Characteristic of the state of spruce plantations in the area of southern taiga forests of the taiga zone in the Udmurt Republic[1]

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Abstract. The results of studying the state of coniferous plantations and describing forest stands in the region of the southern taiga forests of the taiga zone within the Udmurt Republic (on the territory of Yakshur-Bodyinsky, Igrinsky and Kezsky forestries) are presented. Studies have shown that the cellulose-decomposing activity of the forest litter depends on its moisture content, which is associated with the values of the absolute density of forest stands on the studied sample plots. The analysis of physiological and biochemical parameters of Siberian spruce (*Pícea obováta* Ledeb.) Was carried out and their comparison was carried out in individuals of good and satisfactory vital state, which did not show statistically significant differences in the content of chlorophylls and carotenoids in needles. It has been shown that, in general, the potential of Siberian spruce specimens associated with the biochemical level of the formation of adaptive reactions is highest in plants in the northern regions of the republic, i.e. in areas with more extreme growing conditions. Materials have been obtained, on the basis of which it is possible to develop a program for monitoring plantings and restoring forest stands.

Keywords: adaptation, spruce stands, photosynthetic pigments, needles, tannins, tree stand

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A sharp reduction in the area of dark coniferous boreal forests in the European part of Russia and the forecast of forest pathological situation due to the weakening and pest infestation of the remaining forests, of course, have a negative impact on the development of the entire forest industry [1], threatens the integrity of forest ecosystems, entails the destruction of habitats of organisms, and also causes the development of insect pests and diseases of the stand.

Thus, the problem of preserving spruce plantations and improving the ecological methods of their restoration is of significant importance for the economy and ecology of not only the Udmurt Republic, but also the Russian Federation as a whole. In addition, large industrial centers located near them affect the condition of coniferous plantations. However, despite the presence of a complex of negative factors, certain species and individual individuals of woody plants exhibit a high adaptive potential, which is of great interest in the study of adaptive responses and genetic diversity of plant individuals.

At the present time, it has become urgent to study the state of forest litter in spruce stands, subject to complex drying out and damage by the bark beetle-typographer, since the forest litter in the forest biogeocenosis is very important. It is not only a product of the forest and its component, but also a factor that determines the state of the forest [2].

In the present study, the analysis of the influence of a complex of environmental factors on the plant was carried out on the basis of the biochemical characteristics of spruce shoots - according to the content of photosynthetic pigments, ascorbic acid and tannins in needles and shoots.

Photosynthetic pigments play a significant role in the system of plant adaptive reactions. For example, the content and ratio of pigments is an indicator of resistance to stress. With water deficit and high air temperatures, the content of the sum of chlorophylls a and b decreases to 40% [3–6]. One of the possible reasons for this is a reduction in the size of leaf cells under conditions of water deficiency, i.e. there is an increase in the number of cells per unit area (or mass) [3]. Drought suppresses the intensity of plant photosynthesis, causing changes in chlorophyll content and damage to the photosynthetic apparatus [4-8].

In the formation of adaptation to stress factors, it is important to have substances with antioxidant properties, which include ascorbic acid, which is involved in the enzymatic activity of the plant [5]. Some scientific studies are aimed at determining the participation of ascorbic acid in the formation of the immune system of plants. In particular, its intensive production is considered one of the manifestations of active plant immunity, i.e. represents the response of plants to many of their lesions through enhanced biosynthesis of ascorbic acid. Ascorbic acid also plays an important role in photosynthesis, especially in the stabilization of the photosynthetic apparatus, increasing the photochemical activity of plants [9].

The importance of tannins in the formation of the stability of tree plantations is essential. Their content in leaves is influenced by the degree of technogenic load and the peculiarities of the climatic conditions of the growing season. In addition, condensed tannins are active participants in the adaptation processes in woody plants under conditions of technogenic stress and high air temperatures [10-12].

Purpose of the work

Purpose of the work — study of the state of plantations and physiological and biochemical characteristics of Siberian spruce growing within the Udmurt Republic.

Materials and methods

The studies were carried out on the territory of Yakshur-Bodinsky, Igrinsky and Kezsky forestries in the taiga (boreal zone of southern taiga forests) zone of the Udmurt Republic. The object of the study is coniferous stands of Siberian spruce (*Pícea obováta* Ledeb.).

To assess the taxation parameters and the state of spruce plantations, test plots (TP) with a size of 100×100 m were laid on the territory of three investigated forestries. In each forestry, there is one TP in stands with a predominance of spruce, in places of their active drying up and in oxalis types of forest.

According to their vital state, woody plants were divided into three groups: 1) good condition (dense or slightly thinned crown, green/light green needles; some branches withered); 2) satisfactory (openwork crown; needles light green, matte; weakened growth, less than half of the usual); 3) unsatisfactory (drying of branches up to 50%; presence of mechanical damage on the trunk, detection of signs of primary damage by xylophages and/or wood-destroying fungi).

The analysis of forest litter was carried out on accounting plots 10×10 cm using a template in the amount of 10 pcs. per one TP (as a result, 10 individual samples were formed) with division into fractions and layers [13]. The activity of destructors of forest litter was determined by analysis for cellulose-decomposing activity [14].

To study the biochemical characteristics of shoots and needles, five model individuals of a good and satisfactory life state were selected at each TP. Model individuals had a middle-aged generative ontogenetic state (g_2).Mixed samples were taken and formed from model individuals, from which samples were prepared for analysis in three- and four-fold repetition. For the analyzes, the shoots of the current growing season were selected. The analysis of the content of photosynthetic pigments in needles was carried out by the spectrophotometric method in alcohol extracts using a PE-5400UF spectrophotometer; calculation of the concentration of pigments - according to the Holm - Wettstein equations. The content of ascorbic acid was determined according to GOST 24556–89 (titrometric method), the content of tannins was determined spectrophotometrically at a wavelength of 277 nm [15].

Results and discussion

The climate of Udmurtia is moderately continental with long cold and snowy winters, warm summers and well-defined springs and autumn. However, the significant length of the territory from north to south and the heterogeneity of its relief determine significant differences between the northern and southern parts of the republic in temperature and humidity, wind regime, amount of precipitation and duration of sunshine. Kezsky , Igrinskoe and Yakshur-Bodinskoe forestries are located in the southern taiga forests of the taiga zone of the European part of the Russian Federation [16].

The considered southern taiga forest zone is characterized by a moderately cold humid climate. The average annual air temperature ranges from +4°C to + 7-16°C. In addition, 2020 was distinguished by some climatic features recorded in the study areas.

Table 1 shows the taxation characteristics of the spruce stand on the studied TP. Plantations are of the same age, I and II bonitet, the highest indicators of absolute completeness are typical for TP Yashkur-Bodinsky forestry.

Table 1

Taxation characteristics of spruce stand on test plots of Yakshur-Bodinsky, Igrinsky and Kezsky forestry

Forestry	Trial area number	Wood composition	Average values			Wood stock, m^3/ha	Completeness, m^2/ha		Bonitet
			Age, years	Barrel height, m	Trunkdiameter, cm		Absolute	Relative	
Yakshur-Bodyinskoe	1	7E1P1B1Os	77	18	22.2	109.1	3.3	0.2	II
	2	9E1Os+P	74	23	26.8	191.2	8.3	0.5	II
	3	8E2P	74	21	30.8	375	2.4	0.8	I
Igrinskoe	1	8E2P	69	19	22.9	182.2	2.9	0.5	II
	2	9E1P	70	19	23.9	27.7	1.7	0.7	II
	3	8E2P	64	20	21.9	222.1	2.2	0.6	I
Kezsky	1	8E2P	62	19	21.1	196.6	2.0	0.6	II
	2	9E1P	63	21	21.4	225.9	2.2	0.6	I
	3	8E2P	65	21	22.3	213.	1.9	0.5	I

The analysis of the cellulose decomposing activity (CDA) of the forest litter (tab. 2) showed that the Yakshur-Bodinskoe forestry is distinguished by low CDA values at TP № 2 and TP № 3. In Igrinskoye lesnichestvo, no differences were found for this indicator between TP. The highest CDA values are characteristic for TP № 1 of the Kezsky forestry, with some of the lowest absolute stand density values (1.9 m^2/ha) and the highest litter mass. The moisture content of the forest floor was 54.9%.

Table 2

Component composition and cellulose-decomposing activity of forest litter in spruce stands of Yakshur-Bodyinsky, Igrinsky and Kezsky forestries

Forestry	Trial area number	Cellulose decomposing activity,%	Morphological appearance of forest litter (weight of layers, g)		
			$L\ (A_0')$	$F\ (A_0'')$	$H\ (A_0''')$
Yakshur-Bodyinskoe	1	60.83 ± 8.07[1] 48.00…73.67[2]	174.72 ± 39.42 111.98…237.45	75.47 ± 10.37 58.97…91.97	838.38 ± 60.98 686.89…989.88
	2	42.49 ± 2.05 39.23…45.75	126.45 ± 18.22 97.46…155.45	141.53 ± 25.06 101.66…181.40	195.38 ± 44.41 85.06…305.71
	3	28.08 ± 4.13 25.11…33.93	77.18 ± 20.43 44.67…109.70	37.54 ± 11.74 18.86…56.23	656.69 ± 30.26 608.53…704.86
Igrinskoe	1	24.56 ± 2.46 18.46…30.66	40.51 ± 6.97 29.42…51.60	46.07 ± 18.05 17.35…74.79	313.15 ± 3.16 305.31…320.99
	2	48.88 ± 9.00 34.55…63.12	110.29 ± 25.38 69.91…150.67	90.36 ± 26.40 48.35…132.37	281.95 ± 22.34 226.45…337.45
	3	30.28 ± 8.62 23.67…42.46	187.21 ± 9.84 171.55…202.86	45.93 ± 7.57 33.86…57.98	106.21 ± 19.90 74.54…137.88
Kezsky	1	86.76 ± 4.23 80.03…93.49	249.75 ± 23.43 212.42…287.09	150.54 ± 25.10 110.60…190.48	495.93 ± 23.70 458.21…533.64
	2	56.61 ± 1.42 54.35…58.87	242.14 ± 36.82 183.55…300.73	103.16 ± 28.93 57.13…149.18	233.23 ± 14.37 210.37…256.09
	3	53.00 ± 12.03 36.98…66.00	108.65 ± 44.62 37.65…179.65	97.29 ± 12.25 77.79…116.78	129.28 ± 25.30 89.01…169.54
1 - Average value of the indicator ± standard deviation; 2 - confidence interval for the mean at $P < 0.05$; the values with significant differences are highlighted in bold (similarly for tab. 3).					

The results of the biochemical analyzes of the shoot of Siberian spruce are presented in table. 3. When comparing the parameters of the content of photosynthetic pigments in individuals of good and satisfactory life state in different forestries, it was found that statistically significant differences in the content of chlorophyll *a* and *b* and carotenoids were not revealed. The exceptions are individuals of different life states from the trial TPs of the Igrinskoye forestry, where the content of photosynthetic pigments in individuals with a satisfactory life state is significantly lower than in individuals with a good life state, and all spruce individuals have a high stress resistance index (the sum of chlorophylls *a* and *b*). Similar results were obtained for the content of ascorbic acid in needles.

Table 3

Content of physiological and biochemical parameters of Siberian spruce in Yakshur-Bodinsky, Igrinsky and Kezsky forestries

Forestry	The vital state of plants	photosynthetic pigments in needles, mg/g				ascorbic acid, mg/100 g	tannins,%	
		Chlorophyll *a*	Chlorophyll *b*	Carotenoids	Stress tolerance, *a*+*b*		Needles	Stem part
Yakshur-Bodyinskoe	Good	**4.21 ± 0.35**[1] 3.65…4.76[2]	0.55 ± 0.07 0.45…0.66	1.71 ± 0.16 1.45…1.96	4.76 ± 0.42 4.10…5.42	214.90 ± 29.57 167.85…261.95	4.48 ± 0.18 4.19…4.77	**3.10 ± 0.21** 2.78…3.43

	Satisfactory	3.35 ± 1.47 1.01…5. 69	0.54 ± 0.11 0.36…0. 72	1.37 ± 0.62 0.38… 2.36	4.82 ± 1.42 2.55…7. 08	260.21 ± 17.54 232.30…2 88.12	4.09 ± 0.76 2.88…5. 30	**2.24 ± 0.34** 1.70…2. 77
Igrinskoe	Good	**6.97 ± 0.07** 6.86…7. 07	**1.29 ± 0.06** 1.20…1. 38	**2.68 ± 0.06** 2.58… 2.77	**8.26 ± 0.01** 8.24…8. 27	**151.21 ± 7.66** 139.02…1 63.39	**6.62 ± 0.22** 6.27…6. 98	**1.76 ± 0.11** 1.58…1. 94
	Satisfactory	**5.82 ± 0.37** 5.24…6. 40	**0.95 ± 0.08** 0.83…1. 08	**2.34 ± 0.16** 2.08… 2.58	**6.77 ± 0.44** 6.07…7. 48	**129.31 ± 2.70** 125.01…1 33.61	**5.12 ± 0.35** 4.57…5. 67	**2.27 ± 0.07** 2.17…2. 38
Kezsky	Good	4.06 ± 0.28 3.63…4. 50	0.68 ± 0.05 0.60…0. 76	1.82 ± 0.11 1.64… 2.00	4.74 ± 0.33 4.22…5. 26	240.07 ± 19.57 208.93…2 71.21	4.69 ± 0.30 4.21…5. 16	2.59 ± 0.52 1.76…3. 42
	Satisfactory	4.69 ± 0.63 3.69…5. 69	0.89 ± 0.06 0.78…0. 99	2.07 ± 0.17 1.81… 2.34	5.58 ± 0.63 4.58…6. 58	286.49 ± 13.25 265.40…3 07.58	5.39 ± 0.35 4.83…5. 95	2.38 ± 0.56 1.49…3. 28

Individuals with a good life state, growing in the studied forestries, differ significantly in the content of photosynthetic pigments and tannins in needles in Igrinskoye forestry - they are significantly higher. It should also be noted that the indicators of the content of chlorophylls and carotenoids in individuals with a satisfactory life state in the Igrinskoye forestry significantly exceeded the indicators for individuals in a good life state in the Kezsky and Yakshur-Bodinsky forestries.

The content of ascorbic acid in needles, on the contrary, had the lowest indices in Igrinskoye forestry, significantly differing from those in Kezsky with the highest content of ascorbic acid and Yakshur-Bodinskoye forestries in individuals of both life states. It can be assumed that ascorbic acid significantly participated in the redox processes of plants in the Igrinsky forestry, which allowed them to preserve the integrity of chlorophylls and photosynthetic apparatus.

A significantly higher content of tannins (tannins) in needles was also noted in Igrinskoye forestry, but only in individuals with a good life state. The highest concentrations of tannins in the stem part of the shoot were noted in individuals with a good life state in the Yakshur-Bodinsky forestry, in individuals with a satisfactory life state in Kezsky.

The features of Siberian spruce, associated with the content of chlorophyll a, tannins and ascorbic acid in the needles, were revealed: a high content of chlorophyll is accompanied by a high content of tannins, while these individuals have a significantly lower content of ascorbic acid in needles.

In general, it can be noted that the potential of Siberian spruce, associated with the formation of adaptive reactions at the biochemical level, is maximum in plants from more northern regions of the republic, characterized by increased extreme growing conditions.

References

[1] A brief overview of the sanitary and forest pathological state of the forests of the Udmurt Republic in 2013 and the forecast of the forest pathological situation for 2014. Izhevsk: Publishing house – FBU "Roslesozashchita", 2014. 44 P.

[2] Bukharina I.L., Svetlakova O.A., Konopkova A., Ledneva O.S., Absalyamov R.R. Condition of forest litter in spruce plantations of the Republic of Udmurtia // AgroEkoInfo, 2019, № 3 (37). P. 35.

[3] Saydaminov Kh.Kh., Maniyazova N.A., Atoev M.Kh., Abdullaev A. Chlorophyll content in some legumes under conditions of soil drought // Reports of the Academy of Sciences of the Republic of Tajikistan, 2016. V. 59. № 9–10. P. 428–433.

[4] Anjum S.A., Xie X, Wang L. et al. Morphological, physiological and biochemical responses of plants to drought stress // Afr. J. Agr. Res., 2011, no. 6, P. 2026–2032.

[5] Ashraf M., Harris P.J.C. Photosynthesis under stressful environments // An overview-Photosynthetica, 2013, V. 51 (2), P. 163–190.

[6] Kannan N.D., Kulandaivelu G. Drought induced changes in physiological, biochemical and phytochemical properties of *Withania somnifera* Dun. // J. Med. Plants Res., 2011, V. 5, P. 3929–3935.

[7] Reda F., Mandoura H.M.H. Response of enzymes activities, photosynthetic pigments, proline to low or high temperature stressed wheat plant (*Triticum aestivum* L.) in the presence or absence of exogenous proline or cysteine // Int. J. Acad. Res., 2011, V. 3, P. 108–115.

[8] Velikova V., Sharkey T.D., Loreto F. Stabilization of thylakoid membranes in isoprene-emitting plants reduces formation of reactive oxygen species // Plant Signal. Behav., 2012, V. 7, P. 139–141.

[9] Olkhovych O., Volkogon M., Taran N., Batsmanova L., Kravchenko I. The Effect of Copper And Zinc Nanoparticles on the Growth Parameters, Contents of Ascorbic Acid, and Qualitative Composition of Amino Acids and Acylcarnitines in Pistia stratiotes L. (Araceae) // Nanoscale Research Letters, 2016, V. 11, P. 218.

[10] Bukharina I.L., Kuzmina A.M., Kuzmin P.A. Features of the content of tannins in the leaves of woody plants in a technogenic environment // Chemistry of plant raw materials, 2015. № 4. P. 71–76.

[11] Gowda J.H., Palo R.T., Udén P. Seasonal variation in the nutritional value of woody plants along a natural gradient in Eastern Africa // Afr J Ecol., 2019, V 57, P. 226–237.

[12] Vedernikov K.E., Zagrebin E.A., Bukharina I.L. Features of the biochemical composition of spruce wood in plantations subject to drying out in the coniferous-deciduous zone of the European part of Russia // Forest Bulletin // Forestry Bulletin, 2020. V. 24. № 4. P.

33–42.

[13] Soils. Methods for determination of moisture content, maximum hygroscopic moisture content and moisture content of sustainable plant wilting URL: http://docs.cntd.ru/document/1200023556.

[14] Kruglov Yu.V., Kurdyukov Yu.F., Shubitidze G.V. Microbiological activity of southern chernozem, depending on agricultural practices in the arid steppe of the Lower Volga region // Agrarian scientific journal, 2018. № 1. P. 20–23.

[15] By-products of fruits and vegetables. Methods for the determination of vitamin C. URL: http://docs.cntd.ru/document/1200022765.

[16] Vakhrushev K.V., Absalyamov R.R. Forestry complex of the Udmurt Republic: state, problems, prospects for the development of forest relations // Forests of Eurasia - Forests of the Volga region. Materials of the XVII Intern. conf. of young scientists dedicated to the 150th anniversary of the birth of Professor G.F. Morozov, Kazan, October 22-28, 2017 M.: Publishing house "IPC"Mask", 2017. P. 34–38.