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Forest Stand Reproduction in the Changing Climate Conditions on the Example of the Bashkortostan Republic

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ABSTRACT

The paper considers the issues of forest reproduction by plantation type based on selection and genetic approaches in forest cultivation and forest seed production. The research explores the growth condition and regularities of common pine plus-trees, the best individuals with high-quality genetically determined traits for creating seed and vegetative seed plantations and further conducting breeding work are identified. There are findings on the genetic variability of trees on forest-seed plantations by ISSR markers on the example of common pine, identifying the existing gene pool of this species. Studies of forest reproduction by plantation type conducted throughout one republic or the planet as a whole provide preconditions for its improvement and higher efficiency of silvicultural works. Scientific and environmental institutions and authorities should join their efforts to develop effective measures to compensate for reforestation forest management.

1. INTRODUCTION

There is a close relationship between adverse actions on forest areas and extreme weather situations on Earth. Long-term studies on changes in the phytocenotic structure of plantings makes it possible to evaluate the effect of natural factors, including climatic conditions [1]. Climate changes have a significant impact on forest resources. Brazil, Bolivia, Indonesia are the most affected countries in forest loss due to commercial logging and frequent fires. Scholars of Southampton University (England) and George Mason University (Virginia, USA) indicate that the Amazon forests will disappear in the next fifty years if the current rate of deforestation continues. Europe has not escaped the worse fate either [2]. Half of its territory is still covered by forests, which absorb almost ten percent of all carbon dioxide (CO_2) emissions in The Old World. The dry summer in 2019 and 2020 caused terrible forest fires and large-scale tree diseases. Over the past half-century, the composition of European forests has changed. They absorb less carbon dioxide. The European Commission stipulates that higher demand for timber and frequent fires prevent trees from reaching the age when they absorb the maximum CO_2 [3-5].

The number of severe weather events in Russia has increased. There have been more than 400 over the last decades. The forestry statistics confirms the death of forest stands resulted from negative weather. This figure reached 53 thousand hectares in the 2000s, while it did not exceed 21 thousand hectares in the 1990s. Thus, the adverse impact of weather on the Russian economy and the forest sector in the future is likely to grow [3, 6, 7].

To date, academia has not come to a common point of view about the obvious relationship between the causes and consequences of increased CO_2 and global warming. Nevertheless, in 1992, many countries joined the United Nations Framework Convention on climate change to reduce industrial emissions of all greenhouse gases into the atmosphere. The 2015 Paris Agreement provides measures to reduce CO_2 that came into effect in 2020. The International Group on Climate Change claims that the global average temperature is more likely to increase by 1.4-5.8°C until 2100 [8-11] and change the composition and structure of vegetation cover [6]. The level of greenhouse gases in the atmosphere due to human economic activity can be reduced by protecting, growing and regenerating plantings on cut-down territories using modern biotechnology methods [12, 13]. An integrated approach to studying this issue, both on the scale of the region and for the planet as a whole, can outline the current situation for further forecasting of climate change and developing recommendations for farming.

The available statistical data indicates that the area of forest crops globally has decreased to 290 million hectares in recent years, with naturally renewable forests covering an area of 3.765 billion hectares. Compared to 1990, the area of naturally renewable forests has dropped, while the area occupied by forest crops has increased by 123 million hectares. Plantation forest crops account for about 3% (131 million hectares) and 45% of the total forest area of the world. In Russia, plantation crop growth is paid insufficient attention. The reproduction of new forests is focused on conventional forest crops, not on plantation forest cultivation. Thirteen subjects of Russia created 36 thousand hectares of plantation coniferous crops over the last twenty years, which is clearly not enough.

The area of plantation crops created for industrial purposes is the largest in South America, where forests of this type account for 99% of the total area of forest crops and 2% of the total area of forests. In Europe, the share of plantation crops is insignificant – 6% of the area of all forest crops and 0.4% of the total forest area [3].

In general, 44% of plantation forest crops globally are created mainly by alien tree species. There are significant differences in the scope of plantation crops between countries. Thus, in North and Central America, plantation forest crops consist mainly of local tree species and alien ones in South America. In Asian countries, about 30% of the forest area is represented by alien species, more than 65% by local species; in Africa – more than 70% of the forest area is occupied by alien species. There are about 1.11 billion ha of virgin forests without significant environmental violations, of which 61% are located on the territory of Brazil, Canada and Russia. Compared to the 1990s, these forests have decreased (by 81 million hectares) [3]. More than 200 million m^3 of the most valuable tree species are harvested annually in the Russian Federation. It is necessary to take restoration measures to maintain the forest environment, protect water, conserve and recreate the exploited forest stands [14] that provide sustainability and profitability of the forest sector. Foreign experience in creating plantation forest crops of forest-forming tree species and scientific research in this field strongly indicate in favour of introducing this method into the practice of forest cultivation in Russia, based on the developed breeding seed base. Currently, the forest seed breeding is not developed properly. Seed breeding centres in the subjects of the country aimed to control the formation of objects of a unified genetic and breeding complex of the main species and harvest seeds with improved hereditary properties can address this issue.

2. RESEARCH TARGET AND METHODS

The research was conducted in the forest-steppe zone of the Republic of Bashkortostan (RB). The forest inventory in 2018 [15] lists mainly coniferous selection forest-seed plants in this territory with prevailing common pine (Figures 1, 2).

The forest characteristics for conducting scientific research, analysis and comparing the distribution of forest-forming species in the region are based on the forest fund data presented in forest management documents [15, 16], route and field forest surveys in stands of different breeding categories and economic purposes under generally established methods in forestry**.** The main research targets were seed-producing common pine trees growing in forest conditions of the Bashkir Cis-Ural.

It should be noted that common pine is the subject of numerous studies in Europe [17-20], being still relevant at present. The trial plots were laid in plus-tree and normal stands of common pine of seed origin, growing in identical soil and climatic conditions based on the requirements of OST 56-69-83 "Trial areas of forest management. Trial establishment method", using well-known methods in forest taxation.

The given standard specifies a plot sampling method to get objective taxation indicators of plantings, as well as to study the dynamics of their growth and development in natural conditions and as a result of forestry activities. The standard applies to trial plots established during forest management and forestry operations to study available forest resources and their condition. The experimental plots were limited by survey lines indicated by the surveying compass. There were installed mine shafts of 0.7 m the ground part and 16 cm thick at the corners. Each trial area was linked to a net of rides. The sample areas were placed evenly throughout the territory of the object under study to assess common pine trees by indicators that are criteria for their selection in plantings. Each seed-production area included the highest growth class plantings as seed-producing ones (not lower than the II growth class), with a long branch-free zone (>31% for pine), thin branches (up to 3-4 cm for pine) and a uniformly developed crown (the crown length is 30-40% for pine).

731 common pine trees were recorded and measured according to the morphometric characteristics under study. Trial areas were laid in the same-age common pine tree plantations (79-81 years) of the standard breeding category including seed-producing trees in the Diurtiulinskii and Tuimazinskii forest districts. The forest stand is characterized by the following indicators: the stand density is 0.6–0.7 units, the growth class is 1, there are mostly pine trees in the stand from 9 to 10 units, the forest and conditions is the goutweed pine forest, C2.

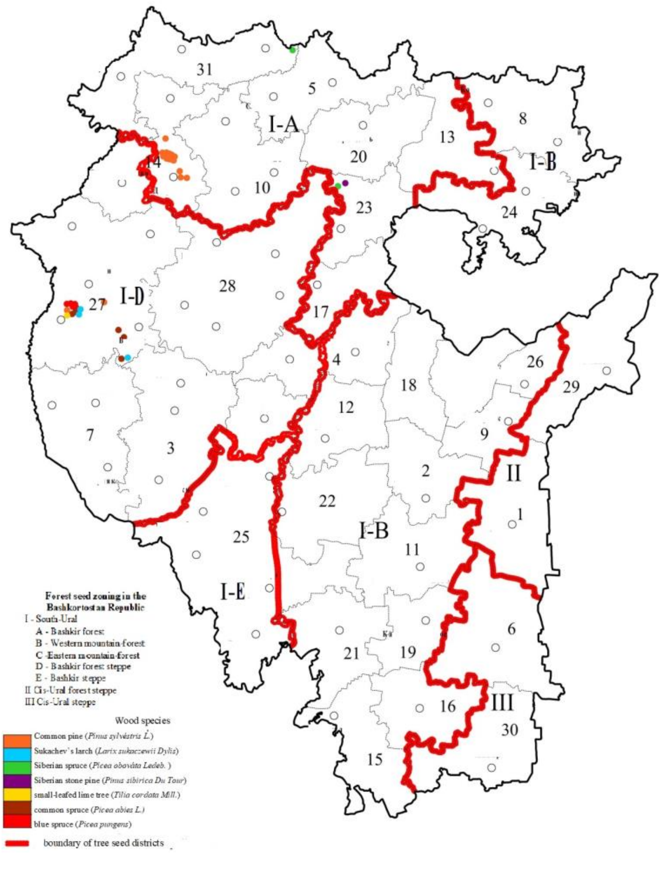

Figure 1. Forest seed plantation scheme by forest districts on the territory of the Bashkortostan Republic: 1 – Abzelilovskoe; 2 – Avzianskoe; 3 – Alsheevskoe; 4 – Arkhangelskoe; 5 – Askinskoe; 6 – Baimakskoe; 7 – Belebeevskoe; 8 – Belokataiskoe; 9 – Beloretskoe; 10 – Birskoe; 11 – Burzianskoe; 12 – Gafuriiskoe; 13 – Duvanskoe; 14 – Diurtiulinskoe; 15 – Zianchurinskoe; 16 – Zilairskoe; 17 – Iglinskoe; 18 – Inzerskoe; 19 – Kananikolskoe; 20 – Karaidelskoe; 21 – Kugarchinskoe; 22 – Makarovskoe; 23 – Nurimanovskoe; 24 – Salavatskoe; 25 – Sterlitamakskoe; 26 – Tirlianskoe; 27 – Tuimazinskoe; 28 – Ufimskoe; 29 – Uchalinskoe; 30 – Khaibulinskoe; 31 – Ianaulskoe

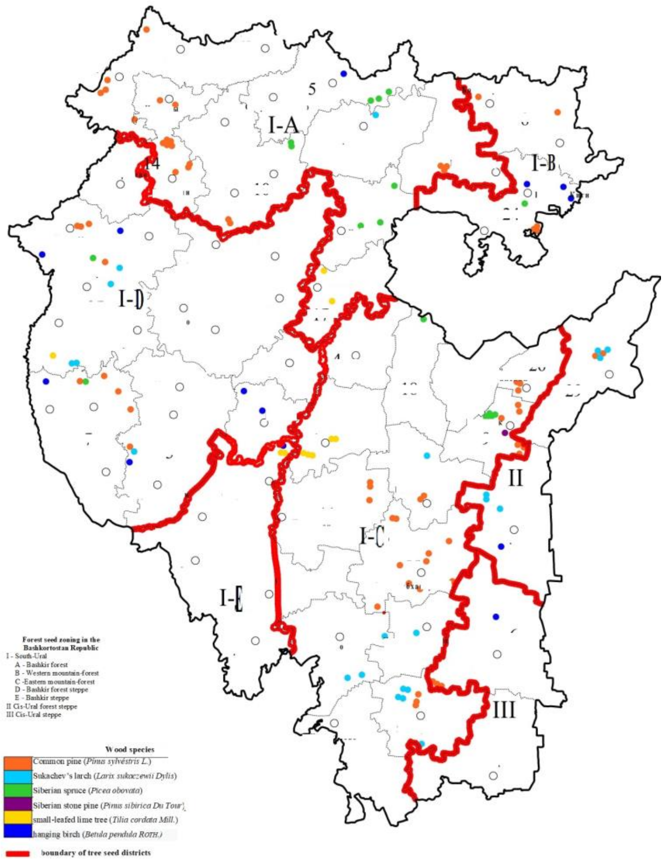

Figure 2. Allocation scheme of plus stands by forest districts on the territory of the Bashkortostan Republic: 1 – Abzelilovskoe; 2 – Avzianskoe; 3 – Alsheevskoe; 4 – Arkhangelskoe; 5 – Askinskoe; 6 – Baimakskoe; 7 – Belebeevskoe; 8 – Belokataiskoe; 9 – Beloretskoe; 10 – Birskoe; 11 – Burzianskoe; 12 – Gafuriiskoe; 13 – Duvanskoe; 14 – Diurtiulinskoe; 15 – Zianchurinskoe; 16 – Zilairskoe; 17 – Iglinskoe; 18 – Inzerskoe; 19 – Kananikolskoe; 20 – Karaidelskoe; 21 – Kugarchinskoe; 22 – Makarovskoe; 23 – Nurimanovskoe; 24 – Salavatskoe; 25 – Sterlitamakskoe; 26 – Tirlianskoe; 27 – Tuimazinskoe; 28 – Ufimskoe; 29 – Uchalinskoe; 30 – Khaibulinskoe; 31 – Ianaulskoe

Plus-trees and standard selection category plants of common pine were selected and measured within the stand of the trial plots. The research covers forest-seed plantations of this tree species. The presence of trees of unified selection type within the main forest-forming tree species in the region was clarified and analyzed according to the reporting documents of the state forest register. The genetic variability of common pine in forest seed plantations was studied by a polymerase chain reaction using 5 ISSR primers.

DNA was isolated according to the standard STAB method [21]. Fresh needles were used as the raw material for the experiment. In total, 40 common pine trees were analyzed on four forest-seed plantations. When processing the research materials, a variance analysis was used, the variability of the evaluated traits was specified according to special scales [22]. The difference significance ($t_{fact.}$) was compared with tabular reliability criteria (t_{05}). The dispersion analysis consists of the following stages: identifying dependent and independent variables; decomposing the total variance; measuring effects; testing the significance; result interpretation. The statistical programs "EXCEL" and "Statistica" were used.

3. RESULTS AND DISCUSSION

The federal project "Forest Conservation" of the Russian national project "Ecology" intends to increase the volume of artificial plantings of the main forest-forming tree species and achieve the balance of forest disposal and reproduction. There are a number of measures aimed at enlarging the area of artificial plantings to 1.5 million hectares. The implementation of the federal project requires to grow 879 million pieces of planting material by 2024. This issue is essential today against the background of the observed climate transformations and their effects on forestry, the environment and the economic sector. The findings of the Laboratory of Specially Protected Natural Territories and Biological Resources of the Research Institute of Life Safety of the Republic of Bashkortostan indicate dryness of certain forest lands, the decline in biomass growth and changes in tree condition. Climate change is evident from higher average annual temperature, lower precipitation and deteriorating conditions for the development of forest plants, especially in the southern part of the region. Thus, there is a tendency for deforestation of some areas and the shift of the southern border of the forest territory to the north of the republic. The growing season starts earlier, and its period has lengthened by an average of twelve days. Climate changes have resulted in the observed dynamics of the forest species composition. The forest fund area of the Bashkortostan Republic is 5.7 million hectares; the forest cover is 39.9% (being on average 46.6% in Russia and 36.5% in the Volga Federal District). The annual maximum allowable volume of logging is 9.6 million m^3, including 1.1 million m^3 for coniferous stands [15].

Until the middle of the XIX century, 70% of the territory of modern Bashkortostan was covered by forest plantations with dominating coniferous and hard-leaved tree species. Pine (*Pinus)* forests [23, 24] and larch (*Larix)* occupied large areas. There is a heterogeneous distribution of forest areas in the region, the forest land percentage varies from 6% in the south-western regions, to 60% in the eastern and north-eastern regions [15, 16].

The conducted comparative analysis of the forest species distribution on the territory of the Bashkortostan Republic in the conditions of climate transformation over the last decades showed the following:

- the area of soft-leaved species, primarily *Betula pendula* Roth. and *Tilia cordata* Mill. significantly increased respectively, by 70.8 (39%) and 74.2 thousand hectares (32%) for the period from 1998 to 2018;

- the areas under coniferous species tend to decline; *Picea and Abies* territories decreased by 57.9 thousand hectares or 15%;

- there was cut in *Quercus robur* short-trunk by 34 percent, high-trunk -6 and *Ace*r – 8 percent.

The expected forecast for reduced coniferous areas and increased mixed and broad-leaved forest stands is mainly due to climate transformation.

Researchers put forward the use of forest territories as one of the options for combating climate transformations. It can be achieved by restoring forests on cut-down areas, growing new ones and protecting them from deforestation. The global forest resources assessment in 2020 showed that 93% of the world's forests, or 3.75 billion ha, are naturally renewable while 7%, 290 million ha, are under forest crops. Since 1990, the areas of naturally renewable forests and their reduction rate have slowed down, with the area of forest crops increasing by 123 million hectares [3, 5]. However, the growth rate of the territory under forest crops has declined in the last decade.

In the Republic of Bashkortostan, it is planned to increase the volume of forest cultivation to 14.7 thousand hectares by 2030. According to the inventory of forest nurseries, 53386 thousand pieces of planting material with an open root system were grown in the region as of 01.01.2020. The annual demand for planting material is more than 31 thousand pieces. As of 01.07.2020, 1,709 tons of seeds were harvested for spring planting, including 1,150 tons of common pine. The forest-seed facilities available in the republic produced 100 kg of seeds of the improved breeding category, which is 5.8% of the total volume of harvested seeds. Seed material of the standard breeding category was sown in an area of 30 hectares, while the share of the improved breeding category did not exceed 4%. Over the past few years, not a single forest seed facility has been opened in the region, which constrains the volume of harvested improved seeds. Existing forest seed plantations do not undergo genetic certification based on the DNA analysis methods that can objectively assess their effectiveness and compliance with the requirements of current standards. The authors of the given study paid close attention to this fact. The main goal of the "Ecology" project is to increase the areas under artificial plantations with improved planting material. Annually 7.4 thousand hectares are planted with forest crops in the Bashkortostan Republic, but it does not ensure the overgrowth of territories after cuttings. Forecasts for 2019-2024 suggest that the ratio of logged forest stands should correspond to the area of reforestation, which is demonstrated in Figure 3.

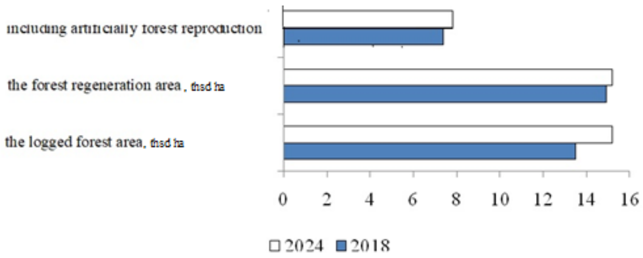

Figure 3. The proportion of the forest regeneration area and the clear-cut area, thsd ha

The present-day trends require a developed forest complex along with business wood production on an industrial scale. The latter must be done on plantations of the highest forest productivity with short-run logging turnover. Plantation forest crops are attracting growing interest both around the world and on the territory of Russia [4, 17, 18, 25-34]. Russia has about 1/4 of the world's wood reserves. This is 82 billion m^3 with 80% of coniferous stands. About 40 thousand hectares of plantation forest crops of coniferous species have been created in recent decades. Today, forest plantations are concentrated on 7% of the total forest area of the planet and provide 35% of the harvested wood per year [3, 34]. The Food and Agriculture Organization believes that forest plantations are currently able to provide 44% of wood worldwide. 80 states, including China, Canada, the USA, India and others, intend to increase the territory of forest plantations, having been involved in plantation forest cultivation for decades.

Much attention is paid to fast-growing, highly productive and demanded forest tree species grown by seed to obtain a preferential increase in wood stock (compared with the growth of ordinary trees). Silvicultural, forestry and forest-reclamation treatments as a whole produce the necessary timber in industrial quantities with accelerated cultivation of stands by the plantation method [3, 34]. This also solves the issue of replenishing forest areas for operational purposes. Natural plantings play the main role of building up the ecological potential. The analysis of foreign sources revealed that forest planting implies forest crops. The Food and Agriculture Organization uses "semi-natural forests" as stands of assisted natural regeneration, planting or seeding. In fact, these are artificial plantings, where forests are imitated according to the main taxational characteristics of natural origin.

Currently, China is a leader in forest reproduction with 77 million hectares. The Chinese government pays considerable attention to forest plantations, firstly, as one of the ways to improve the material situation of the rural population while growing agricultural products and tree species, and secondly, encouraging the creation of forest nurseries, centers for seed storage, collection and processing, special boards for forest reproduction [3, 34]. Special attention is paid to forest plantations in Canada, where they receive the maximum increase and a reserve of 300 m^3/ha at the age of forty. Poplars are widely grown on forest plantations to produce wood. They are also used as wood biomass for biofuels (pellets, briquettes). The following indicators for the average growth on larch plantations in Quebec indicate high productivity – from 5 to 8m^3/ ha at the age of five (sawlog is possible at twenty) [3, 34]. Plantation forest cultivation in the USA has been developing since the time of landowners. Today, there are more than 130 main forest nurseries, where more than 900 million wood specimens are grown annually [3, 34]. Experts believe that logging will increase by 3 times by 2050, and their total area will grow by 60%.

Scientifically-based use of existing and creating new breeding facilities for the main forest-forming tree species, providing the production of seeds and planting material with improved hereditary properties, is the basis for higher forest productivity, quality and sustainability [35-38]. Currently, forest seed production in the Bashkortostan Republic is ineffective in providing forest regeneration and reforestation with high-quality planting material. As of 01.01.2018, the structure of the areas under the unified genetic and breeding complex (UGBK) of the Republic of Bashkortostan is presented as follows (Figure 4).

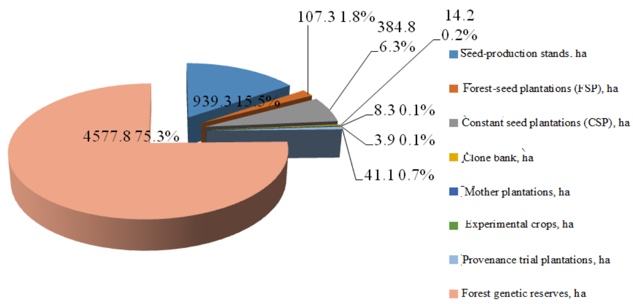

Figure 4. The area structure of the unified genetic and breeding complex objects

The main plant is the forest genetic reserve of Sukachev's larch, allocated on 4577.8 hectares, which is 75.3% of the total area under the UGBK. Plus plantings occupy an area of 939.3 hectares (15.5%), forest-seed plots (FSP) – 384.8 hectares (6.3%). Forest-seed plantations and other objects are located on insignificant areas, the share of which varies from 0.1% to 1.8%. The number of plus-trees is 952 pcs. Over the past 10 years, plus-trees have decreased by 27%, plus plantings by 20% for different reasons. This fact indicates the need to resume breeding work on allocating seed-producing trees and plantings of the main forest-forming tree species growing in the region, taking into account new methods for the selection and genetic evaluation of trees. Forest genetics and breeding issues should be reflected in special regional and federal forestry programs based on the latest achievements of forest genetics, breeding, seed production and plant introduction, providing a better approach to the conservation and rational use of genetic resources. It requires the following external conditions: an adequate financial support for breeding valuable seed-producing trees and plantings; preventing rent of plus trees and plantings to non-breeding experts that can inhibit the work with plus tree species and their partial loss. There is an urgent need to restore breeding work on selecting plus trees and plantings of the main forest-forming tree species growing in the region.

Despite the sufficient availability of the above-named objects of the unified genetic and breeding complex of tree species, the share of harvested valuable seeds is insufficient, 3.4% of the total volume (1709 kg) in 2020. To address this problem, it is necessary to increase the harvest of improved seed material. There are 105 forest nurseries on the area of 790 hectares to cultivate planting material in the republic. 70 million seedlings and young plants, of which 90% are coniferous species, are grown there. The annual demand for planting material for reforestation is 30 million pieces. Selecting the best individuals from plus trees of common pine required a comparative analysis of the main morphometric features of plus trees within plantings.

The statistical estimation of the studied morphometric traits of common pine plus trees revealed the following regularities. The average diameter of the trunk was 49.7±1.14 cm, height-31.9±0.29 m. Compared with the average values for the planting as a whole, the trunk diameter exceeded by 4.7 cm, height by 1.3 m. These values do not meet the requirements for plus trees. Plus trees were not provided with proper care being mandatory for this category of trees. As a result, radial and linear parameters of plus trees developed slowly. By the 24.0±0.46 m clear bole length, the 24.0±0.46 m crown length and the 7.4±0.32 m diameter, plus trees meet standard requirements. The trait variability is in the range of 8.2-14.8%; the experiment accuracy is 0.9-5.2%. It should be noted that plus trees of common pine, in general, are characterized by good growth, vital condition and development. In the comparative aspect, common pine trees of the standard breeding category were evaluated by similar morphometric characteristics. Standard trees had a slightly lower value of radial growth – 45.0±0.65 cm varying within 44-48 cm, linear growth-30.5±0.52 m (30-31m.), the clear bole length – 18.9±0.23 m, the crown length-11.6±0.32 m, the crown diameter-11.6±0.32 m. The trait variability ranges 1.7-21.6%, the experiment accuracy is 1.2-3.3%. The data on the difference reliability between plus and standard common pine trees by the estimated morphological characteristics is given in Table 1. The differences were of low-quality by diameter-$t_{is\ a\ fact}$ = 3.02< t_{05}=5.6, the trunk height t_{fact}= 2.72< t_{05}=5.6, the crown length is t_{fact}= 3.53< t_{05}=5.6 and the crown diameter is t_{fact}= 3.53< t_{05}=5.6.

By the clear bole length, the differences are reliable according to the first probability threshold of an error-free judgment-t_{fact}=9.90 > t_{05}=5.6. According to the one-way analysis of variance (Table 1), the studied morphometric characteristics of the trunks of the common pine are not associated with their breeding category, the best selection properties of species at a reliable level. This conclusion is confirmed by the insignificant value of the factor effect (B=25%) on the variability and dimensional parameters of the estimated morphometric characteristics of plus pine trees. The impact of the factor (A=7%) is not essential in developing studied traits, which is due to the different genetic potential of trees within the species. The given data on the insignificant level of differences in important characteristics of trees being criteria for selecting plus trees in stands convincingly indicate non-compliance with the recommendations for timely forestry care for these breeding objects.

Table 1. The impact of factors on the growth of seed-producing common spruce trees

Factors considered	The value of the confidence criterion			
	$t_{fact.}$	$t_{st.}$ (5%)	$t_{st.}$ (1%)	effect size, %
Planting (A)	0.16	5.60	12.30	7
Seed-producing tree (B)	4.16	5.60	12.30	25
Random factors	-	-	-	68

It is found that the distribution of the average values of the analyzed indicators in the compared plus trees, identified by the phenotypic manifestations of different traits of economic significance, is not the same (Figures 5-7).

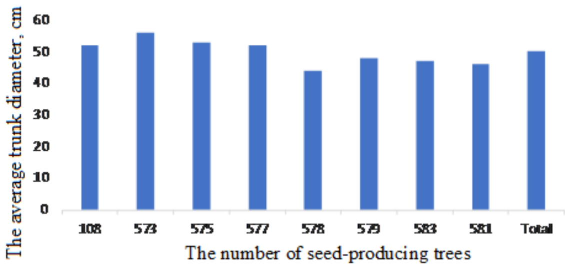

Figure 5. The average diameter of seed-producing common spruce trees (total – unified general value)
Source: developed by the authors based on the conducted research

Thus, by the trunk diameter, the heterogeneity of plus trees is fixed both within each tree and in their array as a whole (Figure 5).

The largest trunk diameter was recorded for the plus trees of common pine with passport numbers 108 (52.6 cm), 573 (56.2 cm), 575 (53.7 cm), 577 (52.8 cm) corresponding to the criteria – 20-30% of the average value of this attribute for planting.

The value of this indicator for other plus trees varies from 44.3 cm to 48.1 cm. Plus trees with these numbers are the most promising for harvesting seeds of an improved breeding category. In contrast to the diameter, the average trunk height of common pine plus trees differs significantly. It is clearly demonstrated in the histogram presented in Figure 6. Similarly, with the trunk diameter, plus trees of common pine with numbers 108, 573, 575 and 577 have better height growth indicators than other selected individuals, representatives of the plus breeding category. The height indicators of the marked plus trees of common pine are 34.2-36.8 m, respectively, or 10-15% of the average height of the stand as a whole, which meets the requirements for the selection of plus trees. Other common pine plus trees' trunk height exceeded the average height of the stand from 3% to 6%, which is significantly lower than the criterion indicator of 8-10%. The revealed regularities in the dimensional characteristics of the radial and linear growth of plus pine trees, as a source of harvesting improved seeds, are important to take into account when creating new forest-seed facilities, and first of all, clone forest-seed plantations. Planting material grown from seeds of this breeding category is a solid basis to grow plantation forest crops.

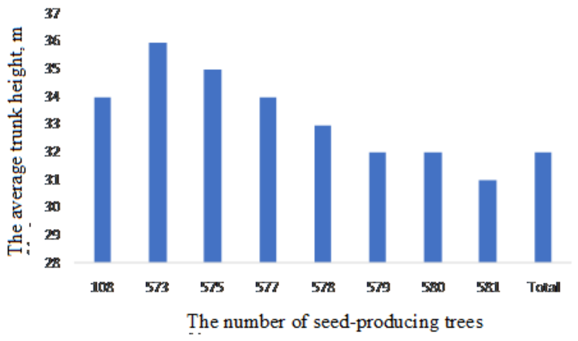

Figure 6. The average height of seed-producing common spruce trees (total – unified general value)
Source: developed by the authors based on the conducted research

When selecting plus trees in stands, the clear bole length indicating the tree quality is a leading indicator. By this indicator, trees with passport numbers 108, 573, 575 and 577 are distinguished. Their clear bole length reaches 25.3-26.2 m. These values meet the requirements for plus trees. Other plus trees had the significantly lower clear bole length of 22.3-24.2 m. Plus pine trees had the crown length of 8-10 m or 25-27% of the trunk height (the criterion indicator is 30-40%), the crown diameter is 6-9 m. In a qualitative and objective assessment of the tree growth, the growth intensity indicator (coefficient) is important, as the relative value of the average height of trees to the cross-sectional area by the size of the average diameter (Figure 7). Statistical analysis of the trunk growth intensity confirmed an earlier suggestion that plus trees of common pine numbered 108 had the best indicators on this basis, as well as on other grounds, being as follows: 1.84 m/cm^2, 573-2.17 m/cm^2, 575-1.86 m/cm^2 and 577-1.76 m/cm^2.

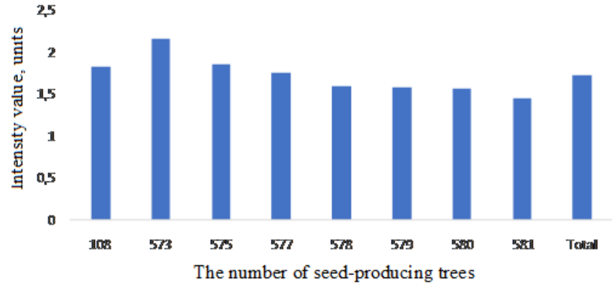

Figure 7. Seed-producing common spruce trees' growth intensity value (total – unified general value)
Source: developed by the authors based on the conducted research

This indicator in other plus trees of common pine varies from 1.60 m/cm^2 to 1.46 m/cm^2, which indicates their successful growth and development. Since the above-mentioned phenotypic differences of trees by this trait were manifested when they grew in the same leveled environmental conditions, they can result from the genotype specifics of plus pine trees. The correspondent differences between plus trees according to the studied morphometric traits were specified during the one-way analysis of variance.

According to the analyzed characteristics, the greatest differences between plus trees of common pine are in the trunk diameter (F_{fact}=27.3), the trunk height (F_{fact}=8.0), the clear bole length (F_{fact}=11.9) and the growth intensity (F_{fact}=10.5) at threshold levels of confidence probability ($F_{05/01}$=5.60/12.30), which indicates their genetic determination. The differences in the crown diameter (F_{fact}=2.9) and the crown length (F_{fact}=3.7) proved to be unreliable. Their experimental values by the Fisher criterion are below the threshold levels. The presented values were obtained under the calculation algorithm of N.A. Plokhinsky. Their calculation according to the algorithm of W.D. Snedeker gave quite a comparable result. The Fisher criterion is used to assess the variance equality of two samples. It belongs to the distribution criteria. In the dispersion analysis, the Fisher criterion makes it possible to assess the significance of factors and their interactions, it is based on additional assumptions about the independence and normality of data samples. Before using it, it is recommended to perform testing for normality.

The calculated criteria for the difference significance (LSD_{05}) and Tukey (D_{05}) made it possible to determine which difference in average values corresponds to the materiality level when comparing plus trees with each other. Findings on plus tree similarity evaluation by the studied traits received in the given order provide the highest values of the trunk indicators: height (characteristic 1), trunk diameter (characteristic 2), clear bole length (characteristic 5), growth intensity (characteristic 6), and the smallest for the crown diameter (characteristic 3) and the crown length (characteristic 4).

We have conducted studies of the genetic variability of common pine trees on forest-seed plantations created in the Bashkir Cis-Urals using ISSR markers. According to the results of DNA ISSR analysis of common pine trees, the proportion of polymorphic loci was 78-87 %, the average value for all identified loci was 82%, the number of alleles (Ne) was 1.385, and the genetic diversity (H) was 0.239. As Shigapov [39] states, this approach to the genetic assessment of plus trees and populations of common pine is justified and provides a more objective description of the selection and genetic significance of the species. Such studies contribute to the qualitative identification of the existing gene pool of valuable tree species, as well as to confirm the true origin of forest seed plantations. The DNA analysis method is being successfully used in examining illegal logging and forest crime [28, 40].

4. CONCLUSIONS

The conducted studies revealed that a high level of genetic variability and conditionality of morphometric characteristics of plus pine trees. In order to preserve the high-quality gene pool of the main forest-forming tree species, it is necessary to actively introduce methods of genetic monitoring of objects of the unified genetic and breeding complex in the Republic of Bashkortostan with their certification into the practice of forest seed breeding. Plus trees of common pine studied according to different morphometric characteristics to select plants by the best taxation indicators differed in individual trunk parameters. Forestry experts are recommended to pay important attention to the safety of the selected plus trees of common pine, monitor their condition, maintain timely and high-quality forestry care, collect cones and harvest seeds of an improved breeding category, preventing mixing with other seeds. This issue is relevant in the context of climate transformation and changes in the species composition of forests.

The differences in the taxation indicators of plus pine trees, identified by the characteristics of the trunks in the studied stands, correspond to a reliable level, which indicates the specifics of their genotypes. The similarity of plus trees among themselves in trunk parameters is not identical in their generalized totality and concerning individual characteristics, which is confirmed by the criteria of difference significance: the least significant difference (LSD) the Tukey D-criterion. This circumstance indicates a different level of non-identity of each plus tree to the others taken in totality. The existing plus trees of common pine have not lost their breeding status and are the most promising for harvesting valuable reproductive material-seeds of an improved breeding category and vegetative material-cuttings for creating artificial plantations, clone and family forest seed plantations. Further research should be undertaken to continue the analysis, spatial modelling and study of the Eco physiological reactions of species to changes in environmental factors, ways to replenish forest lands with valuable coniferous species that will contribute much to the studies in this field.

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