Siberian cedar in subordinate crops

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Abstract. The growth indices of the 56-year-old Siberian cedar, which grows in forest crops under the forest stand canopy of Pinus sylvestris and Betula pendula when the canopy closed 0.1–0.4; 0.5–0.7; 0.8–0.9 and the number of survived specimens in the sites (from 1 to 8 pcs.) in the suburban area of Krasnoyarsk. Initially, in each area measuring 0.7x0.7 m, 9 pieces of four-year-old seedlings were planted under the Kolesov’s planting iron, placing them at a distance of 20 cm. There is a distance of 4 m between the centers of the sites. It was found that indicators of leading trees such as height, diameter of the trunk and crown significantly decrease with increasing closeness of the canopy (the share of the influence of canopy on the height of the leading trees amounted to 84.8%, to the barrel diameter - 91.3%). The share of the influence of the number of Siberian cedar trees preserved in the sites on the indicators of leading specimens is insignificant and amounted to 3.9% in height and 1.7% in trunk diameter. The creation of Siberian cedar cultures is recommended with a lesser density of the forest stand canopy or in an open area.

1. Introduction
The cultivation of forest crops under the forest stand canopy has a relatively long history. As far back as the 19th century, many foresters, starting with G. Gartig, recommended that seeding of fir-tree and other species should be planted under the canopy of sparse plantations. Subsurface crops are created under the canopy of low-density plantations to increase their productivity and sustainability. The production of such crops is aimed at converting light-deciduous stands (birch, pine, larch) into complex plantations that make better use of soil fertility and increase productivity of the stand. They are usually created in stands of II and III age classes. Important issues when creating sub-canopy crops of coniferous trees are planting density, closeness of the forest stand canopy, and others. So, in the work of M. D. Merzlenko and Yu. B. Glazunov [1], who studied the growth of fir-tree and Scotch pine crops with different planting densities, it is noted that at a density of 8 thousand pieces per ha, and the conservation rate was 37% of trees at the age of 30 and 10.5% of trees at the age of 65. The congestion of the stand not only reduces the radial growth of Siberian cedar, but also slows down the rate of ontogenetic stages and phases. The studies conducted in 12-year-old crops of Picea koraiensis with different planting densities showed that in the plantation, where there are more than 1800 trees per 1 ha, the growth and biomass of the tree decreased [2].

The growth rates of the sub-soil crops of Scotch pine and Sukachev’s larch in the Southern Urals, depending on the completeness of deciduous trees, were shown in the work of S.V. Zalesov, et al. [3]. A.A. Malenko and V.A. Usoltsev [4] examined nesting cultures of Scotch pine in the Klyuchevsky forestry of Altai Krai at the sites laid by L. N. Gribanov in 1948. In 56 years after planting, regardless
of density (4000-40000 pcs/ha), only 8-12% of the leading trees are inside the sites, and in 88-92% of cases they are located in their peripheral part.

Similar studies are carried out with Siberian cedar (*Pinus sibirica* Du Tour), which is a unique forest-forming species in Siberia, appreciated by its high forestry and environmental properties, pine nuts, and forms straight-stem wood used in the furniture industry and others [5, 6].

Growing Siberian cedar is carried out both in the area and beyond [7-10, etc.].

A comparison of the growth of Siberian cedar in forest cultures and undergrowth under the forest canopy was carried out by N. Yu. Stashkevich [11], as a result of which a significant lag in the growth of Siberian cedar undergrowth was established in comparison with forest crops growing in the open area.

In the work of O.V. Leskova, et al. [12], indicators of Siberian cedar, which grows when planted by bio groups of 5 pieces, in a seat and in rows (1 pce), are reflected. The best growth of Siberian cedar is noted with the growth of 2-3 plants per seat in the conditions of the Forest Zavolzhye.

Comparing the agrotechnics of growing Siberian cedar in the conditions of the Tomsk Region, N.M. Debbkov and V.S. Panevin [13] recommend increasing their illumination to accelerate the growth of Siberian cedar by clear-cutting of a forest with high efficiency and removing broadleaved species.

A.M. Danchenko and I.A. Bekh [14] in the crops of Siberian cedar, created under the canopy of birch plantations and in the open area, noted the most intensive growth of crops in the open area and the acceleration of growth of the Siberian cedar in sub-pathological cultures after removal of birches, aspens and pines.

The aim of our research was to study the joint influence of two factors, such as the closeness of the forest stand canopy and the number of preserved plants in the sites, on the growth rate of the leading Siberian cedar trees of 56 years old in the crops of the suburban zone of Krasnoyarsk (south Central Siberia).

2. Methods and materials

Subliminal crops of Siberian cedar were created in the spring of 1966 at the Training and Experimental Forestry of Siberian State University led by O. P. Olisova [15].

Four-year-old seedlings were used as planting material. Planting was carried out in platforms with a distance of 4 m between the centers. In seedlings of 0.7 x 0.7 m in size, 9 seedlings were planted under the Kolesov’s planting iron; the distance between them was 20 cm. By the time of accounting, the canopy density of Scotch pines and drooping birches were ranged from 0.1 to 0.9. It was determined ocularly in fractions of a unit by the method of N.P. Anuchin [16].

In each site, the leader trees were identified that have the highest indicators for height and trunk diameter. In the trees leading in each site, the height, trunk diameter at a height of 1.3 m, and crowns were measured. The significance of differences in the indicators between the options was determined by the actual t-criterion in comparison with the table at 5% significance level. A correlation analysis was carried out, establishing the presence, tightness of the connection, and the share of the influence of factors on the indices of Siberian cedar trees. Data processing was carried out using the Excel, Word software package.

3. Results and discussion

The studies have shown that in sub-soil crops, the safety of sites with planted specimens of Siberian cedar was 85-95%. In the sites, 1-8 species were preserved instead of 9 planted species.

When assessing the influence of the forest stand canopy, it was revealed that with closeness of 0.1-0.4 and 0.5-0.6, the difference in the number of preserved Siberian cedar trees in the sites is insignificant: 3.7 and 3.8 pcs., when closeness is 0.7 and above, their average number decreased to 3.2 pcs., i.e. by 13.5-15.8%.

Such biometric indicators as height, diameter of the trunk and crown of the leader trees differ significantly depending on the closeness of the forest stand canopy (table 1).
Table 1. The effect of closeness of the forest stand canopy on the indicators of Siberian cedar.

| Closeness of forest stand canopy | Height $X_{m}$ (m) | $t_f$ | Trunk diameter $X_{m}$ (cm) | $t_f$ | Crown diameter $X_{m}$ (m) | $t_f$ when $t_{30} = 2.00$ |
|----------------------------------|-------------------|-------|-----------------------------|-------|-----------------------------|-----------------------------|
| 0.1-0.4                          | 11.5±0.36         | -     | 11.0±0.38                   | -     | 3.0±0.07                    | -                           |
| 0.5-0.6                          | 9.1±0.32          | 4.98  | 8.2±0.27                    | 6.01  | 2.6±0.09                    | 3.51                        |
| 0.7                              | 7.6±0.25          | 8.90  | 6.6±0.21                    | 10.13 | 2.4±0.10                    | 4.92                        |
| 0.8-0.9                          | 6.9±0.29          | 9.95  | 6.0±0.22                    | 10.99 | 2.2±0.09                    | 7.02                        |

The level of height variation, the diameter of the trunk and crown are medium and high (13.1-27.6%). All trees leading in the sites lag behind in height, trunk and crown diameters, growing with increased canopy closeness. The highest indices in the leading trees are observed in the case when the canopy density is 0.1-0.4.

With increasing closeness of the forest stand canopy from 0.1-0.4, the height of the trees decreased by 21.9-40.0%. The differences with 0.1-0.4 variant are significant, which is confirmed by the t-criterion ($t_f > t_{30}$). The barrel diameter decreased significantly with increasing canopy density by 25.5-45.5%, crowns - by 13.3-26.7%. The decrease in crown diameter is manifested to a lesser extent than the height and diameter of the trunk.

The correlation between the canopy density and the height, diameter of the trunk and crown in the variants with 1-2 trees is close ($r = -0.748-0.887$). In the experiment with 5-8 trees, the correlation coefficients had lower values (-0.623-0.709).

The studies have shown that the biometric parameters of trees are influenced by the light regime, which is mainly associated with the closeness of the forest stand canopy. It was noted that under different light conditions, the growth rate varies along the height and diameter of the trunk, which is consistent with the data of other authors [4, 11, 12].

The number of lateral branches on the lower whorl varied from 1 to 10 pieces and amounted to an average of 4.3 units per experiment at better illumination (0.1-0.5 closeness) and 3.7 pieces with greater closeness. At the same time, the crown is characterized by smaller annual growths and rare needle packing.

When analyzing the joint effect of the closeness of the forest stand canopy and the remaining trees in the site, it was found that with greater illumination (canopy density of 0.1-0.4), the maximum indicators were in the areas where one tree was preserved. A significant decrease in the height of the trees is confirmed in the variants where 7 Siberian cedar trees were preserved in the sites ($t_f = 2.43$). The diameter of the trunk decreases more markedly, starting with option of 4 trees and more in one area (table 2).

Table 2. The influence of closeness of the forest stand canopy on the growth of Siberian cedar with different preservation in the sites.

| Closeness of forest stand canopy | Number of trees in the site, pcs. | Height $X_{m}$ (m) | $t_f$ | Trunk diameter $X_{m}$ (cm) | $t_f$ |
|----------------------------------|-----------------------------------|-------------------|-------|-----------------------------|-------|
| 0.1-0.4                          | 1                                 | 12.2±0.37         | -     | 12.8±0.39                   | -     |
|                                  | 4                                 | 11.2±0.34         | 1.99  | 10.2±0.41                   | 4.59  |
|                                  | 7                                 | 11.1±0.26         | 2.43  | 11.0±0.31                   | 3.66  |
| 0.5-0.6                          | 1                                 | 8.8±0.47          | 0.49  | 8.2±0.40                    | 0.00  |
|                                  | 4                                 | 9.1±0.39          | -     | 8.2±0.48                    | -     |
|                                  | 7                                 | 8.4±0.41          | 1.24  | 7.5±0.37                    | 1.16  |
| 0.8-0.9                          | 1                                 | 6.0±0.31          | 1.56  | 6.0±0.18                    | -     |
|                                  | 4                                 | 6.7±0.30          | 0.20  | 5.9±0.28                    | 0.30  |
|                                  | 7-8                               | 6.8±0.41          | -     | 5.6±0.21                    | 1.45  |
With a greater canopy density of 0.5-0.6, high trees have a smaller trunk diameter (by 9.3%) in areas with 7 trees. Differences in height and diameter of the trunk when the canopy is 0.8-0.9 with a different number of preserved Siberian cedar trees in the site are within the error range. The high variability of biometric indicators is due to competitive relationships with pines and birches, as well as intraspecific in the sites. According to the data of O.V. Leskova, et al. [12], Siberian cedar in biogroups of 2-3 trees per plant has the best indicators. The high resistance of plants in biogroup plantings to recreational effects and adverse environmental factors, which ensures their better preservation, intensive growth is noted.

The share of the influence of canopy density on the height and trunk diameter of the leading Siberian cedar trees is high and amounted to 84.8 and 91.3%, respectively; the number of trees preserved in the site is insignificant and equal in height to 3.9%, trunk diameter to 1.7%.

Since 1–8 trees at the age of 56 survived in the sites, the analysis of the growth of not only leading, but also neighboring trees growing with them in the site was made. With a canopy of 0.1-0.7, in some areas of 9 planted trees, up to 8 were left, while with increased density (0.8-0.9), the maximum number of surviving specimens was 4.

With a canopy of 0.1-0.4, the average height of trees adjacent to the leaders in the sites was 2.0 times lower, the trunk diameter was 2.1 times less; when the canopy density is 0.5-0.6, the height of the trees is 1.8 times lower, the trunk diameter is 1.7 times; with a canopy of 0.8-0.9, the height and diameter of the trunk is 1.5 times less than that of leaders.

Both leading and neighboring Siberian cedar pine trees are significantly behind in height and trunk diameter when they are grown under the forest canopy with increased canopy density.

4. Conclusion

With an increase in the forest stand canopy density from 0.1-0.4 to 0.8-0.9, the height of the trees decreases 1.7 times, the trunk diameter decreases 1.8 times, the crowns decrease 1.4 times. The indicators of leading trees at this age are almost independent of the number of surviving specimens in the site. When creating subsurface crops of Siberian cedar, it is advisable to give preference to stands with a low canopy density or to create them in the open site.

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