgrown forest crops are too dense in the rows (**Figure 11**).
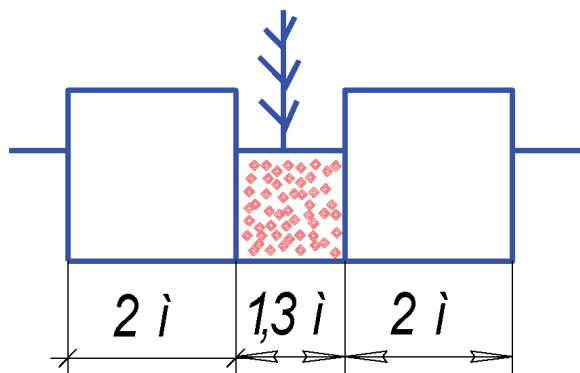

Figure 9.
Diagram of the creation of mixed forest crops.

Figure 10.
Experimental mixed forest cultures of larch and pine (the current composition of 7L3S).

Figure 11.
The state of forest crops in a row.

For a detailed study, four sample plots of 0.5 ha were established in forest crops. The number of trees in the test areas was 1300–1400, which is enough for statistical processing of materials. Processing of materials was carried out separately for the elements of the forest—larch and pine. The general characteristics of forest crops at sample plots are presented in **Table 1**.

Age and composition	Type of forest and type of vegetation conditions	Average height, m	Average diameter, cm	Average site index (bonitet), class	The average relative basal area	Average stock per 1 ha	Area, ha
21 year 7Л3С	Cowberry /B$_2$	10.1 ± 0.30	8.7 ± 0.32	1.5	0.77 ± 0.22	73.6 ± 3.22	.0.4
Larch	Cowberry /B$_2$	11.3 ± 0.50	9.3 ± 0.41	1.0	0.56 ± 0.17	51.7 ± 2.11	0.4
Pine	Cowberry /B$_2$	8.9 ± 0.25	8.1 ± 0.34	3.0	0.21 + 0.05	21.9 ± 0.95	0.4

Table 1.
Average taxation indicators of mixed forest crops of larch and pine.

D1,3	The number of trees, pieces/%	Average height, m	Cross-sectional area of one trunk, m^2	Sum of cross-sectional areas of stem diameter, m^2	Volume of one trunk, m^3	Volume of stem diameter, m^3
4	337/7.9	5.2 ± 0.2	0.0013	0.4381	0.0037	1.2469
6	1283/30.5	6.8 ± 0.3	0.0028	3.5924	0.0101	12.9583
8	1206/28.5	8.5 ± 0.4	0.0050	6.0300	0.0261	31.4766
10	874/20.7	10.7 ± 0.5	0.0078	6.8172	0.0261	22.8114
12	302/7.2	11.5 ± 0.5	0.0113	3.4126	0.0672	20.2944
14	218/5.2	12.0 ± 0.7	0.0154	3.3572	0.0672	14.2464
Total per 2.0 ha	4220/100.0			23.6475		103.034
Total per 1 ha	2110			11.8275		51.51

Table 2.
The results of the inventory of larch trees at the sample plots.

For more detailed information on the tax indicators, the total data for four sample areas is given. The total area of the inventory was 2.0 hectares. **Table 2** shows the inventory indices of larch.

The average cross-sectional area of one tree is 0.0068 m^2, the average diameter is 9.3 cm, the average height is 11.3 m, and the relative basal area is 0.56; the bonitet class is first, the growing stock per 1 ha is 51.5 m^3, and the average volume of the tree is 0.0245 cubic meters.

Figure 12 shows the relationship between the height and diameter for larch at the sample plots.

As we can see from **Figure 12** and **Table 2**, the height and diameter are interrelated. The height ranges from 5.2 to 12.0 m. As an example, **Figure 13** shows the distribution of the number of trees by stem diameter at sample plot 2.

On the ordinate axis, you can see the percentage of the total number of trees and on the abscissa axis, the diameter at the height of 1.3 m in centimeters.

As we can see from **Figure 13**, the distribution does not follow the normal distribution curve, and the trees with a diameter of 6–10 cm prevail. However, it should be noted that there are trees with a diameter of 12 and even 14 cm.
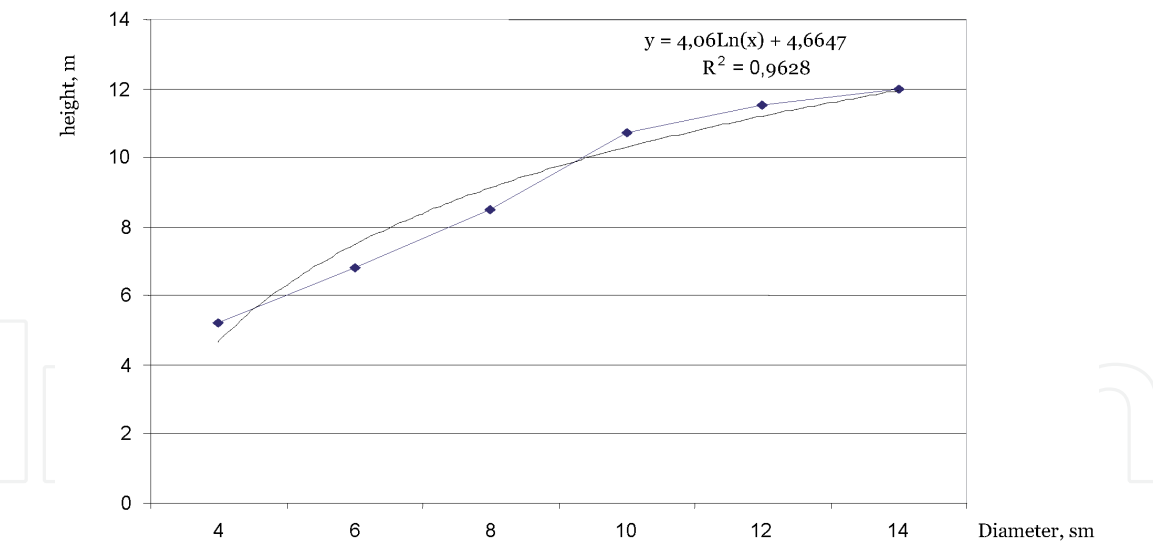
Figure 12.
Relationship of height and diameter in experimental larch forest cultures. On the ordinate axis, the height is in meters; on the abscissa axis, the diameters are in centimeters.
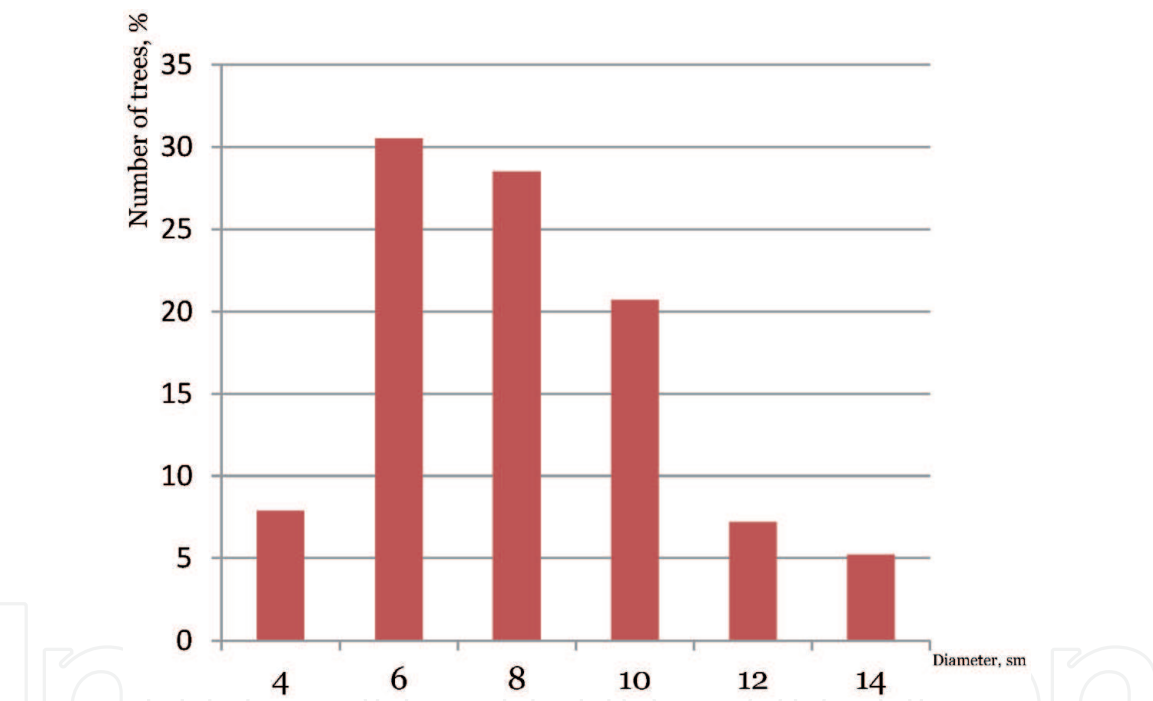

Figure 13.
Distribution of the number of larch trees by stem diameter.

Table 3 shows the total data for four sample plots of pine trees.

The average cross-sectional area of one pine tree is 0.006 m^2, the average diameter is 8.1 cm, the average height is 8.7 m, the relative basal area is 0.21, the bonitet class is third, and the growing stock of pine for 1 hectare is 18.5 m^3. The total growing stock of larch and pine per 1 hectare is 70.02.

Figure 14 shows the relationship between the height and diameter for pine trees at the sample plot.

As it can be seen from **Figure 14** and **Table 3**, the relationship between the height and diameter has a fairly high degree of correlation R2 = 0.9323, and the height of the pine tree ranges from 5.8 to 11.7 m. As an example, **Figure 15** shows the distribution of the number of pine trees by stem diameter at sample plot No 2.

As it can be seen from **Figure 15**, the distribution of pine by stem diameter approximates the normal distribution curve. Most pine trees are from 6 up to 10 cm in

D1,3	The number of trees, pieces%	Average height, m	Cross-sectional area of one trunk, m^2	Sum of cross-sectional areas of stem diameter, m^2	Volume of one trunk, m^3	Volume of stem diameter, m^3
4	141/7.9	5.8 ± 0.2	0.0013	0.1833	0.0010	0.1410
6	539/30.1	7.0 ± 0.3	0.0028	1.5092	0.0107	5.7673
8	527/29.6	8.1 ± 0.4	0.0050	2.6350	0.0225	11.8575
10	438/24.5	10.9 ± 0.54	0.0078	3.4164	0.0225	9.8550
12	143/7.9	11.7 ± 0.58	0.0113	1.6159	0.0657	9.3951
Total per 2.0 ha	1788			9.3598		37.0159
Total per 1 ha	894	8.7 ± 0.4	0.006	4.6799	0.00244	18.5079

Table 3.
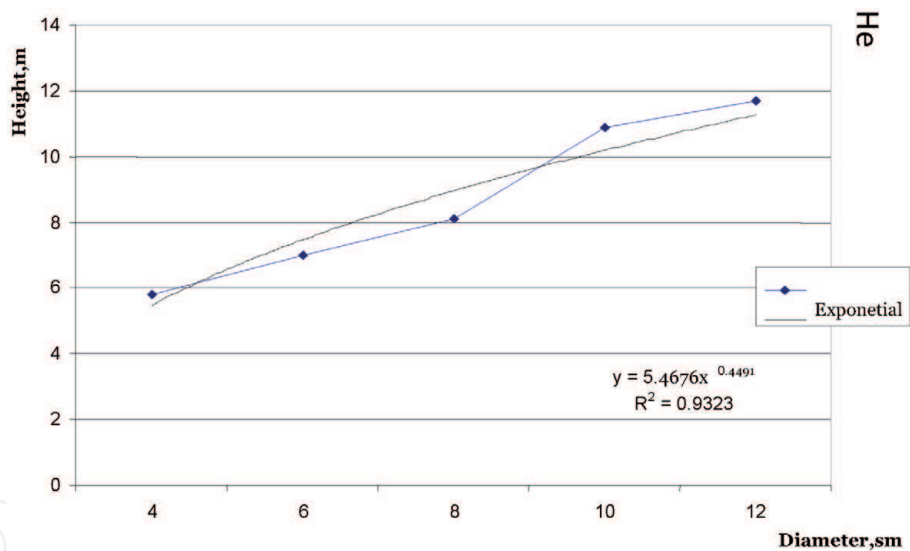*The results of the inventory indices of pine at the sample plots.*

Figure 14.
Relationship of height and diameter of experimental pine forest crops. On the ordinate axis, we can see height in meters and on the abscissa axis, diameter at the height of 1.3 m in centimeters.

diameter. It is important to track the dynamics of growth in height for pine and larch. In **Table 4** data on the annual growth of larch and pine for the last 2 years are given.

As it can be seen from **Table 4**, larch has the highest annual growth in height, and for 2016 and 2017, the increase is higher than the average total growth which is 0.42 m on average, and the increase in height over the past 2 years for some trees reaches 0.61 m. The average total increase for 21 years is 0.42 (column 4). Let us consider the growth in height of pine trees.

The average total increase for 21 years is 0.33 (column 4). As it can be seen from **Table 5**, the pine tree also has a good annual growth in height, and for 2015 and 2016, the growth is higher than the average total growth, which on average is 0.033 m, and the growth in height over the past 2 years for some stem diameter reaches 0.60. On average, the growth of pine is lower than that of larch.
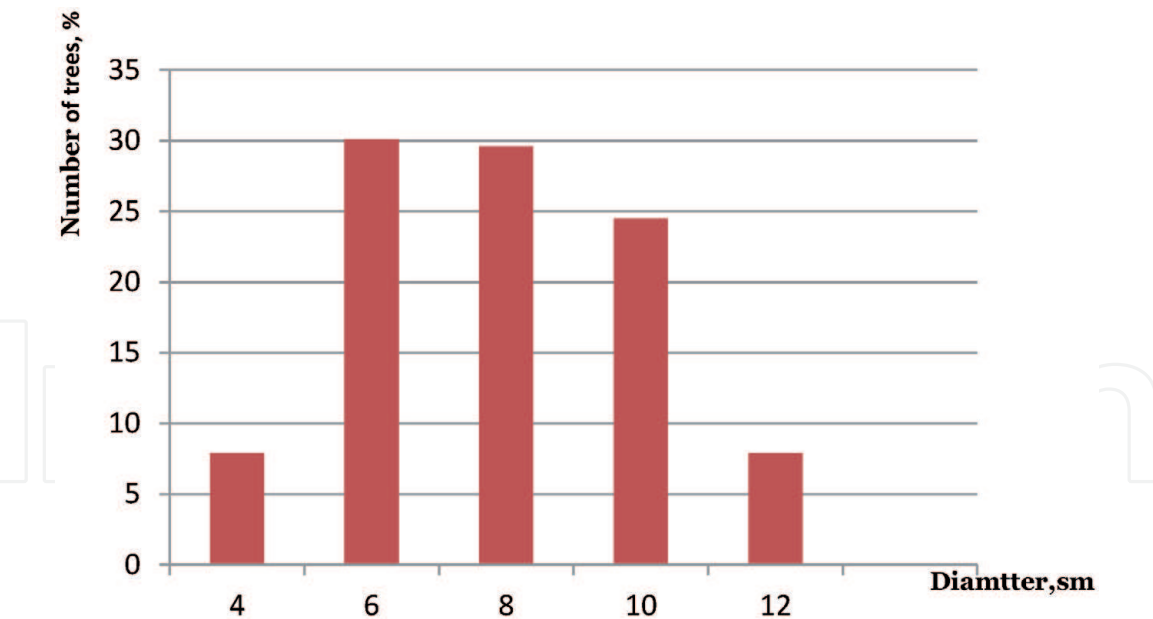
Figure 15.
Distribution of the number of pine trees by stem diameter. On the ordinate axis, we can see the percentage of the total number of trees and on the abscissa axis, the diameter at the height of 1.3 m in centimeters.

Tree view	D1,3	Growth in height, 2015, m	Growth in height, 2016, m	Average total height increase, m
1	2	3	4	5
Larch	4	0.28 ± 0.05	0.21 ± 0.05	0.19 ± 0.05
	6	0.38 ± 0.05	0.23 ± 0.05	0.25 ± 0.05
	8	0.38 ± 0.05	0.36 ± 0.05	0.31 ± 0.05
	10	0.61 ± 0.05	0.60 ± 0.05	0.40 ± 0.05
	12	0.63 ± 0.05	0.61 ± 0.05	0.43 ± 0.05
	14	0.63 ± 0.05	0.60 ± 0.05	0.44 ± 0.05
Average result		0.48 ± 0.5	0.44 ± 0.05	0.42 ± 0.05

Table 4.
Annual growth of the larch in height according to the materials of sample plots.

Tree view	D1,3	Growth in height, 2015, m	Growth in height, 2016, m	Average total height increase, m
1	2	3	4	5
Pine tree	4	0.23 ± 0.03	0.21 ± 0.03	0.21 ± 0.03
	6	0.28 ± 0.05	0.20 ± 0.04	0.26 ± 0.05
	8	0.34 ± 0.08	0.34 ± 0.07	0.30 ± 0.06
	10	0.56 ± 0.07	0.56 ± 0.09	0.40 ± 0.07
	12	0.58 ± 0.08	0.60 ± 0.09	0.43 ± 0.09
Average result		0.38 ± 0.062	0.38 ± 0.064	0.33 ± 0.06

Table 5.
Annual growth of pine trees by height based on the materials of sample plots.
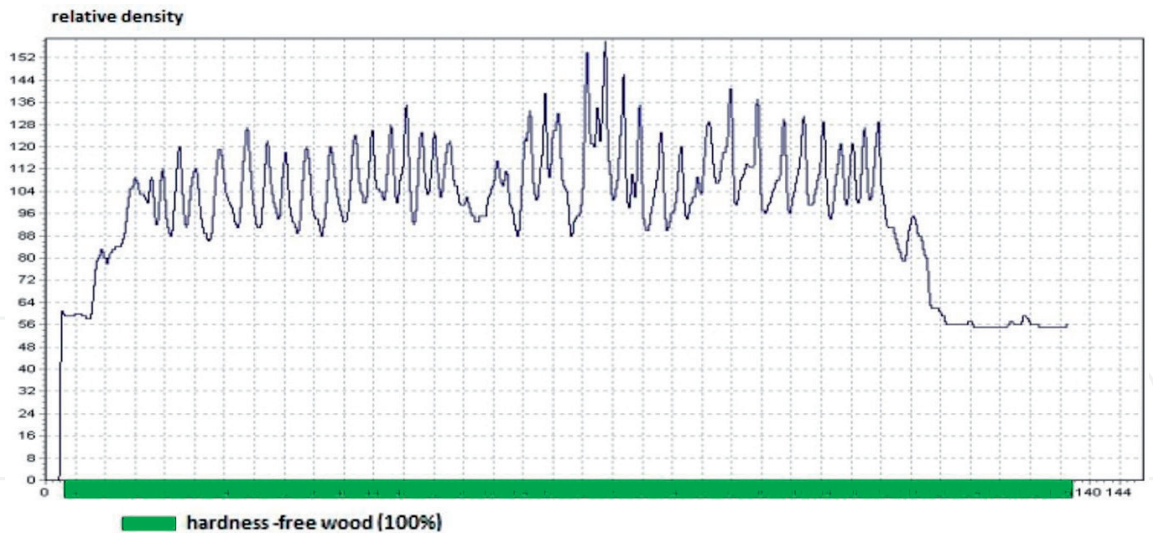
Figure 16.
Resistograms of Siberian larch. On the ordinate axis, we can see the relative density of Siberian larch wood according to the Resistograph 4450 device and on the ordinate axis, the diameter at the base of the tree in centimeters.

Figure 17.
Resistograms of scots pine. On the ordinate axis, we can see the relative density of Siberian larch wood according to the Resistograph 4450 device and on the ordinate axis, the diameter at the base of the tree in centimeters.
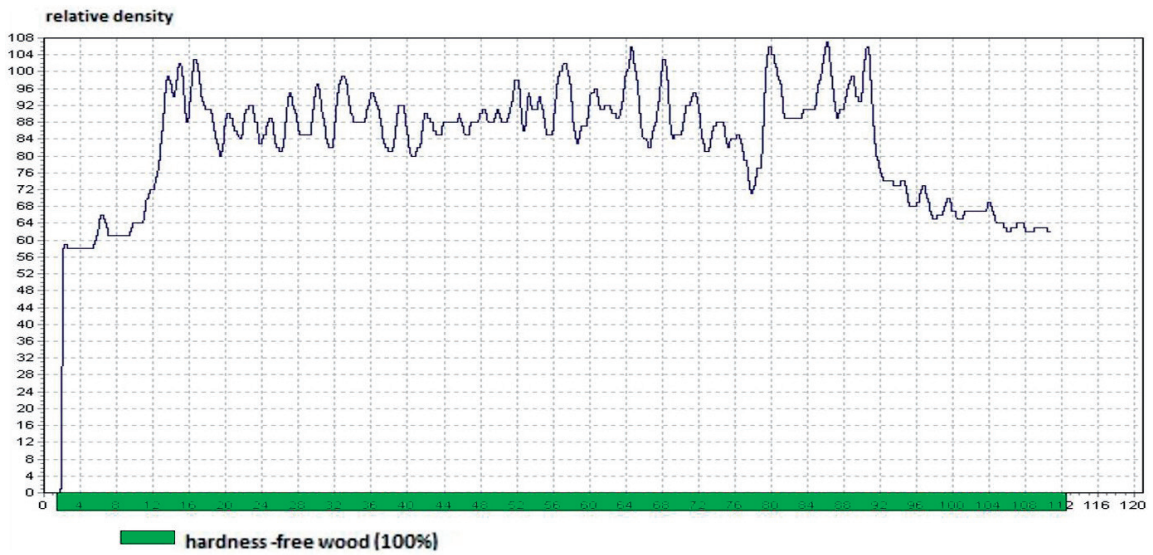
Additionally, using the Resistograph 4450 device, the quality of the wood was evaluated by examining the cross section of test pine and larch trees (40 trees in total). Resistograms showed high strength indicators of the cross section of a tree in the butt part without signs of a decrease in the hardness of the wood (**Figure 16**).

From the resistogram (**Figure 16**), it can be concluded that the Siberian larch wood is healthy, there are no pathologies, and there is a significant decrease in the strength; the presence of rot is not observed. The difference between the relative density of early wood (60 for early wood) and late wood (162 for late wood) is particularly clear. The drop in the relative density values at the beginning and at the end of the resistogram shows the passing through the bark of the studied cross sections of the tree.

From **Figure 17** it can be seen that the wood is healthy and there are no any pathologies. The difference in the relative density of early and late wood is less than that of larch and ranges from 60 for early wood to 108 for late wood. On the basis of comparison of the resistograms, we can conclude that the relative density of late wood of Siberian larch is about 50% higher than that of Scots pine.

4. Chapter conclusions

The studies conducted to identify the growth and structure of wood of experimental mixed forest crops allow us to draw the following conclusions:

1. The main inventory indices of mixed pine-larch stands, including the composition of stands, are formed in the cowberry and cowberry-mixed grass and mixed types of forest at the young age.

2. Young trees in these types of forests have an average productivity that is approximately equal to bonitet class III; mixed young trees of pine and larch represent stable stands with high biological diversity.

3. Experimental mixed forest crops of pine and larch with the total area of 214 hectares, established in the Irkutsk region, indicate that pine and larch by the age of 21 have good growth and development. At the same time larch is higher than pine and can grow up to bonitet class 1.

4. The closure in the rows is high; in general, per 1 hectare the stand density is 0.77 which means that in the rows the density is more than 1.0. In these forest crops, thinning is required to provide additional opportunities for growth and development of forest crops [12, 13]. It is recommended to expand the creation of mixed pine-larch and larch-pine forest crops both by sowing and planting.

5. In forest cultures, slender full-wood trees are formed with good physical and mechanical properties of wood. Thinning young plants (a sufficiently high degree of thinning 35–50%) can achieve more uniform placement of trees in rows, which will increase diameter and height, reduce the severity of intra- and interspecific competition, and increase the productivity of experimental forest crops. It is also recommended to practice creating mixed forest crops of pine and larch by sowing or planting in appropriate forest-growing conditions, thereby preserving larch as the predominant tree species of Russian forests and increasing the biological diversity of light taiga forests in Eastern Siberia [7–9].

6. The prospects for further development of research should be seen in a further study of the growth and development of light-coniferous mixed stands in the Irkutsk region of the Angara region in the design and construction of a mathematical model for the dynamics of light-coniferous taiga plantations with the aim of increasing their biological stability and productivity, as well as improvement of the quality of the trunk and tree canopy and physicomechanical properties of wood of pine and larch, silvicultural measures in particular to optimize the quantity of sowing and planting, and commercial thinning in young stands improving the composition and quality characteristics of pine and larch stands.

5. Gratitude

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