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DENDROCHRONOLOGICAL RESEARCH ON OLD-AGED EASTERN WHITE PINE FROM THE KALUGA REGION – A NATURAL HERITAGE MONUMENT

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ABSTRACT

The eastern white pine (*Pinus strobus* L.) is the North American species introduced in Europe in the 18th century. Although this species has high productivity within its native area, the eastern white pine trees have not become widespread in Russia due to their low resistance to blister rust (*Cronartium ribicola* J.C. Fisch). Mostly, they can be found in parks and botanical gardens. The eastern white pine tree identified in our research in the Dzerzhinsky Forest area in the Kaluga region (on the border with the Ugra National Park) has unique forest inventory parameters. Based on the research results, this tree has been listed in the Register of the Russian National Program "Trees as Natural Heritage Monuments".

Key words: old-aged trees, trees as natural monuments, coniferous introduced trees, Kaluga region, *Pinus strobus* L.

INTRODUCTION

The Russian National Program "Trees as Natural Heritage Monuments" was launched in 2010 by the Council for Conservation of the National Natural Heritage of the Federation Council of the Russian Federal Assembly. The program was developed under the initiative of NPSA ZDOROVY LES and supported by the Federal Forestry Agency (Rosleskhoz) and Moscow State Forest University (UNIQUE RUSSIAN TREES 2019).

As of May 2019, overall, 832 online applications from different Russian regions have been registered at the program website and 480 trees have been listed in the National Register of Veteran Trees. 216 trees from the Register were awarded by the certification board as Natural Heritage Monuments. Currently, trees from 76 Russian regions joining the program (out of 85 regions of the Russian Federation including the Republic of Crimea and the city of Sevastopol) are included in the National Register. The Register covers trees of about 43 species.

The discussion to form the register started with the question concerning tree species with a natural area outside Russia. Can individual trees of such kinds of species be classified as the objects of cultural, natural and historical heritage? The affirmative opinion is because of many reasons. These trees are the result of artificial planting and are usually associated, in historical memory, with the activities of popular public opinion leaders of their time. Old-growth trees of exotic species in this territory, with high aesthetic properties, are interesting examples of silvicultural experiments.

The introduction of tree species exotic in Russia was a common and widely used feature of landscape architecture in the 19th and early 20th centuries. The Eastern White Pine imported to Europe by Lord Weymouth in 1705 became one of such introduced species. Following the landscaping trend of that period, a pine tree of the above-mentioned species was planted in the park on the Rasskazovo Estate (Arzhenka) owned by the Aseevs, the family of merchants and manufacturers.

Formerly, alien pine species such as the eastern white pine, the Balkan pine and the black pine were largely introduced to many regions of the country (SUKACHOV 1934, TKACHENKO 1939, KAPPER 1954, JABLOKOV 1962, LAPIN 1975). Today, they can be mostly found in various parks, botanic gardens and even, in rare case, in forests. According to A. S. JABLOKOV (1962), the founder of the School for Selective Breeding and Reproduction of Forest Species, "If trees of especially high quality that meet the criteria for selection of good or best-of-normal units can be found among the planted trees, such trees should be registered by the scientific institutes, forest management bodies and landscape agencies, listed as protected trees and natural monuments and used for reproduction purposes to get high-quality seeds".

RESEARCH SUBJECT

The first eastern white pine from the Tambov region was listed in the National Register under No 612 on March 23, 2017. This was the tree growing in the park of the Aseevs Estate in the town of Rasskazovo (UNIQUE RUSSIAN TREES 2019). In May of the same year, the team of experts from the Center for Wood Analyses (the leading expert of which was Andrey Cherakshev) travelled to the estate to perform a detailed inspection of the pine tree as a part of the activities under the program. As a result, the experts identified the main inventory parameters of the tree. Its height was 22 m and the trunk diameter was 78 cm. The tree did not have any signs of weakness or infestation with pests or diseases and was of higher aesthetic appeal in comparison with the local native tree species. Based on the age analysis of the wood samples, its age was identified to be 117 years old as of 2019. The obtained result confirms that the tree was planted in the early 20th century when the eastern white pine was prevalent as an introduced species in landscape architecture.

Another eastern white pine was found during the research at one of our study sites in the Ozyorensky forest district of the Dzerzhinsky forest area in the Kaluga region. As far as the forest inventory parameters are concerned, this tree was larger and of higher aesthetic appeal than the pine described above. Its height was 32 m and its diameter was 90 cm as measured at the height of 1.3 m. Growing at the forest stand of the same species, the tree stood out of the neighbouring trees due to its great dimensions and excellent health and therefore it was decided to apply for this tree to join the Russian National Program "Trees as Natural Heritage Monuments" (UNIQUE RUSSIAN TREES 2019). The tree was included in the National Register of Veteran Trees under No 795. The certification board voted for this pine to become a Natural Heritage Monument Tree at their annual general meeting on April 18, 2019. The photo of the tree is shown in Figure 1.

Fig. 1 The white eastern pine from the Ozyorensky forest district of the Dzerzhinsky forest area, the Kaluga region, classified as a Natural Heritage Monument Tree (under registered No 795).

MATERIALS AND METHODS

Methods of core preparing and ring width measuring were described in previous works (RUMYANTSEV 2010, RUMYANTSEV – CHERAKSHEV 2013). The Pressler borer was used for taking a core, Lintab-5 was used for measuring tree ring widths, and the Tsap-Win program was used to control the measurements by the method of cross dating chronologies. The age of the trees was identified based on the original method developed by A.V. Cherakshev (CHERAKSHEV *et al*. 2015, RUMYANTSEV – CHERAKSHEV 2020). This method ensures that tree age is accurately determined even in the cases when the drill does not come through the cross-section center but passes chordwise against the pith. Since it is practically impossible to get the auger precisely into the trunk center especially while inspecting trees of a significant diameter, a certain number of tree rings will fall out of the calculations, which results in obtaining a lower tree age.

There are the age calculations of both eastern white pine trees described step-by-step.

The parameters of the core samples collected from the eastern white pine trees are shown in Table 1.

Tab. 1 Parameters of the core samples.

Tree number according to the Register/Core sample number	Height of the core sampling, m	Circumference at the height of core sampling, cm	Directions of the core sampling
№612-1	1.15	246	East – West
№612-2	1.1	247	North – South
№795-1	1.3	281	North – South

The following calculation steps were completed (based on the original method) to identify the tree age.

1. **Determining the length of the wood section unavailable for study**. If, when drilling, the auger does not come along the radius of the circle with the center at the pith but passes chordwise, it is required to measure the chord length *b* and the segment height *a* of the core sample (Figure 2). Consequently, an isosceles triangle was made and a circle around it which will be of an assumed extension of the tree ring on the core sample was drawn (Figure 3). The radius of the circle drawn around the isosceles triangle is calculated as follows:

$$L_2 = \frac{c^2}{\sqrt{(2c)^2 - b^2}} \quad (1)$$

$$c^2 = a^2 + \frac{1}{2}b^2, \quad (2)$$

where L_2 is a circle radius (length of the wood section unavailable for study), a is a segment height, and b is a chord length (Figure 3).

In this case, the circle radius is the length of the wood section unavailable for study.

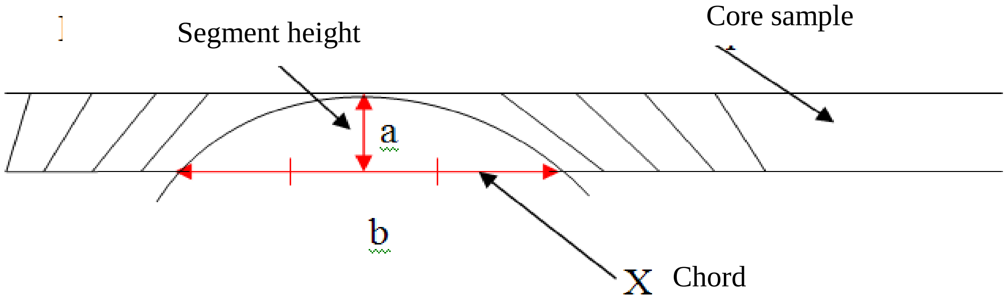

Fig. 2 The wood section and the chord represented on the core sample.

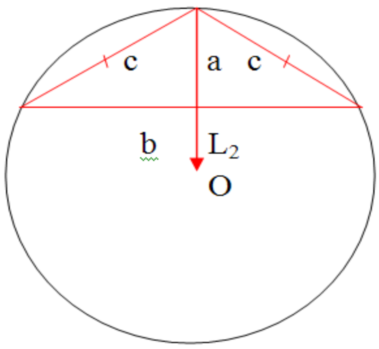

Fig. 3 The isosceles triangle and the circle drawn around it representing the extension of the tree ring.

2. **Calculating the average width of the tree rings in the wood section unavailable for study:**

$$M_x = (x_1 + x_2 + x_3 + x_4 + x_5)/5\,, \quad (3)$$

where M_x is the average tree ring width, $x_1 \ldots x_5$ are the widths of the last 5 tree rings at the closest proximity to the missing wood section.

3. **Finding out the number of tree rings in the wood section unavailable for study:**

$$A_1 = L_2/M_x\,, \quad (4)$$

where A_1 is an estimated number of the tree rings in the unavailable wood section, L_2 is a circle radius (length of the wood section unavailable for study), M_x is an average tree ring width.

4. Determining the tree age based on an individual radius at the height of core sampling:

$$A_2 = A_0 + A_1\ , \tag{5}$$

where A_2 is the tree age at the height of core sampling, A_0 is a number of the tree rings identified in the core sample, A_1 is an estimated number of the tree rings in the wood section unavailable for study.

5. Calculating the number of years required for a young tree to reach the height of core sampling:

$$A_3 = H/b\ , \tag{6}$$

where A_3 is the age required for a tree to reach the height necessary to collect a core sample, H is the height of core sampling, b is a conditional linear growth. The conditional linear growth rate is in a positive correlation with biological and geographic conditions of the tree-under-study growing site and, as a rule, might be from 10 cm to 30 cm a year.

6. Eventually, we can calculate the biological tree age:

$$A_4 = A_2 + A_3\ , \tag{7}$$

Similar to the investigated, the largest tree from the Kaluga region there are other trees of this species forming the linear tree planting and this confirmed the artificial nature of the planting origin. The cores of wood from 10 trees (including the largest) were taken, tree rings were measured and the chronology for eastern white pine stand was built and used for dendroclimatic analysis.

RESULTS AND DISCUSSION

The age of the Natural Heritage Monument Trees described was calculated based on the data presented in Tables 1 and 2. The results are given in Table 3.

Tab. 2 Input data for tree age calculations.

Tree number according to the Register/Core sample number	Chord length b, mm	Segment height a, mm	Wood section unavailable for study, mm	Average width of the 5-10 tree rings closest to the unavailable section, mm	Estimated number of tree rings in the wood section unavailable for study.
No 612-1	9.5	0.5	22.8	2.242	10
No 612-2	16.5	1.5	23.4	2.304	10
No 795-1	37	3.5	50.64	7.8	6

Tab. 3 Tree age calculations.

Core sample number	Number of tree rings on the core sample	Estimated number of tree rings in the wood section unavailable for study.	Conditional linear growth in the early years of tree life, cm	Age when the tree reaches the height of core sampling, in years.	Total age, in years
No 612-1	99	10	20	6	115
No 612-2	99	10	20	6	115
No 795-1	84	6	20	7	97
Total age of Tree No 612 as of 2017:					**115**
Total age of Tree No 795 as of 2018:					**97**

Since the core samples were collected in different years, a certain number of years have to be added to the estimated age in order to get the current age of the trees. Thus, as of today, the age of the eastern white pine from the Tambov region is 119 years and of the pine from the Kaluga region is 101 years. Despite the insignificant age difference, the pine tree from the Kaluga region is greater than the pine tree from the Tambov region as far as their forest inventory parameters are concerned.

The average chronology for tree ring width dynamics by the years for white eastern pine planting from the Kaluga region are shown in Fig. 4. The local minimum values and the local maximum values of this time series give information about years with favorable tree growth environmental conditions, and, on the contrary, about unfavorable ones.

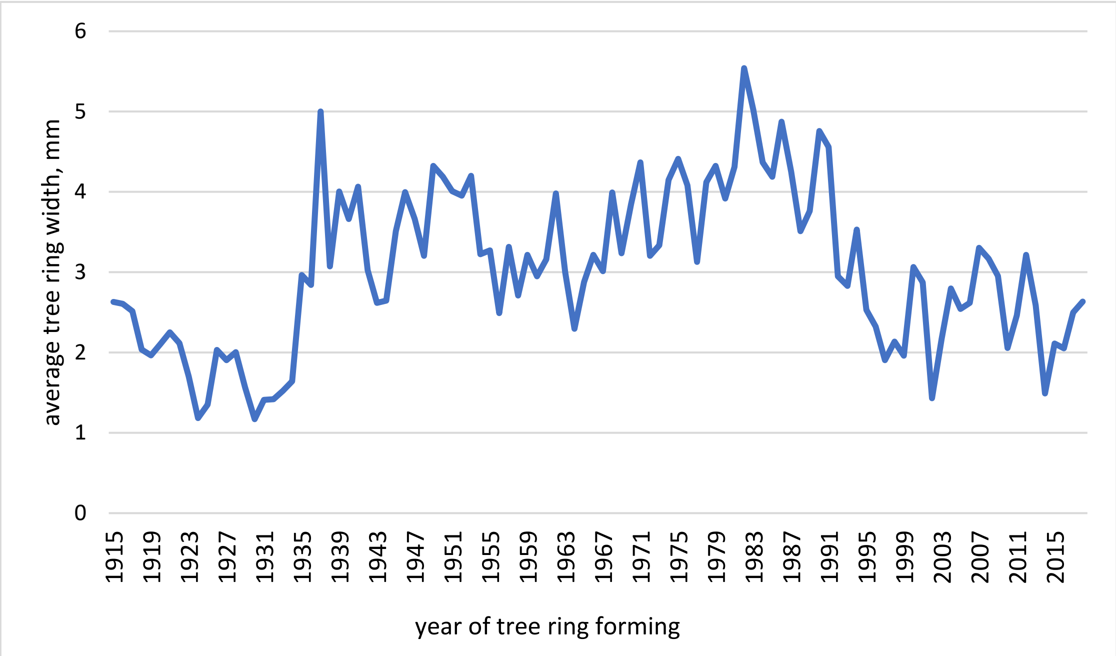

Fig. 4 Average annual ring width values for the calendar years.

The analysis of the dynamics of radial growth shows that clear extremely wide annual rings were formed in 1937, 1962, 1982. Clear extremely narrow annual rings were formed in 1944, 1956, 1964, 1977, 2002, 2014. It may be related to phytocenotic events, or the effect of climatic factors. The correlation coefficient calculation between indexed average chronology and time series of climatic data was conducted for more detailed analysis. Each chronology was indexed by the division of ring width value on average ring value for five previous years. Indexing is needed for removing the effects associated with the presence of the age trends in the time series of radial growth. The results of calculations are shown in Fig. 5 and Fig.6. The significant values of the coefficients for 0.05 level are 0.27 and more. The calculations were conducted during the years 1966 –2017.

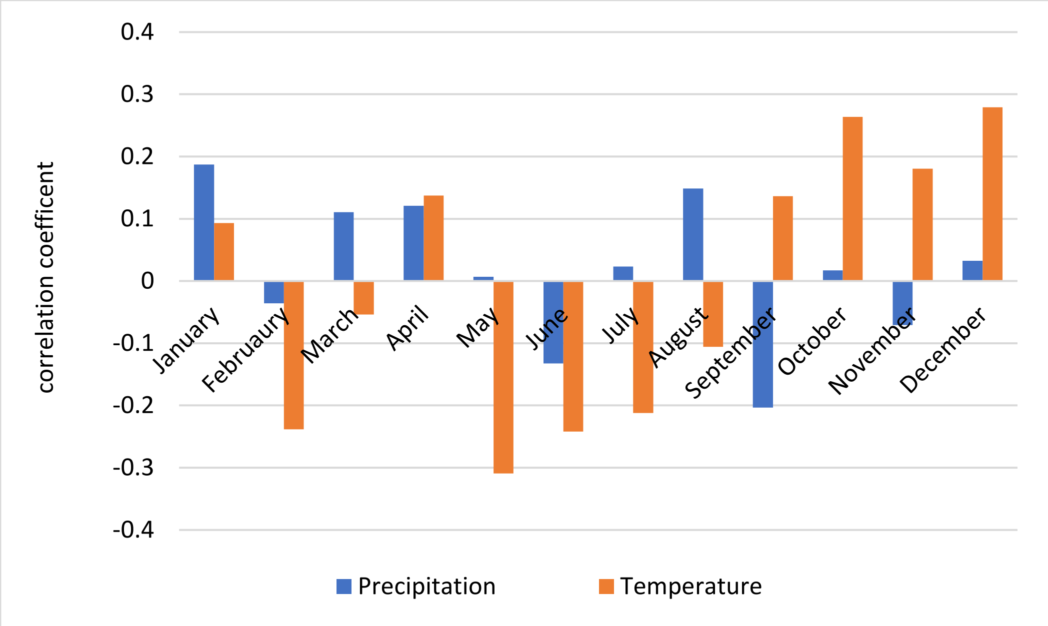

Fig. 5 The influence of climatic data values on tree ring formed during a calendar year of tree ring forming.

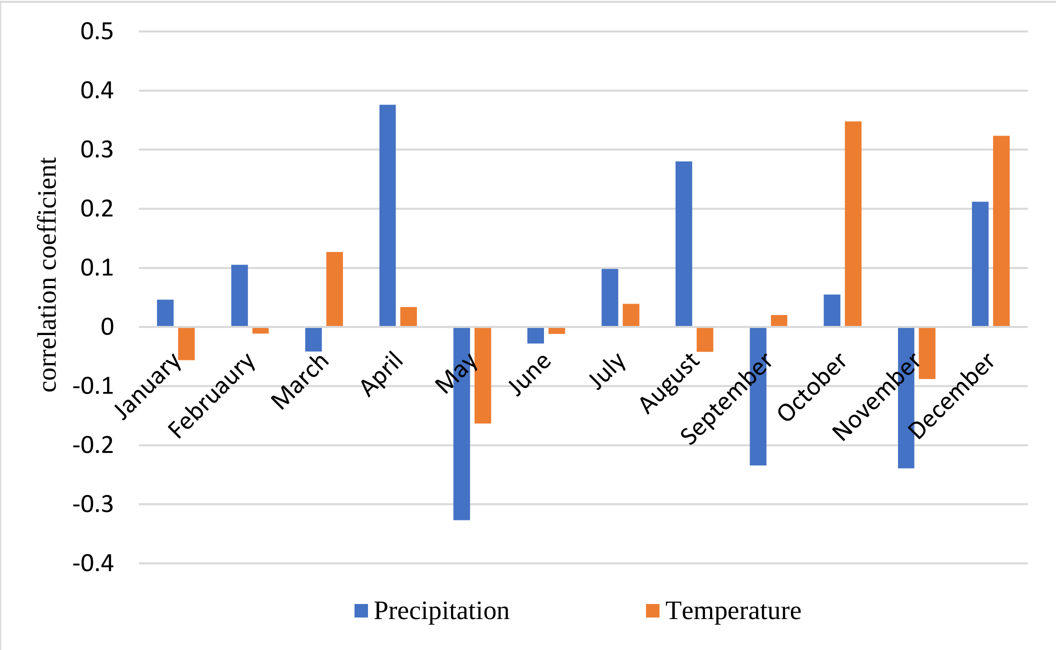

Fig. 6 The influence of climatic data values on tree ring formed during a calendar year previous to tree ring forming.

The results of correlation analysis can be used to explain significant correlation coefficients observed for May (T5), October (T10) and December (T12) temperatures of the year previous to the year of tree ring forming. Also, the sum of rainfall in April (P4), May (P5) and August (P8) during the calendar year of tree ring forming are significant for total width of the annual ring. Such results make it possible to model the dynamics of the radial growth indices using the linear regression equation. As a result of the calculations, an equation of the following form was obtained: $Y = 1.0889 - 0.0115 \times T5 + 0.0076 \times T12 + 0.0013 \times P4 - 0.0021 \times P5 + 0.0009 \times P8 + 0.0365 \times T10 + 0.0135 \times T12$.

The model is characterized by 51% determination coefficient. The graph in Figure 7 has a good synchroneity with real values and it is an even better indicator at a qualitative level.

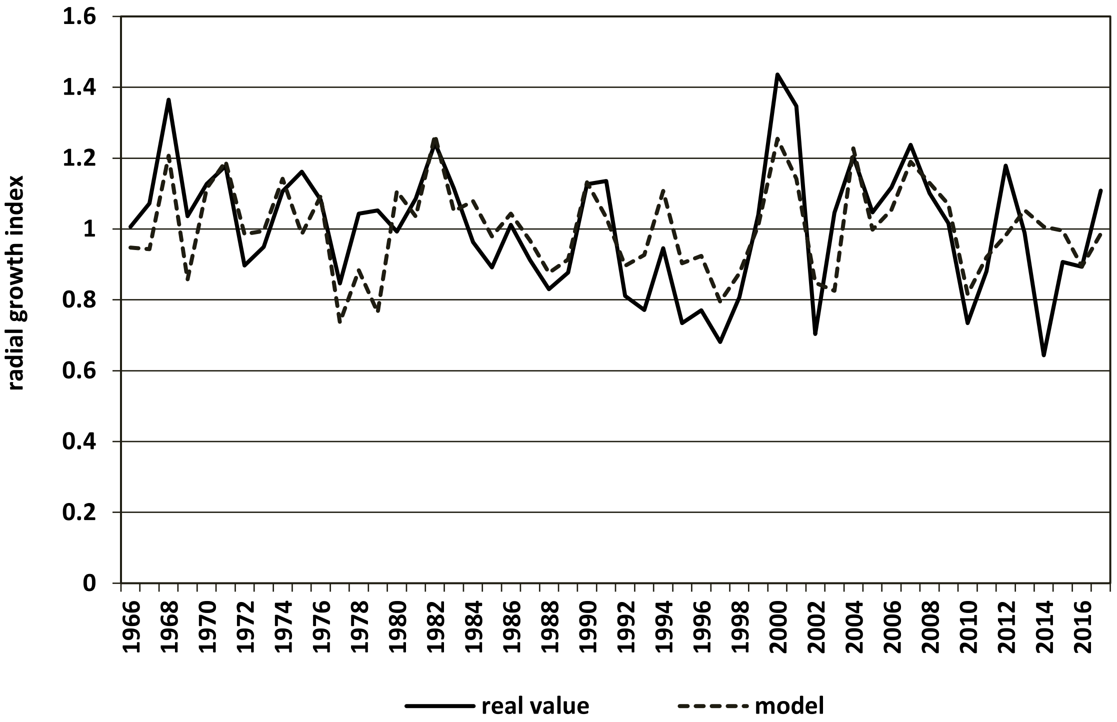

Fig. 7 The comparison of results of radial growth indices modelling.

The results of an investigation differ from the results of other such investigations of this species (RUMYANTSEV, CHERAKSHEV 2013, CHIN *et al*. 2013, CHIN *et al*. 2018). It shows the role and importance of the dendrochronological method in identifying climatic factors limiting the cambial activity of a particular tree species. In the years with critical values of meteo-parameters, the monitoring of the health condition of the trees is needed.

CONCLUSION

For the studied tree, the biological age was determined and climatic factors significant for its growth were identified. The short-term variability of radial increment fluctuations was modeled by a linear regression equation with a 51% determination coefficient. There are no doubts that the described trees are not the only two old-aged eastern white pines growing in the Russian Federation. Therefore, the research into veteran trees of the eastern white pine species and the Macedonian pine species throughout Russia will continue to list them in the National Register under the Trees as Natural Heritage Monuments Program because these introduced species are of a high natural, scientific, historical and cultural value.

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