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Biological indices of Bashkir Lombardy poplar (*Populus nigra* L. × *Populus nigra* var. *italica* Du Roi) in urban landscapes

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Abstract

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Bashkir Lombardy hybrid poplar (*Populus nigra* L. × *Populus nigra* var. *italica* Du Roi) is an ornament woody plant. It is used in landscape architecture. The hybrid poplar tends to grow rapidly. The average height increases in trees aged 30 years or less makes up 0.95 m. The tree is very resistant to atmospheric toxicants. Its vegetative season makes 190 days, while the same period of Berlin poplar is 153 and of Sverdlovsk Lombardy poplar, it is 174 days. All vegetation phases of hybrid poplar follow each other in strict sequence. However, the calendar dates of the beginning (swelling, bud opening) and of their ending (leaf blooming and leaf fall) of the vegetation phases are strongly affected by temperature conditions and precipitation during the prevernal period. In all urban plantings, the hybrid showed high tree ornament qualities. These are vigorous trees with strait timber and dense crown. In the zone of low pollution high sanitary and hygienic points, life status and aesthetic landscape assessment of the trees are observed (I). However, the Student's test (t) which was made to compare these indicators in other pollution zones (II and III) showed a statistically unreliable difference, which also confirms the tolerance of this hybrid to environmental conditions. There was made a research of forest and landscape valuation of hybrid poplar (*Populus nigra* L. × *Populus nigra* var. *italica* Du Roi). The results of the research as well as long phenological observations prove that widespread plantation of this tree can be very perspective for urban landscapes.

Keywords: poplar hybrid; phenology; live status; assessment; resistance; technogenic pollution; climatic factors; ecology; urban environment

Introduction

Green planting is the central core in the urban environment making. It makes an indispensable recreational, protective, emotional and psychological contribution on the back of current air pollution, noise and reduction of recreational space (Gabdrahimov et al., 2018; Konashova et al., 2018; Sultanova et al., 2018). As a buffer culture, which will facilitate the absorption of mineral pollution, decomposition of organic compounds, reduce the risk of leaching and soil erosion, they considered it poplar.

Poplar is a buffer culture. It can facilitate mineral impurities absorption and decay of organic matters. As a buffer culture it will also decrease the risk of soil leaching and erosion (Minogue et al., 2012).

Poplar is found to be good in Cd-phytoextraction processes in moderately polluted soils, whereas in highly contaminated soils it can be considered only as phytostabilizator

(Redovniković et al., 2017). The issues of the global impact of hybrid poplars on the environment are considered, as they are economically and environmentally attractive for the biomass production with a short rotation (Schweier et al., 2017).

Populus trees are fast-growing dioecious plants which grow in temperate climate and belong to the Salicaceae family. They are actively used in landscape architecture. In recent decades, the importance of studying the Populus genus has increased, since the poplar genome was sequenced, and molecular tools for a fundamental research in obtaining poplar hybrids have appeared (Müller et al., 2013).

Poplar species are found in various sites and contain large genetic variations that are used both for economic purposes such as wood production and in landscaping, and also for increasing knowledge about the basic molecular mechanisms of life of woody plants. The study of hybrid poplars is very important (Tsarev & Mashkin, 1985, Kulagin et al., 2000).

Russia has significant genetic potential of domestic and introduced poplar species, forms, selection varieties and hybrids (Tsarev & Mashkin, 1985). However, some species are not known for a wide range of specialists. They are represented only in the collections of regional scientific institutions. This is especially true in regard with poplar, in particular with hybrid poplar (*Populus nigra* L. × *Populus nigra* var. *italica* Du Roi). That's why recommendations for growing these trees in urban plantations are not studied well. There are also problems with growth zoning of these trees.

Bashkir Lombardy poplar (*Populus nigra* L. × *Populus nigra* var. *italica* Du Roi) is an ornament plant. It can be widely used in landscape architecture. Three most important factors determining further growth of trees are variety, ecology and agricultural technology. It was determined that when making artificial plantations the least attention is paid to the characteristics of the variety, although in the same environmental conditions and with standard agricultural technology this particular indicator can reduce the vegetation timing and increase the ornament period of trees. The use of the Populus male in urban plantings relieves from the negative effects of dusting etc. Many researchers note that hybrid poplars show high adaptability to climatic and environmental conditions, and are able to shorten or lengthen the phenological phases (Medvedeva, 2012; Shirokova & Ryabova, 2014).

In 1993 A. M. Berezin developed *Populus nigra* L. × *Populus nigra* var. *italica* Du Roi in the Republic of Bashkortostan. This hybrid poplar is mentioned as Berezin poplar in the State Register of Russia (Putenikhin, 2006). Its morphological features are similar to *Populus nigra*. However, hybrid poplar (*Populus nigra* L. × *Populus nigra* var. *italica* Du Roi) is poorly seeded by stem cuttings (Berezin, 1993; Putenikhin, 2006). The stem of the tree is well-shaped, it has a columnar crown, wide leaf blades with round-cut corners at the fan base with a sharp leaf edge. Leaf blade edges are dense, leafstalks go from leaves at an acute angle of 35. At the base the shoots are green-grey with frequent whitish stripes.

A characteristic feature of the hybrid poplar is its high decorative value and its rapid growth. It can grow even in harsh environment. The tree is resistant to medium frost and drought. It is also tolerant to harmful insect damage and to diseases. With reference to the above mentioned, the hybrid (*Populus nigra* L. × *Populus nigra* var. *italica* Du Roi) is recommended for amenity planting purposes (Berezin, 1993, Kulagin et al., 2000; Putenikhin, 2006).

The purpose of the research is to justify the prospect of hybrid poplar (*Populus nigra* L. × *Populus nigra* var. *italica* Du Roi) and of its use in urban landscapes. To do this, it is necessary to determine the dates of the phenological phases of poplar hybrid in accordance with the climatic conditions and to determine the growth rates of the poplar hybrid growing in urban areas with different pollution levels.

Material and Methods

The objects of the research are poplar hybrid trees (*Populus nigra* L. × *Populus nigra* var. *italica* Du Roi), growing in the city of Ufa of the Republic of Bashkortostan. The Republic is part of the forest-steppe area of the European region of Russia (Fig. 1).

Fig. 1. Line planting of hybrid poplar (*Populus nigra L.* × *Populus nigra var. italica* Du Roi)

The state of trees and the indicators were estimated according to general forest assessment methods within different functional areas of the city of Ufa i.e. on the common area (in the public center), on the territory of limited use (residential) and on the territory of special use (industrial).

In these areas on 100-meter transects the quantitative indicator of extent of the presence and spreading of the species – occurrence of the species (Konashova, 2002). To analyze the phenology and linear growth of lateral shoots of the first order poplar hybrid, a visual method for recording the phenological state of trees by dates was used. According to the standard technique of phenological observations next vegetation phases were highlighted: swelling of the bud (beginning of vegetation), opening of the bud, leafing of the bud, the end of growth and full ripening of the leaves, the colorization of the leaves (change color), leaf fall .

Annual height growth of side shoots was measured every 10 days using the D. T. Klein (1974) method. The life condition of trees was determined with the use of five-point system of the crown characteristic (Alekseyev, 1989) of broadleaved trees. Sanitary and hygienic assessment characterizing conditions of tree crown and stem was made using Gusev's scaling method (Konashova, 2002). Esthetic assessment grade was accomplished using the three-point system of V.A. Agaltseva (Konashova, 2002), which reflects the landscape beauty, colorfulness and harmony in combination of all components of vegetation, taking into account the need for tree care activities.

Dendrochronological analysis of radial growth characterizes with high accuracy the state of landscapes and biota, as their formation is influenced by many factors (Arefyev, 2003). For this purpose, the core samples were taken by drilling in the direction perpendicular to the longitudinal axis of the tree stem. The samples were studied using the ring width measuring device LINTAB.

Statistical Analysis

Using the method of correlation and regression analysis and Statistica 6, Statgraphics Plus 5.0 programs, there was determined the dependences between the values of annual radial growth, average annual precipitation and average annual temperature over the years to identify the dependence of the radial growth on climatic factors and between the values of the annual width ring and average annual ring.

Results and Discussion

There was made an assessment of the occurrence of hybrid poplar (*Populus nigra* L. × *Populus nigra* var. *italica* Du Roi) in urban areas of various functional purposes. In the public area grows 75.3% of the hybrid poplar of its total, in the limited use areas – about 20% and in special purpose areas (industrial) – less than 5%. Depending on the distance to stationary (industrial zone) and mobile (road) sources of industrial waste generators of cities, we have identified three zones: the first zone I with low pollution; the second zone II with medium pollution; the third zone III of gross pollution which is the closest in distance to industrial enterprises and highways. The age of the poplar hybrid zones varies slightly: in the zone I, it is 25-30 years old, in zone II – 10-50 years old, in the third zone, the age of the hybrid poplar is 20-30 years.

It was determined that the value of hybrid poplar trees estimation in the plantation, i.e. its average height and average diameter, does not depend on the distance to stationary and mobile sources of air pollution and to technogenic toxicants. This value changes with the age of the trees, which is typical. The diameter of 25 years old trees growing in the zones I and II is 38.97 ± 0.05 cm and 39.28 ± 0.03 cm, respectively; the average height – 24.10 ± 0.03 m and 24.11 ± 0.01 m, respectively. The difference between the values of these estimation indicators is uncertain statistically: $t_d = 0.040$ and $t_h = 0.004$.

The average diameter of 30 years old plantations in the zones I, II and III varies within narrow limits from 32.68 ± 0.0 to 34.63gross ± 0.07 cm; the average height – from 18.88 ± 21.86 0.03 to ± 0.02 m. The Student's t-test criterion (t) for the diameter and height of 30 years old trees in the zones of low (I) and medium (II) pollution is $t_d = 0.287$ and $t_h = 0.943$; in areas of medium (II) and strong (III) pollution its value is $t_d = 0.056$ and $t_h = 0.825$; in the zones of low (I) and strong (III) pollution – $t_d = 0.0508$ cm and $t_h = 0.0762$ and is less than the table value, which also proves statistically uncertain difference in the value of the estimation indicators in accordance with the pollution zones.

Thus, hybrid poplar (*Populus nigra* L. × *Populus nigra* var. *italica* Du Roi) is resistant and tolerant to the technogenic pollution, no matter which environment it grows in. Regardless of the area of the city, poplar is characterized by high estimation indicators. Up to 30 years of age the hybrid poplar grows intensively both in height and in diameter: the average height increase is 0.95 m. According to P. L. Bogdanov, the ability of rapid poplar growth is caused by more intensive photosynthesis and vigorous activity in formative tissues, which is higher than in other tree species (Bogdanov, 1965).

Radial growth study was made to watch the dynamics of hybrid poplar trees formation (*Populus nigra* L. × *Populus nigra* var. *italica* Du Roi) in the urban environment. In this case growth in height is not always a reliable indicator due to the activities intended to the care of poplars crown, shape pruning of poplars crown.

Dendrochronological analysis of the annual poplar growth during the period of 27 years showed that the maximum values of the annual ring width are typical for the period 1989-1994 (Fig. 2).

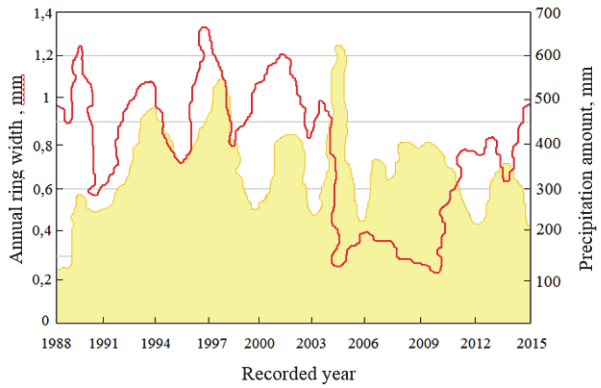

Fig. 2. Graphs of the annual radial growth of hybrid poplars (*Populus nigra* L. × *Populus nigra* var. *italica* Du Roi) and precipitation for the 27-year period

This first five-year period of growth of tree plants is called by scientists the phase of adaptability, individual growth and development (Kobranov, 1930). This is followed by a sudden decrease in growth and the transition to a stable form change in the value of the annual growth in the stage of differentiation and formation of the stem. The differentiation stage is characterized by intensive tree growth. The plateau phase is characterized by a stable level of annual growth in the range from 0.2 to 0.3 mm. In this phase the formation of growth in height, diameter and habitus parameters of the crown, are influenced by plant spacing. Trees reach significant sizes and begin to rival for optimal environmental conditions, which leads to sudden decrease in diameter growth. In the future, there is a differentiation of plants, each of them occupies their own niche with the formation of a single biocenosis. In the period 2006-2015 the width of the annual ring was measured to be around the same (plateau stage). Age of poplar in this stage reaches 20 years.

It is well known that the leading factors in the formation of the development rate for plants from climatic conditions are temperature conditions and humidity. With increasing temperature (to a certain limit) the rate of plant development increases, with decreasing temperature – decreases (Beydman, 1974).

The correlation coefficient r = 0.165 and 0.170, respectively, was determined to establish the close relationship between the annual radial increase, the average annual air temperature and the amount of precipitation. Over the entire 27-year period of poplar growth, the dependence on these indicators was seen to be very weak. However, the graph data in Fig. 2 shows a clear relationship between the annual radial growth of poplar up to 15 years of age and the amount of precipitation. With increasing age of poplar, this relationship weakens. The close relationship between the increase and the amount of emissions to the atmosphere is characterized by a correlation coefficient equal to r = 0.252, which also shows a weak dependence, although somewhat greater than the dependence of the increase of growth based on climatic factors throughout the growth of poplar.

We compared the average daily spring temperatures, precipitation and the onset of the phenological phase of hybrid poplar (*Populus nigra* L. × *Populus nigra* var. *italica* Du Roi). The date of the start of the growing season of hybrid poplar for the years 2015-2017 was set after comparing. In 2015 and 2016 early warm spring with sufficient precipitation (up to 24.8 mm in April) was marked with the transition of temperature through 0° on 1-4 of April (2.27°C), through +5° C – on 10-15 of April. Phenological phases in these years occurred in the same date with a difference of up to 4 days: opening of the buds on 10-14 of April; shoot leafing on 24-25 of April, and the completion of the growth and aging of the leaves occurred on 29 and 30 of April (Fig. 3).

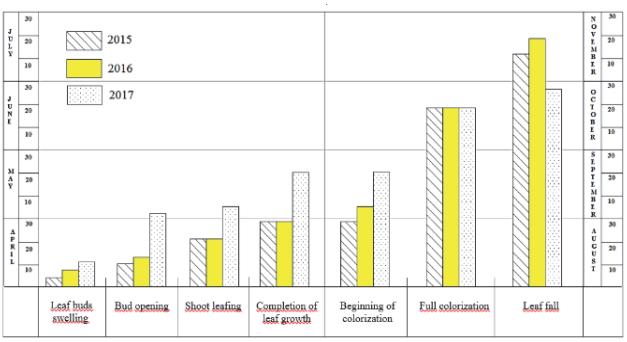

Fig. 3. Timing of the phenological phases in the growing season of the years 2015-2017

In the cold and prolonged spring of 2017 with low precipitation (14.6 mm in April), the transition of the average daily temperature towards higher temperature through 0°C occurred on 6 April (1°C). Therefore, phenological phase is characterized by later onset: opening of the buds on May 2; leafing on May 5; the completion of growth and aging of the leaves occurred on May 20. Cold spring of 2017 with low average daily temperatures, with insufficient amount of moisture led not only to late onset of vegetation, but also to early leaf fall on October 26, compared to the year of 2015

when it was on November 14, and in 2016 on November 20. As the influence of the amount of effective temperatures (AET for short) on the timing of vegetation onset phases, clear patterns have not been identified over a three-year period. Swelling of the buds occurred at AET ranging from 8.95 to 193.58°C; opening of the buds from 23.54 to 237.62°C, leafing from 90.87 to 312.31°C, the completion of leaf growth from 119.59 to 402.38°C, the beginning of colorization of the leafs from 1690.91 to 2764.49°C, the end of the colorization of the leafs and leaf fall at temperatures ranging from 2139.96-3082.96°C.

Moreover, hybrid poplar plantings in all urban plantations have high ornamental indicators. These are vigorous straight trees without bending, having a dense crown and few dry knots at the bottom of the stem. The trees show high indicators in sanitary and hygienic conditions, aesthetic assessment, and life condition in zone I (of weak pollution). However, there are differences in the assessment indicators of other zones which proved to be statistically unreliable. When comparing poplar by the living condition according to the Student's criterion (t) at the examples of 25 years old plantations in the zone of weak and medium pollution (t life cond. = 0.356), and of 30 years old plantations in the zones of low and medium pollution (t life cond. = 0.543), in zones of medium and strong pollution (t life cond. = 0.065), in areas of weak and strong pollution (t life cond. = 0.275), the above-mentioned indicators were less than the table values.

Natural and anthropogenic systems formed within the boundaries of residential places are under constant abiotic stress. Atmospheric pollutants are industrial enterprises and numerous vehicles (Aipov et al., 2018). In recent decades, the protection of the atmosphere, which is deteriorating as a result of human activities, has become a serious problem. Really, compared with other components of the environment, atmosphere, which has greater spatial mobility, is polluted most quickly. Green spaces are the central link in the urban ecosystem and perform sanitary, aesthetic, emotional, psychological and other functions.

Researches of Czech scientists prove the correlation between the growth of spruce and pine with ambient air pollution, temperature and precipitation. The combination of chemical and climatic stress causes the most serious damage (Vacek et al., 2013; Vacek et al., 2015; Vacek et al., 2016). On the other hand, the hybrid we have studied retains the diameter growth rate regardless of the degree of air pollution and climatic factors. In addition, it shows high indicators of life stability, sanitary and aesthetic assessment.

Chinese scientists use hybrid poplars for large-scale low-cost production of high value proteins, as well as for wood production on plantations with short-term rotation. The high growth rates of poplar hybrids contribute to all this (Kim et al., 2012; Liu et al., 2012). In China, special attention is paid to the plantation cultivation of poplar hybrids and to the study of root systems. Soil conditions determine this tree longevity (Zhu et al., 2018).

Scandinavian scientists have summarized the data on the ecology, breeding and use of hybrid aspen (*Populus tremuloides* Michx. × *Populus tremula* L.). It proved to be one of the most fast-growing broadleaved species. It can be used for the production of woody biomass. Its cultivation led to the creation of clones with high productive capacity. It has become an economically valuable broadleaf wood in Northern Europe (Tullus et al., 2012).

Polish scientists consider current data on poplars from ecological, functional and scientific points of view, which proves the need to combine all these aspects with the convenience of using poplars to maximize profits (and not only financial). They also take into account the role of poplars as greenery which was achieved as a result of improving cultivation methods, the introduction of many new hybrids with desired characteristics (Stobrawa, 2014).

We consider poplars as ornamental woody plants suitable for technogenic landscape gardening of modern cities. They are one of the most important tree species in the temperate regions of the world (Zhao et al., 2014). Bashkir Lombardy poplar is a promising hybrid for landscape plantations in the Pre-Urals region. It was found that the trees have a colon-shaped crown. They grow rapidly and have high resistance to atmospheric toxicants. We studied patterns of the growth and development of Bashkir Lombardy poplar (*Populus nigra* L. × *Populus nigra* var. *italica* Du Roi). The tree can grow in conditions of a large industrial center with high gas contamination. After long-term phenological observations of the plantations of the Lombardy poplar we can recommend to use it in alley cropping and line planting of urban landscapes.

It is necessary to emphasize that all phases of vegetation development of a hybrid poplar come in strict sequence, and trees stay foliose even after snowfall. It was determined that the hybrid poplar has a long growing season lasting up to 190 days. The statement of a longer growing season of poplar hybrids is confirmed by other researchers. For example, Berlin poplar average growing season is 153 days, while Sverdlovsk Lombardy poplar makes up 174 days (Medvedeva, 2012). However, late growing season often leads to freezing of poplar shoots. In this connection, there is a need for regular care of urban plantations in order to improve their plant resistance (Conway, 2016).

Conclusions

Bashkir Lombardy hybrid poplar (*Populus nigra* L. × *Populus nigra* var. *italica* Du Roi) is an ornament tree. It can be widely used in landscape architecture. It was determined that the poplar hybrid has a rapid growth rate and up to 30 years of age its average height increase is 0.95 m. According to the growth indicators, which are the average diameter and height, it has high resistance to atmospheric toxicants. It has a long growing season of 190 days, while that of Berlin poplar is 153 and of Sverdlovsk Lombardy poplar -174 days. All phases of poplar vegetation occur in strict sequence. However, calendar-beginning (swelling, opening of the buds) and end (the colorization of the leaves and leaf fall) phases of the growing season are mostly influenced by temperature and precipitation in early spring. Hybrid showed high ornamental characteristics in all urban planting. These are vigorous, straight trees with a dense crown. They showed high indicators of sanitary and hygienic and life tree condition, of aesthetic assessment in the zone of weak pollution (I). However, a comparison of the values of these indicators in other pollution zones (II and III) according to the Student's criterion (t) showed a statistically unreliable difference. This difference confirms the tolerance of the hybrid to environmental conditions. There was made a research of forest and landscape valuation of hybrid poplar (*Populus nigra* L. × *Populus nigra* var. *italica* Du Roi). The results of the research as well as long phenological observations prove that widespread plantation of this tree can be very perspective for urban landscapes.

Bashkir Lombardy poplar (*Populus nigra* L. × *Populus nigra* var. *italica* Du Roi) can grow on the industrial landscape territory with a large number of industrial enterprises. It is able to resist unfavourable environmental factors such as harsh winter and hot summer. Despite all these negative factors, the tree keeps its ability to grow and develop without losing high aesthetic qualities.

References

Aipov, R.S., Yarullin, R.B., Gabitov, I.I., Mudarisov, S.G., Linenko, A.V., Farhshatov, M.N., Khasanov, E.R., Gabdrafikov, F.Z., Yukhin, G.P., Galiullin, R.R. (2018). Mechatronic system linear swing vibrating screen of a Grain Cleaner. *Journal of Engineering and Applied Sciences, 13*(8), 6473-6477.

Alekseyev, V. A. (1989). Diagnosis of life condition of trees and forest stands. *Forestry, 4*, 51-57.

Arefyev, S. P. (2003). Correlation analysis of growth anomaly of trees and bushes of the Tazovsky Bay. In: *Dendrochronology – achievements and prospects. Proceedings of the All-Russian Conference.* Institute of Forest named after V. N. Sukacheva of the Siberian Branch of the Russian Academy of Sciences, Krasnoyarsk, 51.

Berezin, A. M. (1993). *Tree species selection (poplars).* Report, Ufa.

Beydman, I. N. (1974). *Methodology for the study of synphenology.* Science, Novosibirsk.

Bogdanov, P. L., (1965). *Poplars and their crop.* Second ed. Forest industry, Moscow.

Cervelli, E., Pindozzi, S., Capolupo, A., Okello, C., Rigillo, M., & Boccia, L. (2016). Ecosystem services and bioremediation of polluted areas. *Ecological Engineering*, *87*, 139-149.

Conway, T. M. (2016). Tending their urban forest: Residents' motivations for tree planting and removal. *Urban Forestry & Urban Greening*, *17*, 23-32.

Gabdrahimov, K., Khayretdinov, A., Sultanova, R., Konashova, S., Konovalov, V., Sabirzyanov, I., Gabdelkhakov, A., Isyanyulova, R., Martynova, M., & Blonskaya, L. (2018). Reproduction of stable pine forests in the Southern Urals. *Journal of Engineering and Applied Sciences*, *13*, 6494-6499.

Kabisch, N., & Haase, D. (2013). Green spaces of European cities revisited for 1990–2006. *Landscape and Urban Planning*, *110*, 113-122.

Kim, S., Kim, Y. O., Lee, Y., Choi, I., Joshi, C. P., Lee, K., & Bae, H. J. (2012). The transgenic poplar as an efficient bioreactor system for the production of xylanase. *Bioscience, Biotechnology, and Biochemistry*, *76*(6), 1140-1145.

Kleyn, R. M. (1974). *Plant Research Methods*. Kolos publisher, Moscow.

Kobranov, N. P. (1930). *Examining and studying of forest crops.* Work on forest experimentation, Leningrad.

Konashova, S. I. (2002). *Foundation of aesthetic forestry: study guide*. Bashkir State Agrarian University, Ufa, 61-71.

Konashova, S., Sultanova, R., Khayretdinov, A., Gabdrakhimov, K., Konovalov, V., Rakhmatullin, Z., Isyanyulova, R., Nasyrova, E., Gubydullin, A., & Muftakhova, S. (2018). Forestry and ecological aspects of the broad-leaved forest formation. *Journal of Engineering and Applied Sciences*, *13*, 8789-8795.

Kulagin, A. Y., Kagarmanov, I. R., & Blonskaya, L. N. (2000). *Poplars in the Pre-Urals region: dendro-ecological characteristic.* Gilem publisher, Ufa.

Liu, C. C., Li, C. M., Liu, B. G., Ge, S. J., Dong, X. M., Li, W., Zhu, H. Y., Wang, B. C., & Yang, C. P. (2012). Genome-wide identification and characterization of a dehydrin gene family in poplar (*Populus trichocarpa*). *Plant Molecular Biology Reporter*, *30*(4), 848-859.

Medvedeva, E. Y. (2012). Phenological development of some polar species in different ecological environment of Ekaterinburg city. In: *Ecology and nature management: applied aspect. Proceedings of the 2nd All-Russian (with international participation) scientific and practical conference of students, PG students and young scientists*. Bashkir State University, Ufa, 118-121.

Minogue, P. J., Miwa, M., Rockwood, D. L., & Mackowiak, C. L. (2012). Removal of nitrogen and phosphorus by eucalyptus and populus at a tertiary treated municipal wastewater

sprayfield. *International Journal of Phytoremediation*, *14*(10), 1010-1023.

Müller, A., Volmer, K., Mishra-Knyrim, M., & Polle, A. (2013). Growing poplars for research with and without mycorrhizas. *Frontiers in Plant Science*, *4*, 332.

Putenikhin, V. P. (2006). *Dendrology with the fundamentals of landscape gardening. Part 1: Study guide.* Russian History Society of the Bashkir State University, Ufa.

Redovniković, I. R., De Marco, A., Proietti, C., Hanousek, K., Sedak, M., Bilandžić, N., & Jakovljević, T. (2017). Poplar response to cadmium and lead soil contamination. *Ecotoxicology and Environmental Safety*, *144*, 482-489.

Schweier, J., Molina-Herrera, S., Ghirardo, A., Grote, R., Díaz-Pinés, E., Kreuzwieser, J., Haas, E., Butterbach-Bahl, K., Rennenberg, H., Schnitzler, J.-P., & Becker, G. (2017). Environmental impacts of bioenergy wood production from poplar short-rotation coppice grown at a marginal agricultural site in Germany. *Gcb Bioenergy*, *9*(7), 1207-1221.

Shirokova, N. P., & Ryabova, M. S. (2014). Relation between phenology and biology of some plant species of the Central Part of Russia. *Young Scientists*, *21*(1), 260-263.

Stobrawa, K. (2014). Poplars (*Populus* spp.) – ecological role, applications and scientific perspectives in the 21st century. *Baltic Forestry*, *20*(1), 204-213.

Sultanova, R., Gabdrahimov, K., Khayretdinov, A., Konashova, S., Konovalov, V., Blonskaya, L., Sabirzyanov, I., Martynova, M., Isyanyulova, R., & Gabdelkhakov, A. (2018). Evaluation of ecological potential of forests. *Journal of Engineering and Applied Sciences*, *13*, 6590-6596.

Tsarev, A. P., & Mashkin, S. I. (1985). *Poplar varieties recording: monograph.* Voronezh State University, Voronezh.

Tullus, A., Rytter, L., Tullus, T., Weih, M., & Tullus, H. (2012). Short-rotation forestry with hybrid aspen (*Populus tremula* L. × P. *tremuloides Michx*.) in Northern Europe. *Scandinavian Journal of Forest Research*, *27*(1), 10-29.

Vacek, S., Bílek, L., Schwarz, O., Hejcmanová, P., & Mikeska, M. (2013). Effect of air pollution on the health status of spruce stands: A case study in the Krkonoše Mountains, Czech Republic. *Mountain Research and Development, 33*(1), 40-50.

Vacek, S., Hůnová, I., Vacek, Z., Hejcmanová, P., Podrázský, V., Král, J., Putalová, T., & Moser, W. K. (2015). Effects of air pollution and climatic factors on Norway spruce forests in the Orlické hory Mts. (Czech Republic), 1979–2014. *European Journal of Forest Research*, *134*(6), 1127-1142.

Vacek, S., Vacek, Z., Bílek, L., Simon, J., Remeš, J., Hůnová, I., Král, J., Putalová T. & Mikeska, M. (2016). Structure, regeneration and growth of Scots pine (*Pinus sylvestris* L.) stands with respect to changing climate and environmental pollution. *Silva Fennica*, *50*(4), 1564.

Zhao, X., Zheng, H., Li, S., Yang, C., Jiang, J., & Liu, G. (2014). The rooting of poplar cuttings: a review. *New Forests*, *45*(1), 21-34.

Zhu, W., Sang, Y. L., Zhu, Q., Duan, B., & Wang, Y. (2018). Morphology and longevity of different-order fine roots in poplar (*Populus*×*euramericana*) plantations with contrasting forest productivities. *Canadian Journal of Forest Research, 48*(6), 611-620.