Caspian Journal of Environmental Sciences
Online ISSN: 1735-3866
Print ISSN: 1735-3033

Variability of Siberian stone pine cones yield in conditions of introduction to the taiga zone of the East European Plain

Renat S. Khamitov*, Alexandr V. Lebedev, Svetlana M. Khamitova

Russian State Agrarian University – Moscow Timiryazev Agricultural Academy, 49 Timiryazevskaya St., Moscow, 127434, Russian Federation

* *Corresponding author's E-mail: r.hamitov@rgau-msha.ru*

ABSTRACT

The change in the carbon stock in the soil cover during the uplift of fallow areas on leached black soils is considered. The aim of the study is to compare dynamics of carbon stock on fallow lands of black soils. Two objects of the study are in the central part of the Russian Federation in Penza region, which belongs to forest and forest-steppe climatic zones. Studies were carried out on two sites typical for the study area, differing in mesorelief and water regime. Object one is a fallow land of floodplain 30-year-old deposits with meadow vegetation characteristic of the region on meadow-black soil and leached black soil humus heavy loamy hydromorphic soils. The second fallow land is located on the territory of 30-year-old deposits overgrown under birch tree plantation with leached medium-humus heavy loamy black soils. Four control sites were laid on each field, differing in the period of cultivation. The carbon stock in the soil in the thickness of the arable horizon was estimated in the course of the conducted studies. Greenhouse gas emissions were estimated using chambers that do not violate soil flows with further analysis of the selected gases on a chromatograph. The research results demonstrate the spatiotemporal dynamics of carbon dioxide emissions, the maximum values were tracked on a 30-year-old forest fallow site, and the minimum values on a meadow fallow ecosystem. The dependence of soil flows is associated with the warming of the soil cover, the density of soil horizons and the fallowness of the territory, since the amount of available carbon dioxide is elevating due to a large increase in vegetation biomass and litter. Carbon stocks in the arable horizon varied depending on the location of key sites in the relief, soil type, seasonality and mechanized intervention of agricultural machinery. Siberian stone pine is a valuable introduced species in the taiga zone of the East European Plain. In general, this type of pine is cultivated to produce pine nuts. Seed productivity is an important feature of breeding for Siberian stone pine. It also serves as an indicator of adaptive potential for introduced species. The research was conducted to assess the variability of the Siberian stone pine cones yield under conditions of introduction to the taiga zone of the East European Plain. Observations of seed-bearing Siberian stone pine were carried out in one of the oldest plantations of this tree species in the taiga zone of the East European Plain: Chagrino cedar grove, located in the Gryazovets municipal district of the Vologda region. In 2013-2024, the number of cones in the crowns of selected model trees was calculated in this cedar plantation, which made it possible to identify their individual variability on this basis, as well as the plantations overall reproductive capacity. The research results allow us to conclude that the seed production rate of Siberian stone pine in the new soil and climatic conditions corresponds to its biological characteristics, since no years with a complete lack of harvest were detected during the study period. On average, the yield of one tree is 131 ± 17 cones. In addition, correlative features have been identified that allow for the selection of high-yielding individuals. Research data indicate that relatively short individuals with a narrow but extended crown should be selected as maternal producers for further breeding.

Keywords: Siberian stone pine, Cedar, Breeding of tree species, Reproductive capacity.
Article type: Research Article.

Caspian Journal of Environmental Sciences, Vol. 23 No. 3 pp. 749-755 Received: Jan. 06, 2025 Revised: April 19, 2025 Accepted: June 26, 2025
DOI: 10.22124/cjes.2025.8953

Publisher: University of Guilan,

INTRODUCTION

Siberian stone pine in Russia grows naturally in the Urals, in the taiga zone of the West Siberian Plain, Altai and Sayan Mountains. In the European part of the country, the range of Siberian stone pine covers the Middle Urals and the eastern regions of the Komi Republic. This tree species, which are important forest-forming plants within their range, are of interest for introducing into the forests in the European North of Russia. The ecological features of this tree species, as a whole, do not hinder their growth and generative development in forests of the region. The decorative qualities of the plant introduced allowed it to be used for landscaping in cities and towns as well as for creating plantings around them (Sungurova *et al.* 2023; Chukina *et al.* 2024). One of the main valuable properties of the Siberian stone pine that determines the feasibility of its introduction is related to its ability to produce nuts. In natural conditions, large seeds of this species are distributed by spotted nutcracker (*Nucifraga caryocatactes* Linnaeus) or rodents (Tantsyrev *et al.* 2023). The seeds of this woody plant have nutritional value, are used in pharmacology and the chemical industry. Siberian stone pine plantations created near cities and towns attract vacationers, who collect cones, thereby increasing the recreational value of suburban forests (Andriyanova *et al.* 2019). Studies of the variability in the reproductive ability of Siberian stone pine were carried out within the range of this species (Zhuk & Goroshkevich 2019; Novikova *et al.* 2024). The geographical conditionality of the reproductive ability and the impact of climatic change on the yield of seeds and cones, as well as natural reforestation processes, are noted (Zhuk & Goroshkevich 2019; Goroshkevich *et al.* 2022). The genetic polymorphism of populations, and related mechanisms for cedar range expansion and migration in the past, are being actively studied (Oreshkova *et al.* 2022; Novikova *et al.* 2024). To date, sufficient information has been accumulated on individual variability and hereditary nature of yield (Goroshkevich *et al.* 2022). Significant influence is given to the characteristics of the crop structure (the size of cones and seeds, the number of fertile scales on cones; Velisevich 2022). Studies have shown that climatic changes contribute to the expansion of the northern border of the Siberian stone pine range, due to improved conditions for the formation of a seed crop (Velisevich 2022). It should be noted that, under the conditions of climate change, the range of some species of five-coniferous pine trees is decreasing. For example, the whitebark pine in North America has significantly narrowed its range in recent decades (Bower *et al.* 2007; Leirfallom *et al.* 2015; Liu *et al.* 2016; Amberson *et al.* 2018; Goeking & Izlar 2018; Pansing & Tomback 2019; Jenkins *et al.* 2022). The reduction in the range of this species is largely due to the damage caused by the native mountain pine beetle, *Dendroctonus ponderosae* and the invasion of blister rust (caused by the pathogen *Cronatium ribicola*; Perkins 2015; Leirfallom *et al.* 2015; Goeking & Izlar 2018; Amberson *et al.* 2018; Pansing & Tomback 2019; Kichas *et al.* 2020; Jenkins *et al.* 2022; Tomback *et al.* 2022). The ability to preserve the boundaries of the range and the tendency to expand them in Siberian stone pine demonstrate the stability of this species in the face of environmental changes, indicating the prospects for its introduction. A number of environmental factors have a significant impact on the yield of cones and seeds, such as: geographical location, altitude above sea level, age and closeness of the plantation, weather conditions of the period of formation and formation of generative organs, genotypic structure of populations (Zhuk & Goroshkevich 2018). It is believed that in closed plantings, the number of cones formed on a tree is related to the size of the crown (Retzlaff *et al.* 2018; Velisevich, & Popov 2022). To breed a species based on its reproductive ability, it is recommended to select plus trees and their clones at forest seed production facilities with stable high yields of cones (Matveeva *et al.* 2025). Reproductive ability is an indicator of the success of the introduction of a species outside its range (Khamitov *et al.* 2018). In this regard, the assessment of the Siberian stone pine cones yield in plantations created outside its range is an urgent task, which makes it possible to identify the species' introduction potential and select high-yielding individuals for the subsequent cultivation of their seed offspring in local conditions. The purpose of our study was to evaluate the variability in the Siberian stone pine cones yield in the taiga region of the East European plain.

MATERIALS AND METHODS

The research was conducted in the Chagrino cedar grove, located in the Gryazovets municipal District of the Vologda region. The cedar grove is a botanical nature monument of regional significance. This plantation was created as a private garden in 1900-1904 by landowner N.A. Petrov on an estate located in the Chagrino village (Fig. 1). The land area is 3.7 hectares. The planting was carried out by 5-10 summer seedlings of Siberian stone pine with a root balls packed in baskets. The distance between the rows and in the row was assumed to be 10 × 10 m. In addition to Siberian stone pine, several specimens of Siberian larch (*Larix sibirica* Ledeb.), petiolate oak

(*Quercus robur* L.) and Siberian fir (*Abies sibirica* Ledeb.) were planted in the grove. Alley plantings of heart-leaved linden (*Tilia cordata* Mill.) were carried out along the perimeter of the plantings. With the exception of linden and oak, all of these species are introduced in the territory under consideration.

Fig. 1. Location and configuration of the Chagrino cedar grove.

To date, 133 specimens of Siberian cedar pine, two of Siberian larch and one of Siberian fir have been preserved in the grove. In 1965-1966, the grove was supplemented with two-year-old seedlings grown from seeds collected earlier in the grove. The soil on the site is sod–podzolic, quite common in the southern taiga subzone. The ground cover consists of a variety of grasses from forest and meadow grasses, and in the curtainlike undergrowth there is a May rose (*Rosa majalis* Herrm.), raspberry (*Rubus idaeus* L.) and black currant (*Ribes nigrum* L.). At the time of the survey, the average height of Siberian stone pines preserved in the grove was 17.3 ± 0.5 with a trunk diameter of 64.4 ± 4.3 cm. The sparse planting density allowed the trees growing here to form fairly wide crowns (10.3 ± 0.4 m), with a length of 12.5 ± 1.1 m, accounting for 72% of the height of the trees. In accordance with the representation of pines by thickness steps, model trees were selected for long-term observations of their seed production. Only seed-bearing individuals (which formed at least 10 cones at the time of selection) were not considered model trees. The assessment of reproductive ability was carried out by annual accounting of the cones number formed in the crowns of trees. To do this, in the first ten days of July (during the period when the cones reached their maximum size and were well developed in the crown, but had not yet begun to fall), the number of cones was counted on both sides of the crown of each model plant, followed by averaging the data and doubling the result obtained. Observations were not carried out in 2015 due to technical reasons.

RESULTS AND DISCUSSION

In the considered introduced plantation, calendar years with a complete absence of a harvest of cones were not revealed. At the same time, the yield of Siberian stone pine at the studied site varies significantly over the years of observation (Table 1). The year 2014 turned out to be the most productive year. On average, 207 ± 30 cones were formed in the crown of one tree this year. This value is 58% higher than the average yield over the years of observation (64.0 ± 2.6 units). At the same time, the yield range for trees in the plantation ranged from 30 to 400 cones. On average, over the years of observations, the maximum number of cones per tree was 320 ± 29 cones. The year 2019 was the least productive year. The average yield of cones was 66 ± 27 cones, which is 50% lower than the average. The average minimum yield of individual tree specimens over the years of observation was 23 ± 2 cones. The average fluctuation level of the yield index was very high on the scale of A.S. Mamaev, which was 64.0 ± 2.6%. The lowest individual variability was recorded in 2022 (Cv = 53.1%), while the highest in 2019 and 2021 (Cv = 72.3% and 72.7%, respectively). Long-term observations of the model trees reproductive capacity revealed chronographic variability (Table 2). Significant fluctuations in yield over the years of cone generation are characteristic of all model trees. On average, for model trees, the minimum yield was 45 ± 8 cones, and the maximum was 254 ± 32. Over the entire observation period, the smallest number of cones was observed in model tree No. 118 in 2023 (14 pcs.), which is 69% lower than the average minimum. The largest number of cones (402 pcs.) was formed in the crown of tree No. 62 in 2021 and No. 115 (400 pcs.) in 2014, which is 58% and 57% higher than the average maximum, respectively. On average, according to the years of observations, tree No. 77

(252 ± 42 pieces) had the highest yield. Model tree No. 118 had the lowest average yield, producing 24 ± 2 cones per year.

Table 1. Variability of the cones yield by years of observation.

Year	Minimum (pcs.)	Maximum (pcs.)	Medium (pcs.)	Variation coefficient (Cv,%)
2013	24	320	125 ± 24	71.8
2014	30	400	207 ± 30	55.1
2016	22	292	124 ± 19	56.1
2017	32	484	172 ± 35	76.3
2018	22	360	141 ± 21	55.6
2019	16	186	66 ± 27	72.3
2020	26	364	165 ± 27	61.1
2021	24	402	156 ± 30	72.7
2022	24	164	84 ± 12	53.1
2023	14	268	104 ± 17	61.3
2024	22	280	101 ± 19	68.4
Medium	23 ± 2	320 ± 29	131 ± 13	64.0 ± 2.6

Table 2. Chronographic variability of model trees in the cones yield.

Tree number	Number of cones on the tree (pcs.)			Variation coefficient (Cv,%)
	minimum	maximum	medium	
62	92	402	208 ± 27	42.4
66	116	322	161 ± 17	35.5
68	30	116	72 ± 7	33.1
77	38	378	252 ± 42	54.8
106	48	229	105 ± 19	55.8
110	76	180	124 ± 9	24.9
111	46	298	171 ± 28	53.6
112	20	376	187 ± 32	57.5
113	32	302	130 ± 25	64.8
115	24	400	157 ± 32	66.8
118	14	42	24 ± 2	32.1
119	24	180	83 ± 17	69.2
165	32	105	59 ± 7	39.1
170	38	226	105 ± 16	49.5
Medium	45±8	254±32	131 ± 17	48.5±3.8

With a very high level of variability in the number of cones formed in the crowns of trees (according to the S.A. Mamaev scale), characteristic of all tree species, individual specimens were distinguished, characterized by the smallest fluctuation over the years of observations. To a greater extent, this is typical of low-yielding specimens. The yield of tree No. 110 (Cv = 24.9%), as well as the lowest productive model tree No. 118 (Cv = 32.1%), was characterized by the least variability. The average variability of one tree (Cv) in the number of cones produced is 48.5 ± 3.8%. Two-factor analysis of variance without repetition allowed us to assess the severity of individual and chronographic variability in the yield of cones. The yield of cones is determined by both individual and chronographic variability (F05 = 10.11> Fcr. = 1.80; F05 = 5.77 > Fcr. = 1.90, respectively). The effect of individual variability is most evident in the overall variance of the trait. The influence strength (η2) of this source of variation was 0.41. The correlation ratio (η), indicating the closeness of the relationship between the yield of cones and the factor of individual variability, was 0.64, demonstrating their significant conjugacy on the Cheddock scale. The dependence of the crop on the chronographic variability factor is statistically significant, but less pronounced. Its influence was due to 18% of the total variance of the trait (η2 = 0.18). The value of the correlation ratio (η = 0.43) indicates the presence of a moderate dependence of the yield of cones on the factors determining its variability over the years of generation. It should be noted that, in our opinion, the factors contributing to chronographic variability include the weather conditions of the generative organs formation period and the adaptive ability of individuals to them. Considering that, as within the range, when introduced into the forests of the Vologda region, Siberian stone pine retains the biologically determined property of annual seed production, as well as individual and chronographic variability in yield, maternal producers should be recommended for the selection of high-yielding individuals, characterized not only by high yields of cones, but also by a lower variation in the number of cones formed in the different years. Of all the trees under consideration, tree No. 62 was distinguished by this quality, which was 17% lower in average yield than only the leading tree No. 77, but at the same time had a noticeably lower coefficient of variability – 42.4%. Long-term observations are required to select trees with high yields (Matveeva *et al.* 2025). This makes it difficult to breed this species. Long-term observations of seed production are very difficult for practical breeding. In this regard, the issue of searching for correlative traits that make it possible to select high-yielding individuals in a shorter time is relevant. The relationship between yield and tree height, crown diameter, and height-to-trunk diameter ratio was insignificant. This is consistent with V.A. Bryntsev's observations (Bryntsev 2025). To identify the dependence of the yield of cones on the biometric characteristics of the maternal producers, such as the diameter of the trunk at a height of 1.3 m, the height of the tree, the width of the crown, the length of the crown, the crown coefficient (the ratio of its width to length), we performed a correlation analysis. The results of the correlation analysis allowed us to conclude that the reliable dependence of the yield of cones is manifested only on the value of the crown shape coefficient. The value of the correlation coefficient (r = -0.66 ± 0.15) indicates a significant inverse dependence of the yield indicator on this trait. This dependence can be expressed by the formula:

$$F(Nc) = -160.05D/Hcr + 280.75$$

where: Nc — the number of cones; D — the diameter of the crown; Hcr — the length of the crown.

The index of determination (R^2) for this equation, which characterizes the proportion of factorially determined variance, was 0.43. In practical breeding, this dependence indicates the expediency of selecting individuals with a relatively narrow but extended crown. Due to the dependence of yield on the shape coefficient, in our opinion, the number of cones per one meter of crown can serve as a fairly informative indicator of seed productivity. Using this criterion as an additional feature will increase the effectiveness of selection. The number of cones per meter of crown length on average over the period of observations in model trees varied from 3.3 ± 0.3 to 19.0 ± 3.1 pcs. (Table 3).

Table 3. Model trees chronographic variability in terms of the cones number formed per meter of their crown length.

Tree number	The cones number per meter of crown length (pcs.)		
	Minimum	**Maximum**	**Medium**
62	6.1	26.6	13.8±1.8
66	31.9	11.5	16.0±1.7
68	11.5	31.9	12.5±1.2
77	2.9	36.4	19.0±3.1
106	4.8	23.1	10.5±1.8
110	3.9	9.2	6.3±0.4
111	4.7	30.7	17.6±2.8
112	1.2	22.4	11.1±1.9
113	2.0	19.1	8.2±1.6
115	1.6	27.0	10.6±2.1
118	1.9	5.8	3.3±0.3
119	2.8	20.9	9.7±2.0
165	4.3	14.2	8.0±0.9
170	2.4	14.2	6.6±1.0
Medium	5.8±2.1	20.9±2.4	10.9±1.2

In some years, for different model trees, the value of this indicator of reproductive ability ranged from 1.2 pcs. (tree No. 112) up to 36.4 pcs. (tree No. 77). Model tree No. 77 had the highest performance over the entire observation period for this indicator. The use of the cones number per meter of crown (Nc1) is also hampered by the length of the observation period. Correlation analysis revealed the dependence of this indicator on the height of the tree trunk. The correlation coefficient (r) was -0.56 ± 0.18, which indicates the presence of moderate feedback. This dependence can be expressed by the equation of a straight line:

$$F(Nc1) = -1.1955 \times H + 31.87$$

where: H= the height of the tree trunk.

The index of determination (R^2) of the dependence equation is 0.31.
The presence of such a dependence makes it possible to avoid long-term crop monitoring. The largest number of cones per meter of crown is typical for relatively low trees.

CONCLUSION

Raising fallow soils with their transfer to arable lands will lead to a significant decrease in carbon reserves as a result of increased soil and vegetation emissions and requires the development of special measures to minimize the negative impact on the environment. Carbon storage potential of soils contents can be increased via proper land use and managements. Improvements in crop cultivation technologies can be considered as compensatory measures based on the introduction of organic farming systems in combination with numerous existing systems that reproduce and preserve the original soil fertility. The research results indicate that the reproductive ability of the Siberian stone pine, as its biological feature, persists beyond its range in the taiga zone of the East European Plain. Similarly to the areas of natural distribution, Siberian stone pine sows seed here annually. Considering that, the alternation of seed years with non-shift years is characteristic of Siberian cedar pine exclusively in pessimistic growing conditions, it can be concluded that the taiga zone of the East European Plain is a very favorable area for the introduction of this species.

REFERENCES

Amberson, JT, Keville, MP & Nelson, CR 2018, Effects of disturbance on tree community dynamics in Whitebark pine (*Pinus albicaulis* Engelm.) Ecosystems. *Forests*, 9: 566. https://doi.org/10.3390/ f9090566.

Andriyanova, Y *et al.* 2019, Assessment of recreational use of specially protected natural territories of Tatishchevsky district of Saratov region. *RUDN Journal of Ecology and Life Safety,* 2: 117-127. https://doi.org/10.22363/2313-2310-2019-27-2-117-127.

Bower AD, Aitken SN 2007, Mating system and inbreeding depression in whitebark pine (Pinus albicaulis Engelm.). *Tree Genetics & Genomes*, 3: 379–388, https://doi.org/10.1007/s11295-007-0082-4.

Bryntsev VA 2025, Growth and seed production of Siberian cedar pine in introduction crops of plantation type in Moscow region. *Conifers of the Boreal Area,* 3: 44-50, https://doi.org/10.53374/1993-0135-2025-3-44-50.

Chukina, N, Lukina, N, Glazyrina, M *et al.* 2024, Anatomycal, morphological and biochemical features of Pinus sibirica needles on recultivated and non-recultivated ash dump sites in the Middle Urals. *BIO Web of Conferences,* 128: 00004. https://doi.org/10.1051/bioconf/202412800004.

Goeking, SA, Izlar DK 2018, *Pinus albicaulis* Engelm. (Whitebark pine) in mixed-species stands throughout Its US range: Broad-scale indicators of extent and recent decline. *Forests,* 9: 131. https://doi.org/10.3390/f9030131.

Goroshkevich SN, Velisevich SN, Zhuk EA *et al.* 2022, Cone production of stone pines in the south of Western Siberia: Results of 30 Years of Monitoring. Contemp. *Contemporary Problems of Ecology,* 15: 262-269, https://doi.org/10.1134/S1995425522030064.

Jenkins, MB, Schoettle, AW, Wright, JW, Anderson, KA *et al.* 2022, Restoring a forest keystone species: A plan for the restoration of whitebark pine (*Pinus albicaulis* Engelm.) in the Crown of the Continent Ecosystem, *Forest Ecology and Management,* 522: 120282, ,https://doi.org/10.1016/j.foreco. 2022.120282.

Khamitov RS, Andronova MM, Antonov AM 2018, Variability of Siberian cedar pine in the yield of cones under the conditions of introduction. *Lesnoy Zhurnal - Forestry Journal,* 3(363): 84-91, Zhttps://doi.org/ 10.17238/issn0536-1036.2018.3.84.

Kichas NE, Hood ShM, Pederson GT, Everett RG, McWethy DB 2020, Whitebark pine (*Pinus albicaulis*) growth and defense in response to mountain pine beetle outbreaks. *Forest Ecology and Management,* Volume 457: 117736, https://doi.org/10.1016/j.foreco.2019.117736.

Leirfallom, SB, Keane, RE, Tomback, DF & Dobrowski, SZ 2015, The effects of seed source health on whitebark pine (*Pinus albicaulis*) regeneration density after wildfire. *Canadian Journal of Forest Research,* 45: 1597-1606. https://doi.org/10.1139/cjfr-2015-0043.

Liu, J-J, Sniezko, R, Murray, M, Wang, N, Chen, H, Zamany, A *et al.* 2016, Genetic diversity and population structure of Whitebark pine (*Pinus albicaulis* Engelm.) in Western North America. *PLoS ONE,* 11(12): e0167986. https://doi.org/10.1371/journal.pone.0167986.

Matveeva, RN, Komarov, IV & Grishlova, MV 2025, 20-year-old *Pinus sibirica* trees selected by growth intensity and early reproductive development. *Conifers of the Boreal Zone*, 2: 35-39, https://doi.org/10.53374/ 1993-0135-2025-2-35-39.

Novikova, SV, Oreshkova, NV, Sharov, VV, Kuzmin, DA, Demidko, DA, Bisirova, EM, Zhirnova, DF, Belokopytova, LV, Babushkina, EA & Krutovsky, KV 2024, Study of the genetic mechanisms of Siberian Stone pine (*Pinus sibirica* Du Tour) adaptation to the climatic and pest outbreak stresses using dendrogenomic approach. *International Journal of Molecular Sciences*, 25: 11767. https:// doi.org/10.3390/ijms252111767.

Oreshkova, NV, Sedel'nikova, TS, Efremov, SP *et al.* 2020, Genetic polymorphism of Siberian Stone pine (*Pinus sibirica* Du Tour) in Kuznetsk Alatau. Contemp. *Contemporary Problems of Ecology*, 13: 569-576, https://doi.org/10.1134/S1995425520060116.

Pansing, ER & Tomback, DF 2019, Survival of whitebark pine seedlings grown from direct seeding: implications for regeneration and restoration under climate change. *Forests*, 10: 677. https://doi.org/ 10.3390/f10080677.

Perkins, JL 2015, Facilitation of Pinus albicaulis seedling regeneration by Vaccinium scoparium. *Forest Ecology and Management*, 349: 55-65, https://doi.org/10.1016/j.foreco.2015.04.005.

Retzlaff, ML, Keane, RE, Affleck, DL & Hood, SM 2018, Growth response of Whitebark pine (*Pinus albicaulis* Engelm) regeneration to thinning and prescribed burn treatments. *Forest*, 9: 311. https://doi.org/10.3390/f9060311.

Sungurova NR, Strazdauskene SR, Strugova GN 2023, Coniferous species in urban flora of Arkhangelsk. *Conifers of the Boreal Area*, 6: 466–473, https://doi.org/10.53374/1993-0135-2023-6-466-473.

Tantsyrev, N, Sannikov, S & Usoltsev V, 2023, Geographical Features of Pinus sibirica Du Tour Renewal. *Forestry Journal*, 6, 44-56. https://doi.org/10.37482/0536-1036-2023-6-44-56

Tomback, DF, Keane, RE, Schoettle, AW, Sniezko, RA, Jenkins, MB, Nelson, CR, Bower, AD, DeMastus, CR, Guiberson, E, Krakowski, J, Murray, MP, Pansing, ER, Shamhart, J 2022, Tamm review: Current and recommended management practices for the restoration of Whitebark pine (*Pinus albicaulis* Engelm.), an imperiled high-elevation Western North American forest tree. *Forest Ecology and Management*, 522: 119929, https://doi.org/10.1016/j.foreco.2021.119929.

Velisevich, SN 2022, Ecological variability of the harvest quality of Siberian cedar pine (Pinus sibirica Du Tour, Pinaceae) along the latitude gradient in the West Siberian plain. *Problems of Botany in Southern Siberia and Mongolia*, 21: 25-29, https://doi.org/10.14258/pbssm.2022005.

Velisevich, S & Popov, A 2022, Evaluation of cone and seed quality of Siberian stone pine (*Pinus sibirica* Du Tour) for plus-tree selection, *Turkish Journal of Agriculture and Forestry*. 9: 717-729, https://doi.org/ 10.55730/1300-011X.3037.

Zhuk, E & Goroshkevich, S 2018, Growth and reproduction in Pinus sibirica ecotypes from Western Siberia in a common garden experiment. *New Forests*, 49: 159–172. https://doi.org/10.1007/s11056-017-9611-7.

Bibliographic information of this paper for citing:

Khamitov, RS, Lebedev, AV, Khamitova, SM 2025, Variability of Siberian stone pine cones yield in conditions of introduction to the taiga zone of the East European Plain. Caspian Journal of Environmental Sciences, 23: 749-755.