Original article
УДК 630*231
DOI: 10.37482/0536-1036-2024-6-133-146

Features of Restoration of Coniferous-Broad-Leaved Forests

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Received on April 30, 2023 / Approved after reviewing on August 2, 2023 / Accepted on August 3, 2023

Abstract. The article is devoted to the problem of restoration of cut down forests in the forest area of coniferous-broad-leaved (mixed) forests of the centre of the European part of Russia. Due to the intensive use of forest resources, in order to rationally plan their restoration, there is a need for systematic assessment of the natural and artificial restoration of the main forest-forming species. For areas with a developed network of transport routes, the problem of deterioration of the species composition of forests, as well their qualitative condition as a result of prolonged and intensive forest exploitation is currently increasing. This has determined the purpose of the study, which has been carried out through a field survey of undergrowth and forest planations of forest-forming species according to the methodology by A.V. Pobedinsky and the standard methodology for undergrowth inventory. Young stands of natural (undergrowth) and artificial (created by planting) origin in coniferous-broad-leaved (mixed) forests of the European part of Russia after clear-cutting of trees have become the object of the study. An analysis of the structre of production and demand (according to the survey data) has shown that preference is given to harvesting birch (40 % of the volume cut down). The results of comparing the growth characteristics of the younger generation of tree species, taking into account the age and density of their growth, has allowed us to conclude that the undergrowth adapts easier and faster mainly to the growing conditions B_4, B_3, C_3, C_4, A_4, A_3, and occasionally B_2, compared to forest plantations. In many cases, spruce plantations created by planting in the bottom of a furrow are completely destroyed (get soaked) or remain in a volume that does not provide satisfactory reforestation. Cases of exposure of the root system of spruce plantations at the age of 22, which have been created by planting in the dump, have been revealed. Based on experimental data, it has been established that productive young stands of natural origin are successfully formed in the forest area of coniferous-broad-leaved (mixed) forests of the Yaroslavl, Moscow and Nizhny Novgorod Regions. Criteria for the inventory of undergrowth and young growth of soft-wooded broad-leaved species have been proposed. Proposals have been developed to improve the efficiency of reforestation measures in forest-growing conditions corresponding to the A_4, B_4, C_4, as well as in the A_3, B_3 and C_3 conditions. The positive effect of raspberries on self-seeding of the main forest-forming species has been noted. The self-sown plants in such areas is 1.0–1.5 thousand pcs/ha.

Keywords: undergrowth, underwood, forest plantations, natural young stands, reforestation, forest vegetation features, coniferous-broadleaved forests

For citation: Savchenkova V.A., Vasilyev S.B., Nikitin V.F. Features of Restoration of Coniferous-Broad-Leaved Forests. *Lesnoy Zhurnal* = Russian Forestry Journal, 2024, no. 6, pp. 133–146. https://doi.org/10.37482/0536-1036-2024-6-133-146

Научная статья

Особенности восстановления хвойно-широколиственных лесов

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Поступила в редакцию 30.04.23 / Одобрена после рецензирования 02.08.23 / Принята к печати 03.08.23

Аннотация. Статья посвящена проблеме восстановления вырубок на территории лесного района хвойно-широколиственных (смешанных) лесов центра европейской части России. Вследствие интенсивного использования лесных ресурсов, в целях рационального планирования их возобновления возникает необходимость систематической оценки естественного и искусственного восстановления основных лесообразующих пород. Для районов с развитой сетью транспортных путей в настоящее время возрастает проблема ухудшения породного состава лесов, а также их качественного состояния в результате длительной и интенсивной лесоэксплуатации. Это и определило цель исследования, которое проводилось путем полевого обследования подроста и лесных культур лесообразующих пород согласно методике А.В. Побединского и стандартной методике учета подроста. Объектом исследования являются молодняки естественного и искусственного (создание лесных культур путем их посадки) происхождения в хвойно-широколиственных (смешанных) лесах европейской части России после сплошных рубок. Анализ структуры производства и спроса (согласно опросным данным) показал, что предпочтение отдается заготовке березы (40 % от вырубаемого объема). Результаты сравнения особенностей роста молодого поколения древесных пород с учетом возраста и густоты их произрастания позволили сделать вывод, что подрост легче и быстрее адаптируется преимущественно к условиям произрастания B_4, B_3, C_4, C_3, A_4, A_3, единично – B_2, по сравнению с лесными культурами. Во многих случаях созданные путем посадки в дно борозды культуры ели полностью погибают (вымокают) или остаются в объеме, не обеспечивающем удовлетворительное лесовосстановление. Выявлены случаи оголения в возрасте 22 лет корневой системы культур ели, которые были созданы посадкой в отвал. На основании экспериментальных данных установлено, что на территории лесного района хвойно-широколиственных (смешанных) лесов Ярославской, Московской и Нижегородской областей успешно формируются продуктивные молодняки естественного происхождения. Предложены критерии учета подроста и молодняка мягколиственных древесных пород. Разработаны рекомендации по повышению эффективности мероприятий по лесовосстановлению в лесорастительных условиях B_4, B_3, C_4, C_3, A_4, A_3. Отмечено положительное влияние малины на самосев основных лесообразующих пород. Количество самосева на таких участках составляет 1,0–1,5 тыс. шт./га.

Ключевые слова: подрост, подлесок, лесные культуры, естественные молодняки, возобновление, лесорастительные особенности, хвойно-широколиственные леса

Для цитирования: Savchenkova V.A., Vasilyev S.B., Nikitin V.F. Features of Restoration of Coniferous-Broad-Leaved Forests // Изв. вузов. Лесн. журн. 2024. № 6. С. 133–146. https://doi.org/10.37482/0536-1036-2024-6-133-146

Introduction

Today, as a result of natural changes and anthropogenic impact, a significant area covered with coniferous-small-leaved (mixed) forests has formed in the territory of the coniferous-broad-leaved forests of the European part of the Russian Federation (Yaroslavl, Moscow, Nizhny Novgorod Regions).

Such a change of formations can be considered a transitional stage in the restoration of indigenous forest types that were subjected to clear-cutting in the middle of the 20th century using a technology that does not provide for the preservation of undergrowth and young stands of the main stand-forming species. This process has been observed throughout the entire territory of the commercial forests of the European part of Russia. The only difference is the protective forests, untouched by logging in the post-war period. Therefore, a significant volume of annual clear-cutting within the established yield logging site is carried out in plantations dominated by silver birch (*Betula pendula* Roth) (hereinafter referred to as birch) and common aspen (*Populus tremula* L.) (hereinafter referred to as aspen). The second tier of the plantation is formed by Norway spruce (*Picea abies* (L.) H. Karst.) (hereinafter referred to as spruce). Downy birch (*Betula pubescens* Ehrh.) [24] is found on soils with excess moisture.

For example, in the territory of the forest fund of the Yaroslavl Region, the volume of mature and overmature birch wood is 573.3 million ha (38.14 % of the volume of all tree species), and aspen – 222.2 million ha (14.78 %). A characteristic feature for the forests of this region is the presence of forest thinners in the plantation (in the second tier, uniform distribution of the predominant spruce species has been noted) with a trunk diameter at a height of 1.3 m up to16 cm and viable undergrowth (the predominant species is spruce distributed unevenly, by groups) in an amount of more than 1.5 thousand pieces per 1 ha in satisfactory condition.

The problem of increasing demand for wood is related to population growth and infrastructure development [25]. An analysis of the structure of production and demand for wood in the study area, according to the survey data, has shown that preference is given to harvesting birch (40 % of the volume cut down). Aspen wood is commonly affected by stem rot, but due to the significant areas with its predominance, the volume of harvesting amounts to 45 % of the total volume of logging. Spruce wood is of poor quality, the effective volume cut is 10–12 %. Scots pine (*Pinus sylvestris* L.) grows mainly in forest areas belonging to the protective forest category. Sometimes it is cut as part of a mixed plantation, with the volume of harvesting typically accounting for 2–5 % of the total volume of the felled stand.

Analysis of statistical reporting data on the use of wood in the study area has shown that pine (the yield of industrial wood is 80 %) and birch (the yield of industrial wood is up to 90 %) have the highest productivity.

Currently, in the prevailing forest and economic conditions, birch is quite consistent with economic goals. According to the approved Forestry Regulations, which govern activities in the study area, birch is designated as a forest-forming species. However, the Rules for reforestation, form, composition, procedure for approving a reforestation project, grounds for refusing refusal to approve it, as well as requirements for the format of the reforestation project in electronic form, approved by Order of the Ministry of Natural Resources of the Russian Federation dated 12/29/2021 no. 1024, provide for signs that characterize viable undergrowth of only coniferous and hardwood species. The conversion coefficient of small and medium-sized undergrowth into large is determined without taking into account the distinctive features of softwood species. Undergrowth is classified similarly for all tree species according to height, density and distribution over area.

The plantation consists of various components, a change in even one of them leads to a violation of the natural ecological balance. An important unit that makes up a forest phytocenosis is the undergrowth, which reacts to new environmental conditions, for example, after clear-cutting [15, 19, 20, 26].

The urgent task of the development of the forestry sector of Russia is to increase forest productivity, preserve and restore forest biodiversity [2, 5, 16, 17, 19, 23, 28]. At the same time, it is important to establish a rational relationship between artificial and natural reforestation [6, 7, 11, 18, 21, 26].

In this regard, the aim of the study is to assess the growth rates of natural and artificial restoration of forest-forming species in the coniferous-broad-leaved forest area of the central European part of Russia, as well as other components of the plantation, to determine the most effective method of reforestation and the criteria for softwood undergrowth inventory.

Research Objects and Methods

The object of the study is young stands of natural (undergrowth) and artificial (created by planting) origin in coniferous-broad-leaved (mixed) forests of the European part of Russia after clear-cutting of trees.

To achieve the aim, research has been conducted on forest plots with measures taken to promote natural forest regeneration and forest plantations created according to the methodology by A.V. Pobedinsky [13] and the standard methodology for undergrowth inventory.

Plots of 10 m^2 have been laid out at the same distance from each other on the tapes of the layout placed every 50 m. The number of plots has been determined depending on the square of the forest site being surveyed (from 30 to 100 plots in each site). A total of 378 cuttings have been surveyed, ranging in age from 1 to 22 years.

The height, diameter, density of undergrowth and forest plantations of forest-forming species have been measured. Additionally, clear-cut areas up to 50 years old have been studied to determine the dynamics of the density of the younger generation of the main forest-forming species. An assessment has been made of their distribution over the area of the surveyed sites (according to their occurrence in the registration sites), the completeness of their placement, the degree of soil mineralization and its sodding.

The experimental data obtained have been systematized and combined into homogeneous groups.

Taking into account the self-evident knowledge about the dependence of the growth of forest crops and undergrowth on forest-growing conditions, the species composition of the underwood [4] and living ground cover has been studied.

The density of tree species placement has been determined by the ratio of the sum of the crown projection areas to the area of the site.

The living ground cover has been studied by the method of quadrat sampling (of 1 m^2). Within the sample, raunkiaers (1 × 1 m) have been laid out diagonally at equal distances, on which the entire species composition has been recorded and the coverage, occurrence, abundance, and viability have been determined. The projective covering of a particular species and tier has been considered. The ratio of the projection of the above-ground parts of plants to the total area of the sample plot, taken as 100 %, has been visually taken into account.

In order to determine the difference between the experimental data obtained and the entire general population, the non-sampling error has been calculated and the confidence limits of relative values have been determined [10]. Taking into account the sample size of the experimental data, the kurtosis index (e) has been calculated, indicating the deviation of the distribution from the normal one [3].

To determine statistical relationships, correlation analysis has been carried out as a method of processing statistical data. The correlation coefficients between the density of the preserved undergrowth and young stands and the volume of tree crowns, as well as the age of the clear-cut area, have been studied. The coefficient of determination for the equation describing these relationships has been found in order to determine the magnitude of the change in the resultant feature under the influence of a factorial one (the closer its value is to one, the stronger the dependence).

Results and Discussion

Grouped data on the age, height, diameter, and density of spruce, pine, birch, and aspen undergrowth are presented in Table 1.

Table 1

The grouped data on the spruce, pine, birch and aspen undergrowth

Species	Age, years	Height, m	Diameter, cm	Placement density
Spruce	5	0.8	0.5	0.6
	6	1.0	0.8	0.6
	7	1.4	0.9	0.7
	8	1.8	1.0	0.8
	9	2.2	2.0	0.8
	10	2.7	2.5	0.7

The end of Table 1

Species	Age, years	Height, m	Diameter, cm	Placement density
Spruce	15	3.3	3.0	0.7
	18	4.0	4.0	0.7
Pine	5	1.0	1.0	0.5
	6	1.3	2.0	0.5
	7	1.8	2.0	0.6
	8	2.3	2.5	0.7
	9	2.7	2.5	0.7
	10	3.0	3.0	0.8
	15	5.0	4.0	0.8
	18	6.0	5.0	0.8
Birch	5	1.3	1.0	0.6
	6	1.5	1.0	0.6
	7	2.0	2.0	0.7
	8	2.6	2.0	0.8
	9	3.2	3.0	0.8
	10	3.7	4.0	0.7
	15	6.0	6.0	0.7
	18	8.0	7.0	0.7
Aspen	5	2.0	1.0	0.6
	6	2.3	1.5	0.7
	7	2.6	2.0	0.7
	8	3.0	2.0	0.8
	9	3.5	2.5	0.8
	10	4.0	2.5	0.8
	15	6.5	4.0	0.7
	18	9.0	5.0	0.7

The growth and productivity of plantations depend on the forest vegetation characteristics of the site where they grow [8, 9, 18]. Of all the inventory indicators characterizing the productivity of the plantation and at the same time reflecting its relationship with the quality of growing conditions, the height at a certain age is the most important. The greater it is, the better the growing conditions and the higher the productivity of the plantation.

During the study, it has been established that at the undergrowth stage, the parameters characterizing the productivity of the stand at the same age have significant differences in growth rates (from 0.6 to 49.0 cm in height and from 0.5 to 1.7 cm in diameter) and correspond to intermediate values between the 2nd (high) and 3rd (medium) quality classes.

The study found that natural young stands are formed from undergrowth of different age, which contributes to the preservation of the forest environment within the swaths. At the same time, undergrowth species are also developing with bird cherry (*Prunus padus* L.), black alder (*Alnus glutinosa* (L.) Gaertn.), rowan (*Sorbus aucuparia* L.) and goat willow (*Salix caprea* L.) predominating. Shrubs are actively growing such as red raspberry (*Rubus idaeus* L.), fly honeysuckle (*Lonicera xylosteum* L.), black currant (*Ribes nigrum* L.) and alder buckthorn (*Frangula alnus* Mill.). In the swaths, the living ground cover is represented by forest species of herbaceous vegetation (up to 90 % of the projective covering). And only on the trails do meadow species of herbaceous vegetation predominantly grow (70–100 %). It should be noted that the condition of the trails varies not only in terms of the projective covering of herbaceous vegetation, but also in the presence of tree and shrub species.

It should also be noted that in the first year after clear-cutting, the undergrowth and young stands of coniferous trees preserved in the swaths are exposed to the effects of increased solar radiation due to the removal of the stand in one go, causing a sharp change in environmental conditions. The study found that the undergrowth and young stands left in the swaths, seemingly unviable at first glance, adapt within 2 years after clear-cutting. Subsequently, a forest area is formed from undergrowth of different ages, passing into the stage of natural young growth at the age of 5 to 40 years. Its density increases due to the growth of new individuals. Fig. 1 shows the relationship between the density of undergrowth and young stands of coniferous tree species and the age of the cutting.

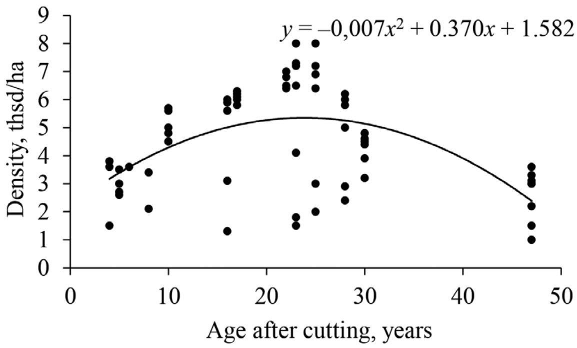

Fig. 1. The ratio of the density of undergrowth and young stands of coniferous forest-forming species of natural origin from the age of the cutting

Fig. 1 shows that the density of undergrowth of coniferous tree species increases every year to the age of 23–25 years, gradually passing into the stage of young growth. A negative kurtosis index indicates the heterogeneity of the plantation and the absence of competition until the specified age. Then the density of the young stands decreases and during the formation of an adult plantation, depending on the forest vegetation characteristics of each plot and tree species, it stabilizes.

The results of inventory and measurements of undergrowth and young stands of forest-forming species have shown that the density of softwood species exceeds the density of coniferous by 1.6–2.5 times. The largest number of specimens per 1 ha has been noted at a height of up to 1.5 m. Later, as a result of natural thinning, the density of birch and aspen forests decreases.

The relationship between the density of undergrowth and young stands and the age of the cutting can be described by a square polynomial. The coefficient of determination ($R^2 = 0.85$) indicates that with a change in the age of the cutting, in 85 % of cases there will be a corresponding change in the density of undergrowth and young stands of forest-forming species.

During the examination of forest areas, it has been established that large young trees (age class 2) and groups of middle-aged trees (age classes 3–4), as well as seed trees, are preserved during the clear-cutting, the adaptation of the preserved undergrowth is accelerated and the effectiveness of measures to promote natural reforestation increases (Fig. 2).

Fig. 2. The condition of undergrowth and young stands in the swaths after clear-cutting with partially preserved young trees of age classes 1 and 2

The figure shows a viable young plantation that has recovered within 1–2 years after clear-cutting. It has been established that natural young stands in the swaths have a crown density from 0.4 to 0.7 already in the first year after clear-cutting. In the future, its value increases. The forest herbaceous vegetation is preserved, contributing to a faster restoration of the original forest type than in the areas with artificially created forest plantations. The overgrowth with herbaceous vegetation in the first years after its creation, caused by a sharp change in the ecological situation, contributes to their strong suppression and often death.

It has been noted that in the forest plantation areas the projective covering of the rush is 85–100 %. This indicates a high level of soil moisture. A characteristic feature of the study area is a hill-and-plain relief. After cutting, a type of clear-cut area is formed with a characteristic excessive moisture, a feature of which is currently water stagnation. With excessive moisture, the process of waterlogging develops. According to a preliminary assessment, which requires further research, this is due to a decrease in the rate of water exchange in river systems, a decrease in solid runoff, and a change in climatic conditions as a result of the creation of a number of reservoirs on the rivers of the European part of the Russian Plain. In addition, many rivers are characterized by snow feeding with a significant proportion of rain and groundwater [22].

The analysis of the taxation characteristics of the studied forest areas and experimental data have shown that mesohygrophilic and hygrophilic soils (B_3, C_3, B_4, C_4) predominate over more than 60 % of the territory of the study area [14]. In many cases, spruce plantations created by planting in the bottom of a furrow are completely destroyed (get soaked) or remain in a volume barely exceeding the threshold value. Their subsequent addition does not produce the desired effect. The most effective way of to create, as shown by many years of practice, is planting into a dump (on micro-elevations of the created furrows). The loss of seedlings has been noted within the normal range, the number of viable seedlings is 2.0 thousand pieces per 1 ha or more. However, in the course of the study, the facts have been established of the exposure of the root system of spruce plantations by the age of 22 years as a result of soil leaching from the micro-elevations (Fig. 3). This has a negative effect on the condition of the plantations. Cracks form, rot develops, and wood marketability is significantly reduced.

Fig. 3. The 22-year-old spruce plantations (planted in a furrow dump)

During the current stage of the study, an assessment of the state of forest plantations has been carried out. Table 2 presents the grouped data on measurements by age, height, diameter, and density of the spruce and pine plantations.

Table 2

The grouped data on growth rates of the spruce and pine plantations

Species	Age, years	Height, m	Diameter, cm	Placement density
Spruce	5	0.7	0.5	0.6
	6	0.9	0.8	0.6
	7	1.1	0.9	0.7
	8	1.5	1.0	0.8
	9	1.8	2.0	0.8
	10	2.7	2.0	0.7
	15	3.1	2.5	0.7
	18	3.7	3.0	0.7
Pine	5	0.8	1.0	0.4
	6	1.1	1.5	0.4
	7	1.5	1.5	0.5
	8	1.8	2.0	0.5
	9	2.1	2.0	0.6
	10	2.5	2.0	0.6
	15	4.0	3.0	0.7
	18	5.0	4.0	0.7

The analysis of the presented data has shown that the pine and spruce plantations have a lower height than the undergrowth of these species. Based on a full-scale survey of the cuttings, it has been revealed that the forest plantations created in the study area are represented by the spruce species in almost 100 % of cases. At the same time, the pine plantations take root and develop more efficiently than the spruce ones, but are subject to mass destruction by wild ungulates [1, 12].

Based on the measurements of the plantations and the young stands of natural origin formed at the same time, a graph of the ratio of the height with the age of the cutting has been plotted (Fig. 4).

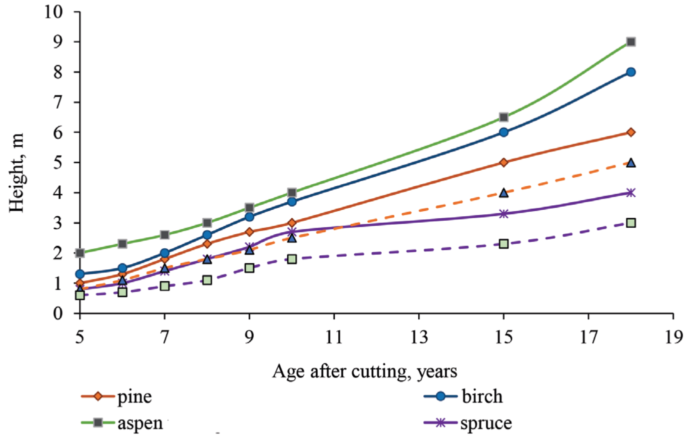

Fig. 4. The ratio of the height of pine and spruce plantations, as well as the simultaneously formed pine, spruce, birch and aspen undergrowth with the age of the cutting

The undergrowth adapts easier and faster mainly to the growing conditions B_4, B_3, C_3, C_4, A_4, A_3, and occasionally B_2. As can be seen in Fig. 4, the height of deciduous stand-forming species exceeds the height of natural coniferous young stands by 1.2–1.9 times, and that of coniferous species plantations – by 1.5–2.8 times. This indicates that the undergrowth of coniferous species is negatively affected by the deciduous to a lesser extent than the forest plantations. The formation of a mixed stand with equal participation of both deciduous and coniferous species is observed.

During the field study, it has been established that the density of aspen placement is higher than that of the young birch trees and spruce and pine plantations (Fig. 5).

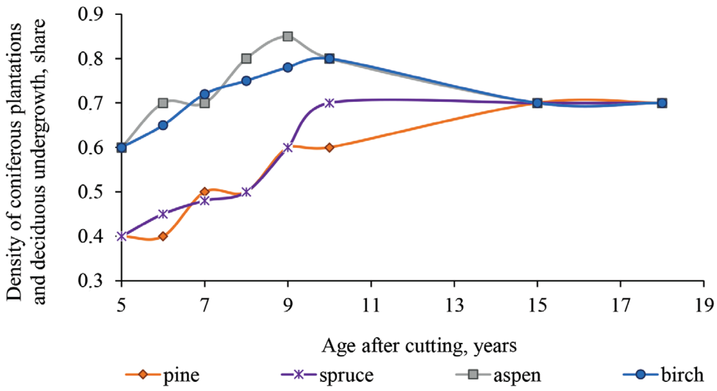

Fig. 5. The ratio of the placement density of spruce and pine plantations, as well as the formed birch and aspen undergrowth with the age of the cutting

The advantage of aspen in terms of placement density and height relative to the artificially created plantations contributes to the suppression of the latter.

As a result, the areas of forest plantations require agrotechnical tending and timely liberation cutting.

However, with an increase in the age of viable undergrowth, the density of their placement begins to equalize.

In the young stands of natural origin, it has been established that aspen has no significant advantage and does not suppress other forest-forming species (Fig. 6).

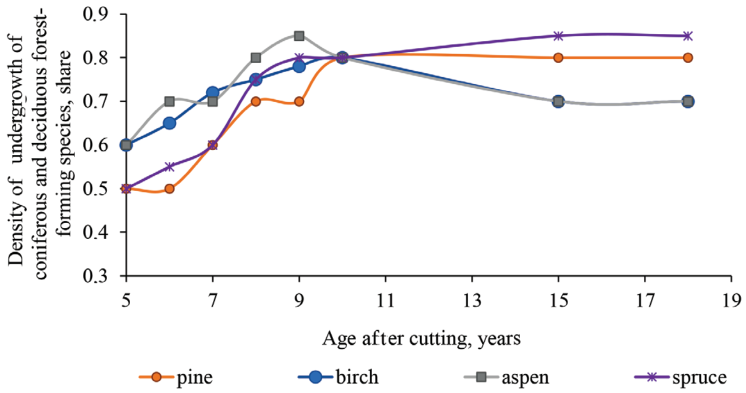

Fig. 6. The ratio of the placement density of spruce, pine, birch and aspen undergrowth with their age

Fig. 6 shows that the density of undergrowth of all tree species is close in value. By the age of 10–12 years after cutting, it reaches its maximum level, and then decreases and stabilizes at the level of 0.7. At the same time, the placement density of coniferous undergrowth increases.

The study took into account the accompanying undergrowth species. They perform an important silvicultural role and contribute to increasing the stability of the younger generation of forest-forming species: they provide the necessary shading from the intense influx of solar radiation (the optimal placement density or crown density of 0.5–0.6) and prevent soil sodding by shading light-requiring meadow herbaceous species. Their number per 1 ha during the years of adaptation of natural young stands after clear-cutting does not exceed 1,000 pcs/ha.

It has been noted that the density of forest plantations increases due to the natural renewal of forest-forming species in the rows and inter-row spaces.

The study has established a positive effect of raspberries on the degree of preservation of the forest environment on the skidding trails (Fig. 7): the multi-tier nature of the living ground cover is preserved – green mosses (*Orthotrichum*s sp., *Leucodon sciuroides*, *Pylaisiella polyantha*, *Hylocomium splendens* (Hedw.) Bruchetal) grow at the lower tier with a 60 % projective covering, false lily (*Maianthemum bifolium* (L.) F.W. Schmidt) and wood-sorrel (*Oxalis acetosella* L.) with an even projective covering of up to 35 %; above them there is a tier of wood horsetail *Equisetum sylvaticum* L. (15 %), addersmeat *Stellaria holostea* L. (10 %), male fern *Dryopteris filix-mas* (L.) Schott (10 %), fireweed *Epilobium angustifolium* L. (10–15 %), European blueberry *Vaccinium myrtillus* L. (distributed unevenly by groups, with 40 % covering).

a

b

Fig. 7. Skidding trail: *a* – overgrown with raspberry; *b* – formed living ground cover of forest herbaceous plants formed on the skidding trail under the raspberry canopy

Raspberries provide shading of the soil surface, inhibiting the development of meadow herbaceous plants, and also prevents the burning out of forest species of herbaceous vegetation, preventing the soil from sodding. This helps to accelerate the formation of favourable conditions for the growth of self-seedlings in the areas without undergrowth.

The amount of self-seeded plants in such plots is 1,000–1,500 pcs/ha. Self-seeding is represented by 30 % spruce, 20 % pine, 25 % birch and 25 % aspen. Its species composition and percentage ratio of the included species depend on the growing plantation directly adjacent to the cutting.

Conclusion

In the coniferous-broad-leaved forest areas of the European part of Russia, young stands of natural origin are formed in the cuttings with the preserved mixed undergrowth, forming independent allotments with a completeness of 0.4–0.7. Large undergrowth adapted in the first 2 years after clear-cutting in the swaths, shading the lower tiers, prevents the regeneration of aspen and birch.

In the forest-growing conditions corresponding to A_4, B_4, C_4 and, if necessary, in the conditions A_3, B_3, C_3, reforestation should be carried out by preserving the undergrowth, leaving it in the swaths.

Taking into account the growth rates of pine and birch, in order to increase the effectiveness of reforestation measures it is advisable:

to increase the percentage of pine participation in the creation of forest plantations and implement their fencing;

in cuttings with a predominance of birch undergrowth, measures should be taken to promote the natural forest regeneration with subsequent care of the plantation in order to form merchantable birch wood.

Taking into account the demand for birch wood in the current economic conditions, it can be argued that it is the main (target) tree species and to assess the effectiveness of promoting natural reforestation, it must be taken into account together with coniferous and hardwood forest-forming species.

On the basis of experimental data on the height of undergrowth of soft-wooded undergrowth, it is advisable to distinguish three categories of its size: small –

up to 1.5 m, medium – from 1.6 m to 3.0 m and large – over 3.1 m (up to a height not exceeding 1/4 of the height of the trees in the main canopy). According to the density, the undergrowth of soft-wooded species can be divided into four density categories: sparse – up to 5,000, medium density – from 5,000 to 15,000, dense – from 15,000 to 20,000 and very dense – more than 20,000 plants per 1 ha.

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Конфликт интересов: Авторы заявляют об отсутствии конфликта интересов
Conflict of interest: The authors declare that there is no conflict of interest

Вклад авторов: Все авторы в равной доле участвовали в написании статьи
Authors' Contribution: All authors contributed equally to the writing of the article