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PRODUCTIVITY OF FOREST PLANTATION CROPS

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Abstract. Reduction of time for commercial wood cultivation and increasing the productivity of plantations is an urgent direction of scientific research considering supply of forest resources in the country and the growing need for timber. One of the ways of intensive forest reproduction is the creation of forest plantation crops. Plantation of forest crops involves the cultivation of technically valuable tree species in a shorter period of time. Our country has experience in the creation of forest plantation crops, but due to the reorganization in the forest industry, many areas were left without proper care. However, for 34 years research scientists at the Mytischi Branch of the Bauman Moscow State Technical University (formerly Moscow State Forest University) have been systematically monitoring the growth and development of spruce forest crops created in 1984 with intermediate agricultural use between the rows. The method of creating test crops is aimed at providing the most favorable conditions for growth and development of the main tree species in the first years after planting, the use of the natural growth of plantations during the entire period of crops cultivation, cost optimization for frequent silvicultural care, obtaining stands with high economic and aesthetic properties, prevention of wood defects. The article presents the technology of creating spruce crops, which is a distinctive feature of this method. We analyzed changes in the diameters and heights of trees grown by creating forest crops in the traditional way and with the use of intermediate agricultural use between the rows. The reliability of differences in the average values of independent samples was assessed, confirming the advantage of the spruce test crops. Their species composition is 100 % spruce, the absolute taper of which is 2.13 times less than those created by the traditional method. A higher probability of obtaining trunks with a volume of more than 0.02 m^3 by creating test crops has been established. The results of statistical processing of experimental data indicate the prospects of the method of planting spruce forest crops with intermediate agricultural use between the rows, which contributes to the formation of high-quality stands.
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Introduction

For reliable development of forest plantations with preservation of forest functions, it is necessary to address the issue of their reproduction in all areas of felled and dead trees, and therefore a reasonable choice of method of reforestation is required. The country's forests are heterogeneous not only in terms of forest-growing features, but also in terms of national economic significance. In this regard, a template approach is not allowed when deciding on a reforestation method. The creation of forest crops is possible on the basis of the organization of science-based technology of artificial reforestation. Forest crops created for the accelerated production of round timber are of particular interest all over the world [14–21].

The topic of relevance of agricultural use on forest lands was discussed at the 12th Forest World Congress held in Quebec (Canada) in September 2003. Productivity Commissioner in Australia Neil Byron noted the need for an integrated approach to reforestation, creation of plantations of forest crops, protection of biological diversity of aesthetic values, as well as environmentally conscious consumption. Rodney Keenan, spokesman of the Australian National University, noted the importance of forest plantations in Australia and the need to develop them on agricultural lands.

Plantation of forest crops involves the cultivation of technically valuable tree species in a short time. In this regard, the management of intermediate agricultural use in reproduction of forests can have a positive effect [7, 8, 10]. Continuous tillage of cuttings, which is preceded by uprooting stumps, is not widespread due to its high cost, the study of which is the task of the next stage of our research. However, many scientists have highlighted the high importance of using forest land for agricultural use, not only to obtain additional products for various purposes, but also to solve environmental problems by increasing the productivity and biological diversity of forest phytocenoses, zoocenoses, conservation and improvement of forest soils [2–5, 11–13].

It is also mentioned that the Forest code of the Russian Federation defines the creation of forest plantations of target species, referred to as forest plantations, as entrepreneurial activity. The current trend of intensification of forest use in Russia includes meeting the needs of the forest industry and aims to increase the economic impact of forest use [1, 9]. This causes mixed reviews from forestry experts and prevents investment in the creation of forest plantations of target species.

Until 1995, Russian foresters laid out 35 ths ha of plantation crops [6], but due to the reorganization of the forest industry, many areas were left without proper care. Most of the forest crops became low-quality and mixed, some of them died. However, in the areas created in 1984 plantation crops technology of planting and care was carried out in full volume and until now they are monitored.

Objects and methods of research

Given the uneven supply of forest resources in the country and the growing demand for commercial timber, there is a need to reduce the time of its cultivation. In this regard, the issue of the method of laying out forest crops is relevant.

The research purpose at the intermediate stage is a comparative assessment of growth and taperness rates, of single-age stands created by the method of intermediate agricultural use between the rows of forest crops (hereinafter – test crops) and the traditional method of planting in the bottom of the furrow (hereinafter – typical crops).

Monitoring the development of the created forest crops was carried out by forming 105 test areas measuring 16 m (length) by 30 m (width) and measuring the diameters of the trunk lower part of each tree growing on the test area: at the root collar, at a height of 0.5 m, 1.0 m, 1.3 m, 1.5 m, 2.0 m. The planting distance between seedlings was 0.75 m. The distance between the rows was 4 m. The altimeter was used to determine their height. Statistical data processing was performed.

During the study of test and typical spruce crops at the age of 34, the sample size of the trees selected for the survey was 11.6 %. Many times repeated indicators of the diameter of the tree at the root collar were grouped.

In the course of studying the project documentation and description of the experiment on laying out forest crops in 1984, it was found that in the studied forest areas before the continuous felling grew spruce (*Picea tumoxalidosum*), the species composition of which was represented by 5 aspens, 3 birches and 2 spruces (5A3B2S) with a single admixture of English oak (*Quercus robur* L.) and Norway maple (*Acer platanoides* L.). The plantation had the following valuation characteristics: I quality class, 70 years old, and 320 m^3/ha stockpile. Renewal of the predominant species European spruce (*Picea abies* (L.) H. Karst.) (hereinafter – spruce) under the canopy of the plantings was unsatisfactory (0.8 ths pcs/ha).

The growing conditions of the studied forest areas correspond to the category C2 – fresh relatively rich soil, sod-medium podzolic, medium loam on the cover loam. Mineralization of the studied areas is more than 70 %. Rush family-reedgras type of cutting with intensive development of grassy vegetation represented by the wood sorrel (*Oxalis acetosella* L.), hairy wood-rush (*Luzula pilosa*), ground-ivy (*Glechoma hederacea* L.), unspotted lungwort (*Pulmonaria obscura* Dumort.), squinancywort (*Asperula cynanchina* L.), snowdrop anemone (*Anemone silvestris* L.), and green mosses (*Rhytidiadelfus triquetrus* (Hedw.) Warnst, *Hylocomium splendens* (Hedw.) Schimp, *Pleurozium schraiberi* (Willd. ex Brid.) Mitt.). Development of natural plantings with prevalence of low-value deciduous species of aspen and alder is found. The undergrowth is represented by common hazel (*Corylus avelana* L.), rough spindle tree (*Euonymus verrucosa* Scop.), red elderberry (*Sambucus racemosa*), and occasionally by mountain ash (*Sorbus aucuparia* L.).

In the course of the research, the technology of creating forest crops by the considered method was studied. The strips with a width of 20 m were uprooted. Determining the direction of placement of furrows was aimed at improving the conditions of cultivated spruce and thus selected from west to east. Strips were left along the perimeter of the studied areas with a width from 10 to 15 m for natural overgrowth, on the area of which uprooted stumps and felling residues were stored by uniform placement and in shafts with simultaneous mineralization of the soil (up to 80 %). Taking into account the requirements of forest fire safety rules, the width of the swaths was 3 m and the height was up to 1 m (fig. 1).

Work on uprooting the strips was carried out by the stump remover-gatherer D-513 on the basis of the tractor T-130. The aim was to preserve the upper soil horizons as much as possible. At the same time, the need for subsequent surface planning was taken into account. Therefore, the uprooting was carried out from the center of the rooted strips towards the belt of trees left for natural overgrowth. The stumps were shaken to ensure maximum preservation of the fertile soil layer in the area of rooted 20-meter strips.

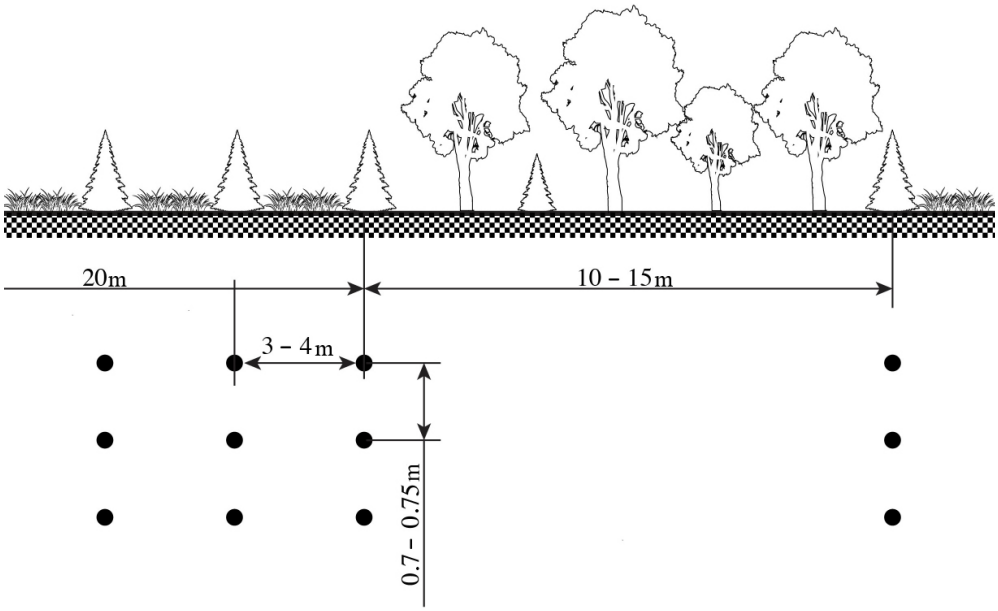

Fig. 1. Scheme of creation of spruce crops with intermediate agricultural use between the rows

For the purposes of the experiment at processing of the specified strips in one case at soil processing by the plow PN-4-35 the was turned to a depth of 25 cm and the harrow BDT-2,2 disking was twice carried out. In the other case, soil preparation was carried out without turning the layer, but with two-fold disking. In the third case – only two-fold disking was carried out.

Planting of 5-year-old spruce seedlings (2-year-old seedlings were grown at the School Department) was carried out by the planting machine MDR-1 with a planting step of 70–75 cm. On the area between the rows of planted spruce, the distance from 3 to 4 m was observed and for two years agricultural crops (were grown on it oats, potatoes, clover, oatmeal and peas) with the introduction of fertilizers provided by the agricultural technology. A distance of 50 cm, free of vegetation, was maintained between the created spruce crops and agricultural crops (fig. 2).

Fig. 2. Growing oats between the rows of forest crops

In the areas of the reproduced crops without cultivation of agricultural plants between the rows for 3 years as the planting places were overgrown with herbaceous vegetation, agrotechnical tending with cultivator KLB-1,7 was carried out. In addition, silvicultural care was carried out in young stands.

Results and discussion

Tables 1 and 2 show the most typical indicators for the test areas. Trees with the same diameter at the root collar were grouped. Deviations within the group were 0.1–0.4 cm. The number of trees in the group ranged from 94 to 106.

Table 1

Changes in the diameter of spruce in typical crops

Indicators	Average diameter by groups, cm						
	1	2	3	4	5	6	7
Trunk height at which the diameter was measured, m: at the root collar	9.5	11.5	13.0	15.5	18.0	27.0	30.0
0.5	9.0	10.5	11.0	14.0	16.5	25.0	23.5
dynamics (±)	0.5	1.0	2.0	1.5	1.5	2.0	6.5
1.0	8.0	10.0	10.0	13.5	16.5	23.0	22.0
dynamics (±)	1.0	0.5	1.0	0.5	0	2.0	1.5
1.5	7.0	9.0	9.5	13	16	22.5	21.0
dynamics (±)	1.0	1.0	0.5	0.5	0.5	0.5	1.0
2.0	6.0	8.0	9.0	12.5	15.5	22.0	20.5
dynamics (±)	1.0	1.0	0.5	0.5	0.5	0.5	0.5
Absolute taper, cm	1.75	1.75	2.0	1.5	1.25	2.5	4.75

Analysis of changes in the diameter of typical spruce crops showed that the range of changes in the average diameter at the bottom of the tree trunk is 0.6–2.4 cm for each 0.5 m of its height. The value of the absolute taper on average is 2.21 cm per 1 m height.

Table 2

Changes in the diameter of spruce in test crops

Indicators	The average diameter of the groups, cm						
	1	2	3	4	5	6	7
Trunk height at which the diameter was measured, m: at the root collar	10.6	12.0	16.5	18.0	20.5	34.5	36.5
0.5	9.5	11.0	14.5	17.0	19.5	34.5	36.0
dynamics (±)	1.1	1.0	2.0	1.0	1.0	0	0.5
1.0	9.0	10.0	14.5	17.0	19.0	34.0	36.0
dynamics (±)	0.5	1.0	0	0	0.5	0.5	0
1.5	9.0	9.5	14.0	16.5	18.5	33.5	35.5
dynamics (±)	0	0.5	0.5	0.5	0.5	0.5	0.5
2.0	8.5	9.5	13.5	16.5	18.0	33.0	35.0
dynamics (±)	0.5	0	0.5	0	0.5	0.5	0.5
Absolute taper, cm	1.05	1.25	1.5	0.75	1.25	0.75	0.75

Analysis of changes in the diameter of test spruce crops showed that the range of changes in the average diameter as the height of the tree increases is less than in typical crops and averages 0.38–0.75 cm for every 0.5 m. The value of the absolute taper on average is 1.04 cm per 1 m of tree height.

Fig. 3 shows a comparison of diameters at a height of 1.3 m of test and typical spruce crops and the ratio of diameters at a height of 1.3 m of trees in a row, in which the indicator of the diameter of crops is characterized most accurately.

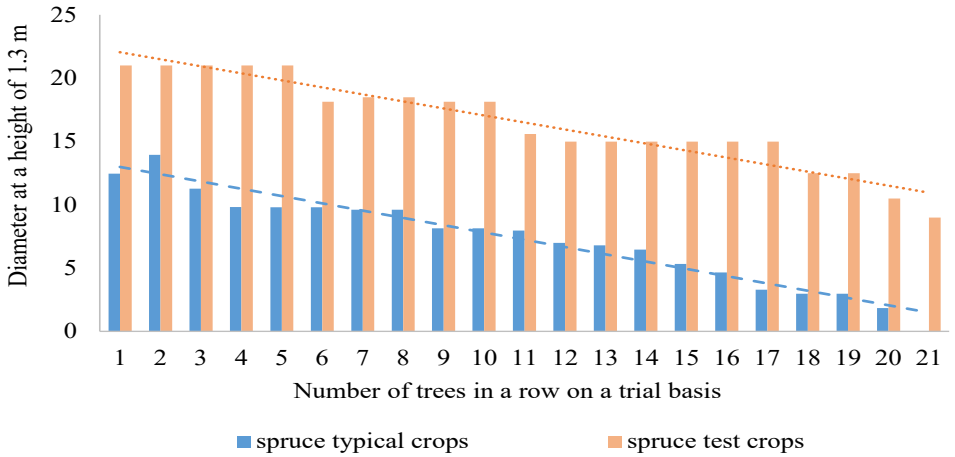

Fig. 3. Diameter ratio at a tree height of 1.3 m

In the diagram it can be seen that the diameter of typical spruce crops is predominantly different for each woody plant. And in test crops of spruce, groups of trees with identical diameter were noted. The diameter size of spruce test crops at a height of 1.3 m exceeds the diameter of typical crops by 41 %.

To identify the effectiveness of the method of creation of forest cultures we assessed the reliability of differences in the mean values of independent samples. When comparing the average values, the following was revealed: the average height of typical forest crops is 12 m, and test crops – 14.5 m; the average diameter of typical forest crops is 11 cm, and test crops – 13.3 cm.

Statistical reliability of differences in the average values of independent sample populations was found during the evaluation of the *t*-criterion at 5 % significance level, since the calculated value of the specified criterion (4.26) is higher than the tabular one (1.99).

The survey revealed the differences in species composition. In the forest areas occupied by typical crops, the species composition of 9 spruces, 1 willow, plus alder, plus aspen, plus hazel (9S1W+Al+As+H) was formed. In the rows and between the rows willow, alder, aspen and hazel of natural origin in the volume (stock) of 90 m^3/ha grow. At the same time, in the areas occupied by typical crops, there was often a typical damage of the spruce trunks formed by the fall of dead trees of secondary species renewed naturally and falling out of the plantation during its formation – bark peeling and cracks with resin stains. The number of damaged trunks is 7–10 % of the total number of trees.

In test crops, there is no damage to the trunks, since secondary breeds are rare. Breed composition is 10 spruces (10S).

The volume dynamics of tree trunks of test and typical crops is close in value to the normal distribution and is characterized by equations with a high tightness of the relationship between the indicators that are shown in fig. 4. Trees with the same trunk volume are grouped together.

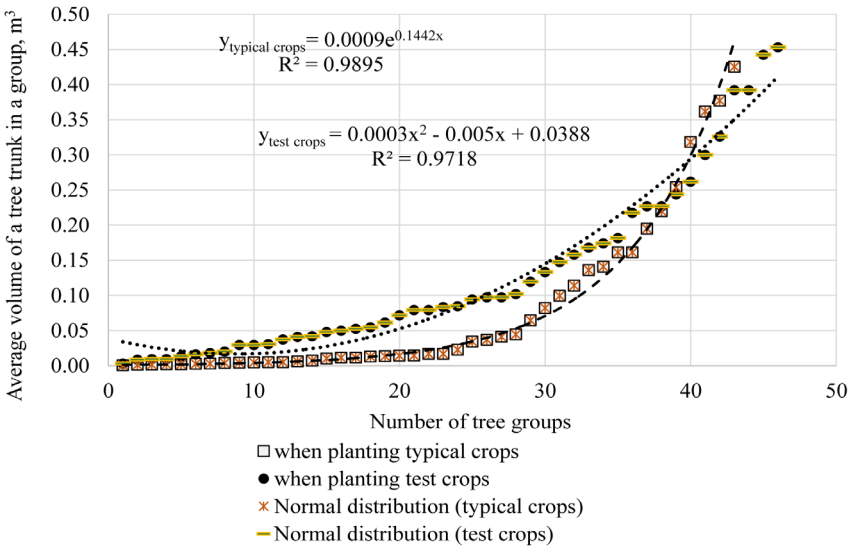

Fig. 4. Dynamics of tree trunk volume in 34-year-old crops

The graph shows that the probability of obtaining trunks with a volume of more than 0.02 m³ by creating test crops is higher than typical ones (volume indicators from the 8th to the 39th group of trees).

A sharp increase in the exponential curve that characterizes the dynamics of the volume of tree trunks of typical crops is associated with the amount of change in the diameter of the tree trunk that exceeds this indicator of test crops by 2.15 times.

The results obtained during the research indicate the monotony of the development of the process of trees renewal, both in typical and test crops. However, the volume of trunks of test crops exceeds the volume of trunks of typical crops by 3.7 times on average.

Conclusion

The indicators of test crops exceed the typical ones in average height by 2.5 m, average diameter by 2.3 cm, diameter at a height of 1.3 m by 41 %, and the volume of trunks by 3.7 times.

Reliability of differences between the average values of independent sample populations is a sufficient basis for the assertion that the method of creating test crops is more effective than the method of creating typical crops.

Trunks of trees grown by the method of creating typical crops are strongly tapered, since the value of absolute taper of their lower part is 2.21 cm per 1 m of tree height.

Trunks of trees grown by the method of creating test crops are weakly tapered, since the value of absolute taper of their lower part is 1.04 cm per 1 m of tree height. This makes it possible to obtain a forest stand with high productivity. The research results suggest that in forest areas renewed by the method of intermediate agricultural use between the rows of crops, it is possible to obtain a forest stand without significant mechanical damage. Improved indicators show the possibility of reducing the time of

reforestation to the state of serviceability. Therefore, the considered method can be referred to the high-intensity silvicultural production.

Analysis of the research results allows us to make a conclusion about prospects of cultivation of plantation forest crops for the purpose of intensive reproduction of forest resources of the country and expediency of inclusion of actions for creation of plantation forest crops in structure of the transferred powers of subjects of the Russian Federation in the field of reproduction of forests. In this regard, the study of costs of plantation forest crops will be continued.

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ПРОДУКТИВНОСТЬ ЛЕСНЫХ ПЛАНТАЦИОННЫХ НАСАЖДЕНИЙ

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Аннотация. С учетом неравномерного обеспечения страны лесными ресурсами и растущей потребности в лесоматериалах, актуальным направлением научного исследования становится сокращение сроков выращивания товарной древесины и повышение продуктивности насаждений. Одним из способов интенсивного воспроизводства лесов является создание плантационных лесных культур. Плантация лесных культур предполагает выращивание технически ценных древесных пород в сокращенные сроки. В нашей стране есть опыт создания плантационных культур, но в связи с реорганизацией лесной отрасли многие такие участки оказались без надлежащего ухода. Однако на протяжении 34 лет научные работники Мытищинского филиала Московского государственного технического университета имени Н.Э. Баумана (ранее Московского государственного университета леса) систематически ведут наблюдение за ростом и развитием созданных в 1984 г. лесных культур ели с промежуточным сельскохозяйственным пользованием в междурядьях. Способ создания опытных культур направлен на: обеспечение максимально благоприятных условий для роста и развития главной древесной породы в первые годы после посадки, использование естественного хода роста насаждений в течение всего периода выращивания культур, оптимизацию затрат на частые лесоводственные уходы, получение полнодревесного древостоя с высокими эстетическими свойствами, предупреждение образования пороков древесины. В статье приведена технология создания культур ели, являющаяся отличительной особенностью указанного способа. Проанализировано изменение диаметров и высот деревьев, выращенных путем создания лесных культур традиционным способом и с использованием промежуточного сельскохозяйственного пользования в междурядьях. Проведена оценка достоверности различий средних значений независимых выборок, подтверждающая преимущество опытных культур ели. Их породный состав представлен на 100 % деревьями породы ель, абсолютный сбег которых в 2,13 раза меньше, чем у созданных традиционным способом. Установлена более высокая вероятность получения стволов объемом более 0,02 м^3 путем создания опытных культур. Результаты статистической обработки экспериментальных данных свидетельствуют о перспективности метода посадки лесных культур ели с промежуточным сельскохозяйственным пользованием в междурядьях, который способствует формированию древостоя с лучшими характеристиками.

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Ключевые слова: плантация лесных культур, промежуточное сельскохозяйственное пользование, лесные культуры, продуктивность.

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