УДК 630*234

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STABILITY OF NATURAL REGENERATION AT RAVINE-GYLLY SYSTEMS

Peculiarities of growth and current sanitary condition of natural regeneration of Scots pine on ravine-beam systems of Rzhyshchiv-Kaniv dislocations are analyzed. Coefficients of tree growth tension were determined that indicate their greatest values occur in dense places where plants with the minimum diameter try to reach the maximum possible height. It is correlated with sites. At the same time, they are strongly associated with the age of the plants. At a young age, the stress of tree growth becomes greatest and over time decreases. As a result, young plants have a maximum loss. The index of sanitary condition which is in an interval I.6–II.3 is established. This allows us to state the condition of the plantations as weakened, which is confirmed by the coefficients of tension of their growth. Plants of natural regeneration due to dense placement experience increased competitive influence from other trees, which affects the intensity of their growth. This accelerates differentiation, natural selection and increases the resilience of forest ecosystems to global climate change, to avoid mass drying of Scots pine. For the first time, an attempt was made to experimentally apply the coefficient of growth tension of natural regeneration on ravine-gully systems in order to clarify the feasibility of forestry measures in plantations on fallow lands. The results of research indicate the importance of regulating the density of natural regeneration, determining the duration of intervention in ecosystem change and the feasibility of their implementation on the basis of experimental justification of the number of trees by the growth rate.

Key words: sanitary state, growth, coefficient of tension, natural regeneration, thinning, fallow lands, self-seedling.

For citation: Khryk V. M., Kimeichuk I. V., Nosnikau V. V., Rabko S. U., Kozel A. U., Maliuha V. M., Yukhnovskyi V. Y. Stability of natural regeneration at ravine-gylly systems. *Proceedings of BSTU, issue 1, Forestry. Nature Management. Processing of Renewable Resources*, 2021, no. 2 (246), pp. 103–111 (In English).

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УСТОЙЧИВОСТЬ ЕСТЕСТВЕННОГО ВОЗОБНОВЛЕНИЯ НА ОВРАЖНО-БАЛОЧНЫХ СИСТЕМАХ

Проанализированы особенности произрастания и современное санитарное состояние естественного возобновления сосны обыкновенной на овражно-балочных системах Ржищевско-Каневских дислокаций. Определены коэффициенты напряженности роста деревьев, которые указывают на то, что их наибольшие значения встречаются в местах с высокой густотой, где растения с минимальным диаметром пытаются достичь максимально возможной высоты, что также хорошо коррелирует с условиями местопроизрастания. В то же время они тесно связаны с возрастом растений. В молодом возрасте напряжение роста деревьев становится наибольшим и со временем уменьшается. В результате в молодых насаждениях происходит максимальный отпад. Рассчитан индекс санитарного состояния насаждения, который варьирует в интервале I.6–II.3. Это позволяет констатировать состояние насаждений как ослабленное, что подтверждается коэффициентами напряженности их роста. Растения естественного возобновления за счет густой посадки испытывают повышенное конкурентное влияние со стороны других деревьев, что сказывается на интенсивности их роста. Это ускоряет дифференциацию, естественный отбор и повышает устойчивость лесных экосистем к глобальному изменению климата, что позволяет снизить степень массового усыхания сосны обыкновенной. Впервые предпринята попытка экспериментального применения коэффициента напряженности роста сосны естественного возобновления для определения возможности проведения лесохозяйственных мероприятий в насаждениях на залежных землях. Результаты исследований указывают на важность регулирования густоты естественного возобновления,

определения продолжительности вмешательства в изменение экосистемы и целесообразности их осуществления на основе экспериментального обоснования количества деревьев по скорости роста.

Ключевые слова: санитарное состояние, рост, коэффициент напряженности, естественное возобновление, изреживание, залежь, самосев.

Для цитирования: Хрык В. М., Кимейчук И. В., Носников В. В., Ребко С. В., Козел А. В., Малюга В. М., Юхновский В. Ю. Устойчивость естественного возобновления на овражно-балочных системах // Труды БГТУ. Сер. 1, Лесное хоз-во, природопользование и перераб. возобновляемых ресурсов. 2021. № 2 (246). С. 103–111.

Introduction. Due to global climate change, natural regeneration is especially important, as it is the natural environment that forces woody plants to adapt to new conditions.

It is necessary to study the course and success of natural regeneration of Scots pine in different age plantations [1, 2]. The peculiarity of this process on eroded ravine-beam lands is different in compareson with the natural regeneration on cuttings. In ravine-gully lands, where the forest environment begins to form in uncharacteristic specific harsh conditions, when it is difficult for seeds to get into the soil and germinate there, it is important to determine the course of natural regeneration of Scots pine, especially recently when the use of natural forest biogeocenosis is widely promoted. Due to the need to preserve species and genetic biodiversity, increase the biological stability, quality and productivity of tree species, the question of studying this in different age stands is of paramount importance [3, 4].

The last decade has been marked by a sharp deterioration in the sanitary state of forests due to the negative effects of a complex of factors related to global climate change. This causes an increase in the area of drying plantations. As of January 1, 2019, their total area was over 413 thousand hectares, of which 222 thousand hectares of Scots pine plantations [5, 6].

The success of natural regeneration of tree species depends on the seed years, the adequacy of seed yield, regenerative maturity of the soil, the criterion of which is the state of forest litter, as well as the conditions for further growth and development of selfseeds [3].

Maliuha [7] studed the natural regeneration of pine on the ravine slopes of Rzhyshchiv-Kaniv dislocations and he came to conclusion that the regeneration is possible, although often pine self-seedling completely die in the third and subsequent years, especially on the slopes of the southern insulated exposures. The author does not completely rule out the possibility of natural regeneration on the slopes of ravines, but considers it problematic [8–10]. This scientist studies artificial plantings and determines the intensity of living space [11].

To date, similar research on natural regeneration in Ukraine outside the forest fund is not enough. This has become the subject of our research.

The purpose of the study is to assess the possibilities of natural regeneration of Scots pine on ravine-gully lands and to provide scientifically sound proposals for improving their biological stability in the context of global climate change.

Material and methods. The first experimental site with trial plots (TP) 20–01; 20–02; 20–03 is located on the lands of Tarashcha Agricultural College, which came out of permanent agricultural use in 1995. They were planted with pine forests with an area of 2.5 hectares, which died due to lack of timely agronomic care. However, due to coincidence, a natural regeneration was formed in this area.

A mature mother stand with a composition of 10Ps (*Pinus sylvestris* L.) grew next to the experimental plot, the seed years coincided, due to which this area was sown by wind by spreading forest seeds. A good role was played by good soil moisture, as well as pre-planting preparation of the forest area. The latter has reduced soil turfing and competition for pine self-seeding from grass vegetation.

The plantation formed due to natural renewal has a high degree of closure in the absence of undergrowth and understory. The thickness of the forest litter is 2.5 cm.

The natural renewal of Scots pine in the Pidkova tract at TP 20–04, 20–05; 20–06 turned out to be exceptionally peculiar to the conditions of the former eroded agricultural lands (block 44, unit 25 in Myronivka agricultural college) on the area of 3.3 hectares. The unit is located in a hollow with an angle of inclination of the north-western and south-eastern slopes up to 10°. Adjacent to the basin on two sides are the slopes of the ravine with a steepness of 17–19°, on which there are 48–49-year-old artificial plantings with a composition of 10Ps, which served as a source of seeding of the experimental site. Due to a favorable coincidence – early fruiting of pine in these plantations and the primary tillage carried out in the basin with strips for planting black mulberry pine self-seedlings survived, overcoming the competition of grass cover. The size of the trial sites was 0.1 ha.

Assessing the state of natural regeneration of pine stands on fallows, we applied the coefficient of growth tension of the middle tree in order to clarify the feasibility of forestry activities in the study area. To do this, use the formula (1):

$$K_n = h\ 100 / g, \quad (1)$$

where K_n – coefficient of growth tension of middle tree; h – middle height of thickness level, m; g – basal area at breath height, cm^2.

During the list of trees in the trail sites for each of them determined the category of the state by the sum of biomorphological features, which included the density and color of the crown, the presence and nature of the distribution of needles, relative growth of shoots, the age of the needles stored on the shoots, the presence of dry branches, the condition of the bark and etc. The needles are affected by infectious and non-infectious necrosis, pests and pathogens [12, 13].

The index of sanitary state of plantations was calculated by the ratio (formula 2) [14]:

$$I = \frac{n_1 + 2n_2 + 3n_3 + 4n_4 + 5n_5 + 6n_6}{n_1 + n_2 + n_3 + n_4 + n_5 + n_6}, \quad (2)$$

where: n_1, n_2, ..., n_6 – number of trees of relative category of sanitary state.

The state of plantings was established according to the following values of the sanitary condition index: up to 1.5 – healthy plantations; 1.6–2.5 – weakened; 2.6–3.5 – strongly weakened; 3.6–4.5 – dry; more than 4.5 – dead [14].

During the field work on the trail sites all manifestations of negative impact on the state of forest phytocenoses of other biotic and abiotic factors (pests and forest diseases, forest fires, damage by late frosts, as well as wild and domestic animals, etc.) were recorded.

To determine the sanitary state of plantations of natural origin, a reconnaissance survey of stands was performed on six trail sites with a continuous list of trees.

Mathematical and statistical processing of the results was performed using Microsoft Excel software packages [15].

Results and discussion. It is important to have objective data on the state of plantations when planning and conducting forest management activities (Tables 1, 2).

Characterizing the obtained data on the distribution of trees of natural regeneration by degrees of thickness, which were formed at different age intervals, we see that higher coefficients of growth tension occur in younger plantations (Tables 1 and 2).

The coefficient of growth tension of the middle tree shows how many centimeters of height is per 1 cm^2 of its basal area. The smaller the value of height per cm^2 of basal area of the middle tree, the lower the coefficient of tension of its growth, the more stable and confident it feels. There are trees of different ages in the research plantations. Consider what happens at the same age, which is represented by two options:

The first option (Table 1) is presented trail plots 20–01, 20–02, 20–03 where the age of the youngest trees in the plantation is 22 years.

The situation was as follows: for a degree of thickness of 6 centimeters of height were distributed respectively: 7.9; 7.6; 7.7 m, which in turn correspond to the highest growth rates – 28.2; 27.1; 27.5.

Table 1

Coefficient of growth tension of the middle tree of natural regeneration of Scots pine on fallow lands of Myronivka Agroforestry

Age, years	Degree of thickness, cm	Number of trees in the TP, pcs.	Average height, m	Basal area g, cm^2	Coefficient of tension of middle tree $h\ 100 / g$
TP 20–01					
22	6	55	7.9	28	28.2
22	8	38	8.2	50	16.4
23	10	69	10.5	79	13.3
25	12	68	12.5	113	11.1
26	14	22	12.8	154	8.3
27	16	10	13.8	201	6.9
29	18	4	14.1	255	5.6
TP 20–02					
22	6	50	7.6	28	27.1
22	8	40	7.9	50	15.8
23	10	81	10.1	79	12.8
25	12	44	12.3	113	10.9
26	14	11	13.0	154	8.4
27	16	10	13.5	201	6.7
29	18	9	14.0	255	5.5
30	20	5	14.3	314	4.6
TP 20–03					
22	6	60	7.7	28	27.5
22	8	62	8.0	50	16.0
23	10	84	10.3	79	13.0
25	12	34	12.1	113	10.7
26	14	8	12.9	154	8.4
27	16	10	13.7	201	6.8
29	18	11	13.9	255	5.5
30	20	8	14.2	314	4.5

With the increase in the degree of thickness at the same age to 8 cm in height were distributed, respectively, 8.2; 7.9; 8.0 m, which affected

the growth rates of 16.4; 15.8; 16.0. Increasing the age of trees in the plantation to 29–30 years with an increase in the degree of thickness of 18–20 cm contributed to a decrease in the coefficients of growth tensions to 5.6–4.5.

The second option (Table 2) is presented trail plots 20–04, 20–05, 20–06 age also 22 years, but in the oldest trees where the degrees of thickness were greater. For a degree of thickness of 16 cm of height were distributed, respectively, 12.9; 13.0; 14.0 m, which in turn correspond to the coefficients of growth intensity – 6.4; 6.5; 7.0. With the increase in the degree of thickness at the same age to 18 cm in height were distributed, respectively, 13.3; 13.7; 14.3 m, which affected the coefficients of growth intensity – 5.2; 5.4; 5.6, which have decreased significantly, but there is a trend – a higher height corresponds to a larger value of the growth rate.

Table 2

Coefficient of growth tension of the middle tree of natural regeneration of Scots pine on fallow lands of Tarashcha lands

Age, years	Degree of thickness, cm	Number of trees in the TP, pcs.	Average height, m	Basal area g, cm^2	Coefficient of tension of middle tree $h\,100\,/\,g$
TP 20–04					
15	6	58	7.5	28	26.8
17	8	53	7.8	50	15.6
19	10	51	9.8	79	12.4
20	12	42	11.8	113	10.4
21	14	31	12.4	154	8.0
22	16	11	12.9	201	6.4
22	18	9	13.3	255	5.2
TP 20–05					
15	6	58	7.3	28	26.1
17	8	61	7.7	50	15.4
19	10	43	10.1	79	12.8
20	12	38	12.1	113	10.7
21	14	16	12.6	154	8.2
22	16	25	13.0	201	6.5
22	18	9	13.7	255	5.4
TP 20–06					
15	6	50	7.1	28	25.4
17	8	69	8.1	50	16.2
19	10	53	10.4	79	13.2
20	12	34	12.3	113	10.9
21	14	22	13.3	154	8.6
22	16	14	14.0	201	7.0
22	18	10	14.3	255	5.6

In both cases, at the same age (22 years), different coefficients of tensions were found: in the first – the highest, in the second – the lowest because the age of the youngest trees is 22 years (depressed and therefore less stable), and in the second – the oldest under appropriate conditions.

That is, with increasing values of basal areas, the coefficients of growth tension of medium-sized trees in the plantation decrease, but their difference is explained by the change in height. With the same basal area, the growth rate is greater where the greater the height.

Taking into account the peculiarities of natural regeneration, when different-age plantations are formed, an attempt is made to generalize the coefficients of growth tensions of medium-sized plantations in general (Table 3). To obtain summary data on the coefficients of tree growth tension in the stands of Scots pine natural regeneration average weighted indicators of heights and diameters using the quantitative representation of trees in terms of thickness were analysed. As a result of calculations, the following consolidated coefficients of growth tension of medium-sized trees were obtained: in plantations of natural regeneration of Scots pine on the fallow lands of Tarashcha lands from 8.2 (TP 20–02) to 12.8 (TP 20–01); in plantations of natural regeneration of Scots pine on the fallow lands of Myronivka Agroforestry from 11.1 (TP 20–06) to 12.4 (TP 20–05).

Table 3

Summary data of growth tension coefficients of medium trees of natural regeneration of Scots pine in the trail plots

Code of TP	$A_{avr.}$, years	N, pc./ha	Average		P, unit	G, cm^2	K_n, $h\,100\,/\,g$
			h, m	d, cm			
20–01	24	2660	10.6	10.3	0.91	83	12.8
20–02	24	2500	8.8	11.7	0.88	107	8.2
20–03	27	2770	10.6	10.9	0.94	93	11.4
20–04	19	2550	10.0	10.6	0.88	88	12.0
20–05	19	2500	9.7	10.0	0.88	78	12.4
20–06	19	2520	10.7	11.1	0.85	97	11.1

According with the obtained data comparing the two options, it can be noted that the natural regeneration of Scots pine forms comparable results (close coefficients of growth tension).

For a better representations and practical comparison of the results of the study of the calculation of this coefficient, which characterizes natural plantations at a density of 1.0 and 0.7 (data obtained from tables of growth of closed pine stands of natural origin [16] and experimental data of test plots) (Fig. 1).

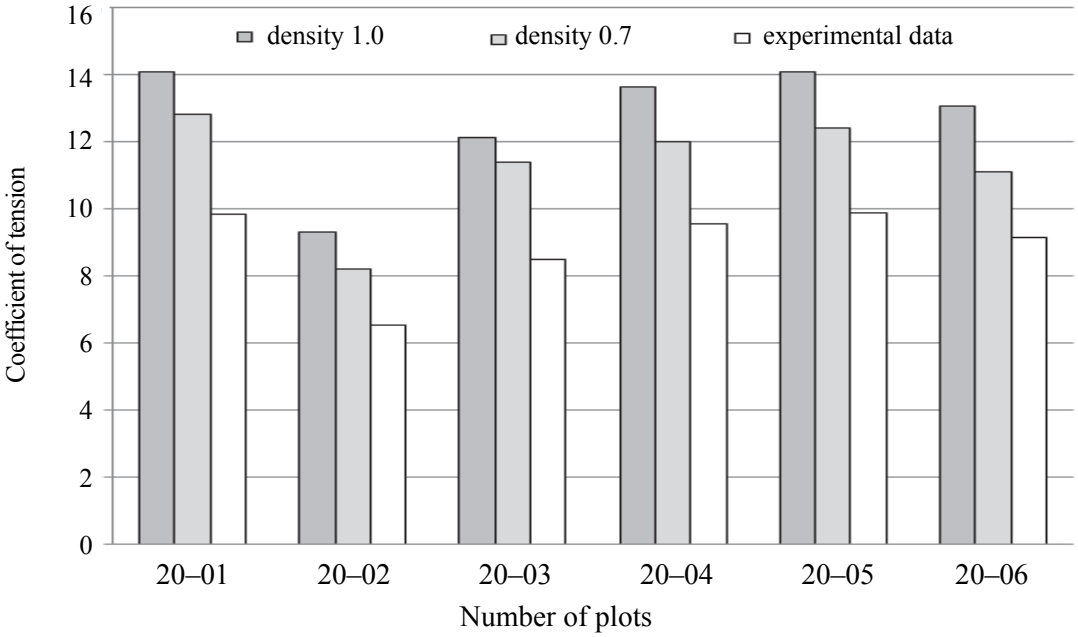

Fig. 1. Coefficient of growth tension of trees
of natural origin according to standards [16] and experimental data

In plantations of natural origin trees are differentiated in a timely manner according to growth and development, which indicates optimal natural liquefaction, especially of stunted and damaged trees. According to our experimental data, the relative density varies from 0.85 to 0.94, the average age is 19 (TP 20–04, TP 20–05, TP 20–06), 24 years (TP 20–01, TP 20–02), 27 years old (TP 20–03). Therefore, according to experimental data in the trail plots, natural selection takes place without the subjective intervention of the human factor, according to the rules of deforestation and reforestation, it is necessary to carry out the thinning.

To determine the sanitary state of natural regeneration, we set up 6 test plots in two experimental sites of different ages and density. The distribution of Scots pine trees in natural plantations by categories of sanitary state (I_{SS}) in fresh sites is given in Table. 4.

Graphically obtained data on the sanitary condition of temporary test areas are presented in Fig. 2.

Thus, the most represented is the first class of sanitary condition, and the least is the sixth class, which indicates a satisfactory state of natural regeneration. According to the index of sanitary condition, plantations of natural origin of Scots pine in all test areas are classified according to the "Sanitary rules in the forests of Ukraine" as weakened (I.9), due to high competition from older trees and the competition for light.

Table 4

Distribution of the number of trees by categories of sanitary state

Code of TP	Number of trees in the trial area, pcs.	Number of trees by sanitary state categories: numerator, pcs.; denominator, %						I_{SS}
		I	II	III	IV	V	VI	
20–01	266	148	66	23	25	3	1	I.8
		55.6	24.8	8.6	9.4	1.1	0.4	
20–02	250	150	65	19	11	2	3	I.6
		60.0	26.0	7.6	4.4	0.8	1.2	
20–03	277	137	80	43	12	2	3	I.8
		49.5	28.9	15.5	4.3	0.7	1.1	
20–04	255	130	60	28	26	7	4	I.9
		51.0	23.5	11.0	10.2	2.7	1.6	
20–05	250	110	61	46	32	1	0	II.0
		44.0	24.4	18.4	12.8	0.4	0.0	
20–06	252	63	86	60	40	2	1	II.3
		25.0	34.1	23.8	15.9	0.8	0.4	
Weighted average sanitary state index								I.9

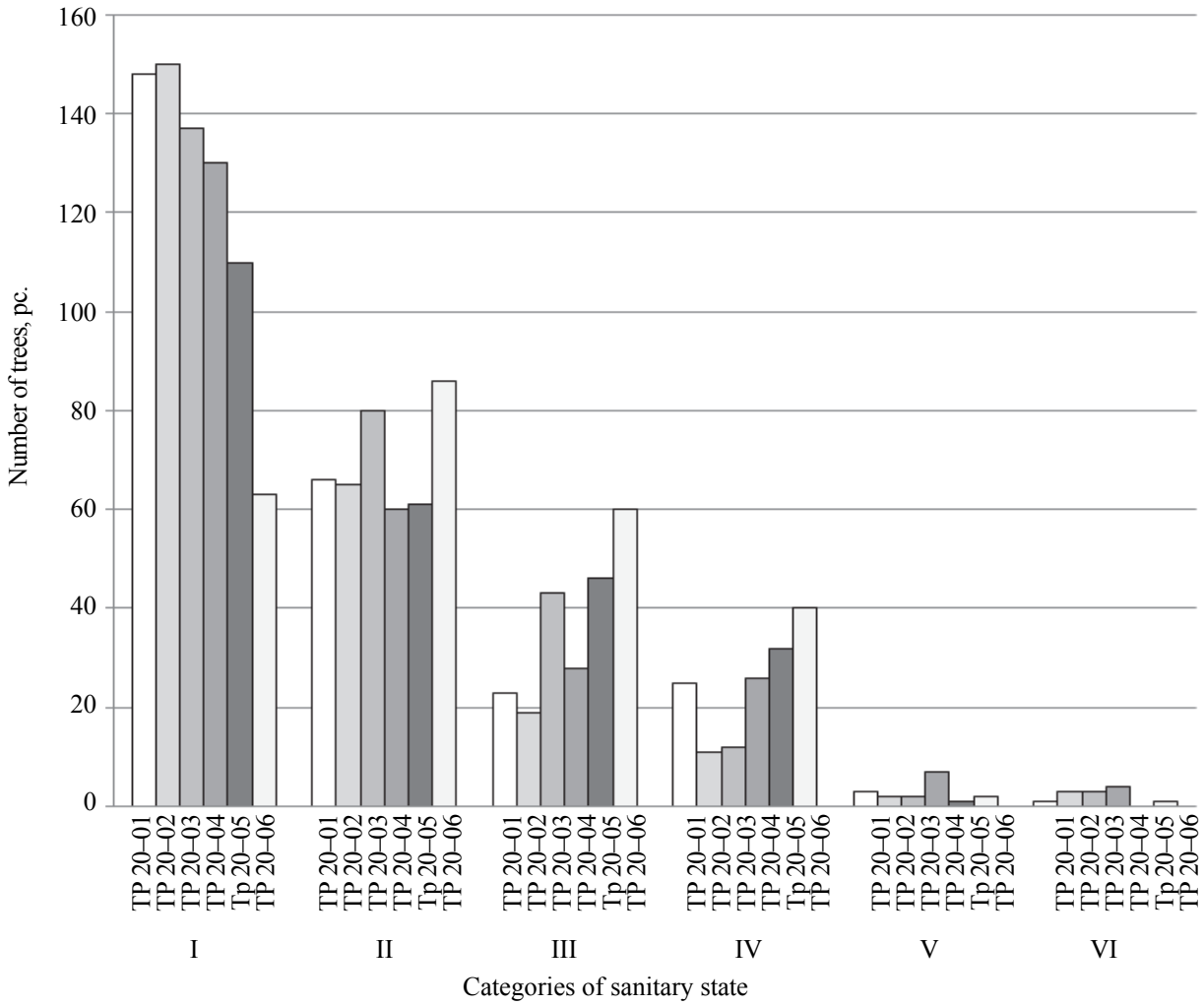

Fig. 2. Distribution of natural regeneration trees by categories of sanitary state

Conclusion. The determined coefficients of tree growth tension indicate that their greatest values occur in dense places where plants with the minimum diameter try to reach the maximum possible height, which correlates well with the types of forest sites. At the same time, they are strongly associated with the age of the stands. At a young age, the stress of tree growth becomes greatest and over time decreases. As a result, young plants have a maximum loss. Therefore, the coefficients of growth tension of trees are due to differences in environmental conditions and age.

For the practical application of the calculated coefficient of growth tension of the middle tree in order to provide recommendations to forestry on the proper quality of thinning of forest formation and rehabilitation, the generalization of experimental data on growth and placement of trees in plantations of natural origin on fallows.

Although no forest management measures were carried out in the natural regeneration plantations, but tree differentiation and real natural selection were successful. They were not affected by anthropogenic factors, which were reflected in their condition, before the onset of cleanings and thinning.

The calculated index of the sanitary state of natural pine plantations, which is in the range of 1.6–2.3, indicates that the plantations belong to the weakened ones in all test plots.

It is found out that the most influential factors of significant deterioration of the sanitary condition of trees of natural regeneration of pine are the drying of trees due to the natural selection of suppressed trees.

In order to reduce the negative impact of extreme and local manifestations on the growth and state of pines of natural origin should be mainly preventive measures in cluttered areas. Timely and systematic thinning in plantations will reduce natural decline, improve sanitation, clutter and conditions for the development of pests and pathogens. In the plantation, respectively, will reduce the density, the number of trees per unit area, and this will increase the light of the territory, the growth of trees in height and diameter.

The question of the possibility of creating a natural way of regeneration pine plantations on ravine-beam lands should be answered in the affirmative. This process is significantly different from the natural restoration of tree species under the canopy and on the cuttings. It is much more complex and problematic, requires more attention and creativity during a set of forestry activities. However, the factor of greater stability of natural plantations and fuller performance of their protective functions should compensate for the complexity of the forestry process of growing such plantations in the relevant areas.

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Поступила 01.03.2021