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Vorobyeva N.S.[1], Rumyantsev D.E.[2] *, Melikhova M.A.[3]

[1, 2, 3] Mytischi Branch of Bauman Moscow State Technical University, Mytisci, Russia

* Correspodning author (dendro15[at]list.ru)

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STUDY OF THE RADIAL GROWTH DYNAMICS OF THE ASPEN (*POPULUS TREMULA* L.) AT THE NORTH BORDER OF FOREST-STEPPE ZONE OF THE EUROPEAN PART OF RUSSIA (MORDOVIAN RESERVE)

Research article

Abstract

The article presents the results of studying the dynamics of radial growth of aspen trees in arid conditions on the northern border of the forest-steppe zone of the European part of Russia in the Mordovian State Nature Reserve named after P.G. Smidovich. As has been establish the formation of annual rings has a cyclicity about 11 years, which coincides with the cycle of solar activity. However, the formation of abnormally narrow annual rings can occur outside of this cycle, non periodically. The great above average monthly temperatures of the summer months have a negative effect on the formation of the annual ring next year. Also, the combination of increased precipitation in May with reduced precipitation in June in the year of the formation of the annual ring leads to the formation of extremely narrow annual rings too. The years with increased precipitation in June are favorable for growth.

Keywords: annual rings, dendrochronology, dendroclimatology, Populus tremula L., Mordovian Reserve.

Воробьёва Н.С.[1] *, Румянцев Д.Е.[2], Мелихова М.А.[3]

[1, 2, 3] Мытищинский филиал Москвоского государственного технического университета им. Н.Э. Баумана, Мытищи, Россия

* Корреспондирующий автор (dendro15[at]list.ru)

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ИССЛЕДОВАНИЕ ДИНАМИКИ РАДИАЛЬНОГО ПРИРОСТА ОСИНЫ (*POPULUS TREMULA* L.) НА СЕВЕРНОЙ ГРАНИЦЕ ЛЕСОСТЕПНОЙ ЗОНЫ ЕВРОПЕЙСКОЙ ЧАСТИ РОССИИ (МОРДОВСКИЙ ЗАПОВЕДНИК)

Научная статья

Аннотация

В статье представлены результаты изучения динамики радиального прироста деревьевосины в засушливых условиях на северной границе лесостепной зоны Европейской части России в Мордовском государственном природно заповеднике имени П.Г. Смидовича. Установлено, что формирование годичных колец имеет цикличность около 11 лет, что совпадает с циклом солнечной активности. Однако формирование аномально узких годичных колец может происходить и вне этого цикла, апериолически. Высокие месячные температуры летних месяцев оказывают отрицательное влияние на формирование годичного кольца в следующем году. Также к формированию экстремально узких годичных колец ведет сочетание повышенных осадков мая с пониженными осадками июня в год формирования годичного кольца. Благоприятны для роста годы с повышенным количеством осадков в июне.

Ключевые слова: годичные кольца, дендрохронология, дендроклиматология, *Populus tremula* L., Мордовский заповедник.

1. Introduction

European aspen (*Populus tremula* L.) is a mesophytic tree species, wchich has a continuous area of distribution in Russia in the forest zone. Due to the low drought resistance of this species, it can be expected that at the southern border of the forest tree-ring chronologies of aspen will contain a clear drought-dependent climatic signal. This kind of information has interest from the point of view of reconstruction and forecasting of droughts on the territory of the Russian Plain, as well as from the point of view of forecasting the reaction of aspen forests to global climate warming. The aim of the research was to establish the own features of radial growth dinamics of aspen in Mordovian Natural Statae Reserve wchich is situted near the north border of forest-steppe zone of Russian plain.

2. Methods

Mordovian State Nature Reserve named after P.G. Smidovich was founded in 1990. Its territory is located near the border of forest and forest-steppe zones in the conditions of the European part of Russia. The trial area was laid out in the Pushkin district forestry in block 441 of allotment 6. Stand composition at the plot: 9 Aspen 1 Birch + Scots Pine + Lime. Undergrowth composition was *Acer platanoides* L. and *Populus tremula* L. Understorey composition was presented by *Corylus avellana* L. Forest live cover compositionat at the plot: *Gymnocarpium dryopteris* (L.) Newman, *Anthyrium filix – femina* (L.) Roth ex Mert., *Dryopteris filix – mas* (L.) Schott, *Asarum europaeum* L., *Gleochoma hederaceae* L.

The average diameter of studied trees is 36 cm and average height is 32 m. The most part of trees stems had fruit bodies of *Phellinus tremulae* ore had signs of the development of rot in the trunk wchich was found on the cores. Apparently, all the trees are of the same age, approximately 85 years old. We took 1 test core from each recorded tree at the height of 1.3 m in September 2017. Holes in the stem were mended by tree-pruning paste. Test cores were placed in paper bags of a special form, labeled and taken to the laboratory. The tree rings were measured by using Lintab with accuracy 0.01 mm and after that cross dated by using computer program TSAP Win. Aspen is a species with unclear understanding of border between annual tree rings. For easier measuring the cores were scolded by special knife and rubbed with chalk.

Graphic and statistics data analysis was carried out with the help of a spreadsheet Microsoft Excel. Climatic component of annual changeability of increment was singled out by means of increment index calculation. Indexes were calculated as ratio of annual ring width of this year to the average annual ring width for the past 5 years [1]. Chosen method of indexing provides non-specific elimination of effects from long-term factors of a various kind [2]. Individual indexing chronologies were averaged, and generalized chronology was used for correlation analysis of climatic impact on radial growth.

3. Results

The width of annual rings depends on many factors. It is essential to single out the most important ones – weather conditions of growing season, age, phytocenotic interrelations, edaphic and orographic factors. The analysis of time series of radial increment allows us to identify the impact of various factors on the aspen trees' growth [3], [4]. Obtained time series of radial increment for aspen stand is shown on the graph of figure 1.

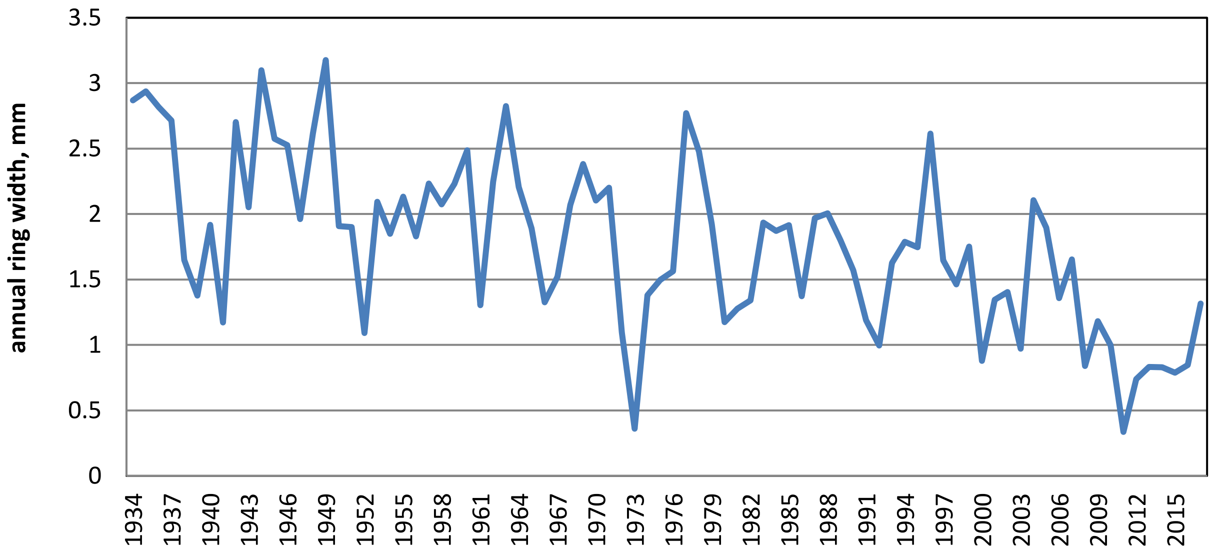

Fig. 1 – The average means of the annual ring widt for investigated aspen stand by the years

We have observed two tendencies in increment variability. The first trend is the following. The width of an annual ring is decreasing gradually with age. It is due to the fact that the concentration of auxins at the point of cambial sections in core drilling place is going down because of gradual shift of canopy upwards the growing tree stem [5].

Also, the width of an annual ring varies great from year to year, which is usually connected with the weather conditions changes [1], [2], [3], [4] For remove the age trend from the time series of the width of the annual rings, an indexing procedure is used. One of its variants may be attributing the width of the annual ring of an individual year to the average width of the annual ring over the past five years [1], [2].

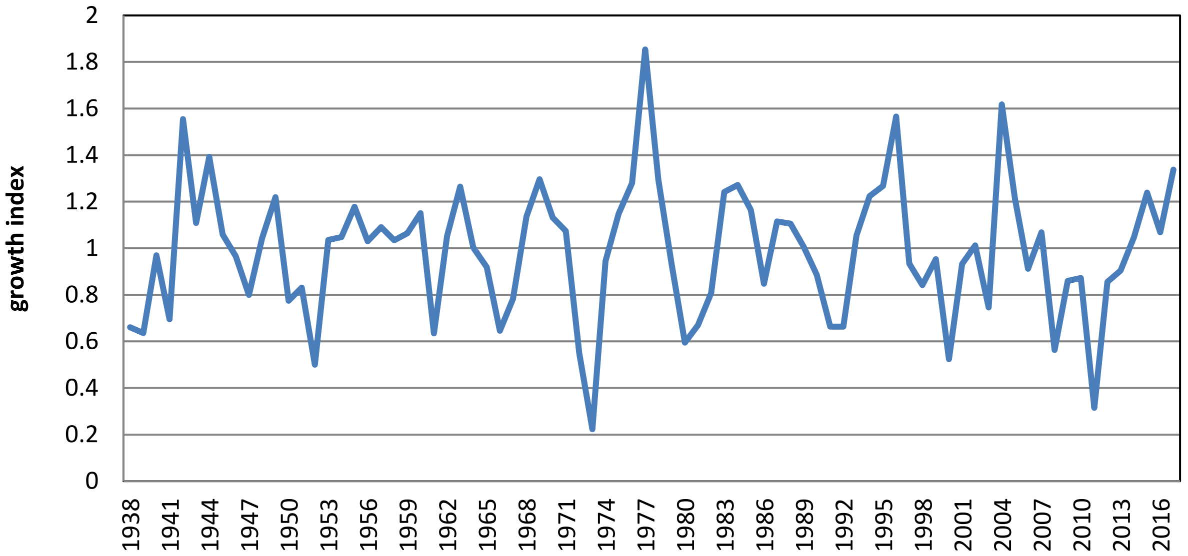

Fig. 2 – The average means of the radial growth index for investigated aspen stand by the years

As can be seen from figure 1,2, the most iunfavourable conditions for aspen growth in the studied forest stand were in 1941, 1952, 1961, 1966, 1973, 1980, 1991-1992, 2000, 2008, 2011 which resulting in formation of abnormally narrow annual rings. There is a certain periodicity in forming of abnormally narrow annual rings, with the cycle nearly 11 years: 1941-1952-1961-1973-198-1991-2000-2011 (11-9-12-7-11-9-11). The 11 – year cycle has been mentioned many times by researchers of various species in the northern border of forest-steppe zone [6], [7]. Apparently, the primary reason for it is the 11-year cycle of solar activity, as the majority of researchers claim [6], [7]. Such information is necessary for long-term forecasts. According to our data, the closest worsening of growth conditions in the studied forest stand will be observed in 2022. The most common view is that the influence of solar activity on growth is mediated through the influence on the processes of atmospheric circulation and weather regime changes [7].

In the first phase of dendroclimatic investigation of aspen growth features we conducted a correlation analysis. The length of the time interval for which the calculation of correlation coefficients is 66 years old. When the number of degrees of freedom 64 and the confidence level of 0.05 reliable values of the correlation coefficients from are 0.24 or more. Reliable values of the correlation coefficients are highlighted in table 1. The analysis was performed for average monthly temperatures only because there were no continuous time series for the monthly precipitation amount.

Table 2 – The value of the correlation coefficients between meteorological parameters and dynamics of radial growth of aspen trees

Month	Meteoparameter	
	The current year temperature	The last year temperature
January	-0,00	0,03
February	-0,01	-0,03
March	0,01	-0,05
April	-0,13	0,06
May	0,15	0,13
June	-0,19	**-0,27**
July	-0,22	**-0,40**
August	-0,19	**-0,36**
September	0,15	-0,01
October	**-0,28**	-0,19
Novemder	0,05	-0,01
December	**-0,27**	-0,16

Thus, there is a significant and biologically explained relation between values of the radial growth index and average monthly temperatures of the summer months of the year preceding the calendar year of the tree ring forming. The connections with the temperatures of October and November of this year are weak and biologically not interpreted, because the formation of the annual ring during this period has already ended. Apparently, they are random in natury. The influence of elevated summer temperatures affecting the width of the annual ring with a time lag of one year is quite well known [1], [2]. This is associated with the negative effects of a small number of shoot buds laid under such conditions, which determines a decrease in the biomass of the assimilating surface in the next growing season. Also is important that the assimilation products stored during the growing season for the next year are used for the purposes of rapid growth of shoots and the formation of an assimilation surface, and the intensity of photosynthesis for the next year will ultimately depend on their amount.

In the second stage of the analysis, we analyzed the weather conditions in the years of extremely low and extremly great growth with the climagramm (climatogramm) method [8]. The results of the comparison with average means meteoparameters values are shown at figure 3,4,5,6.

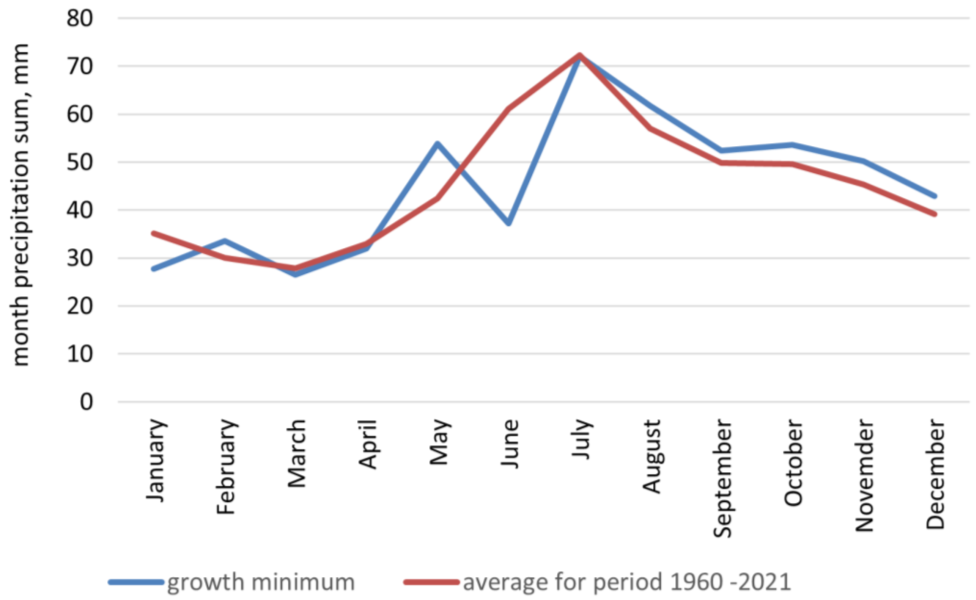

Fig. 3 – The average means of month precipitation sum for yeasr of the radial growth index minimums and for period 1960 - 2021 years

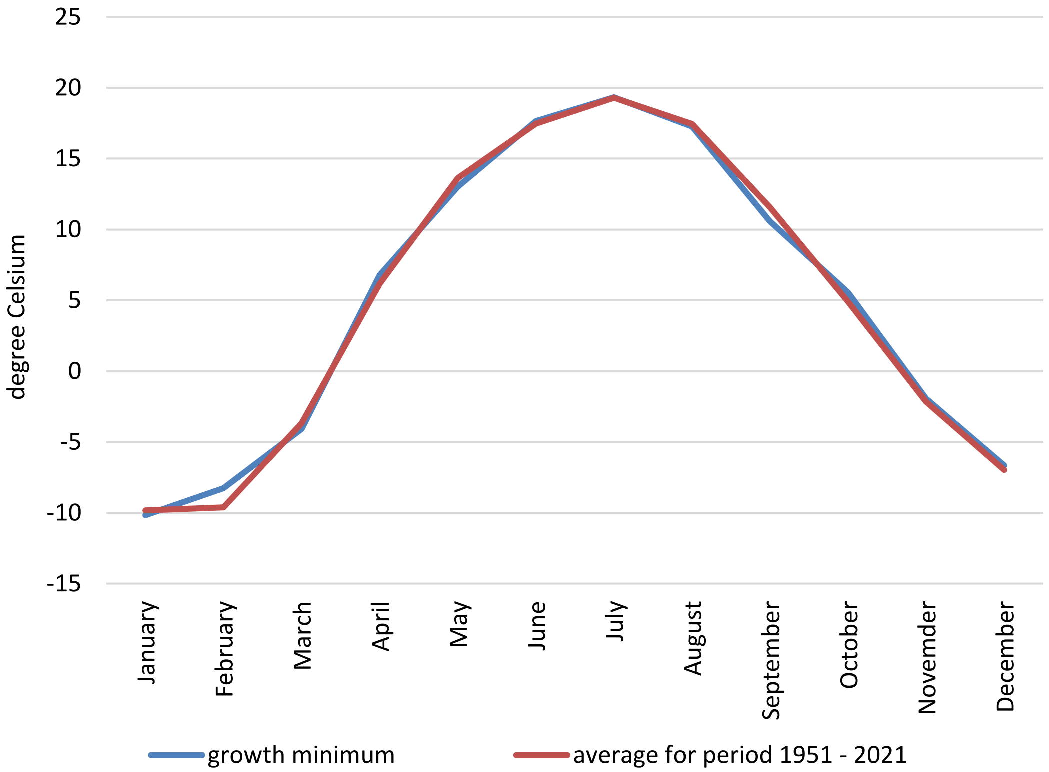

Fig. 4 – The average means of average month air temperatures for yeasr of the radial growth index minimums and for period 1960 -2021 years

The analysis showed a clear difference in meanth of precipitation of May and June for yeasr of the radial growth index minimums and for period 1960 -2021 years. This means that this kind of combination in the temporal distribution of precipitation negatively affects the physiological state of aspen trees. Abundant moisture in May can stimulate the growth of thin roots as well as the formation of a large crown biomass, which requires the receipt of large volumes of water and minerals. With such initial parameters, the sudden onset of drought in June leads to a sharp deterioration in the aspen tree heals. So, not only meanth of meteoparameters, but combination of this meanth too can affect to tree rings weeds, wchich is rarely taken into account in dendroclimatic studies and cannot be established by correlation analysis.

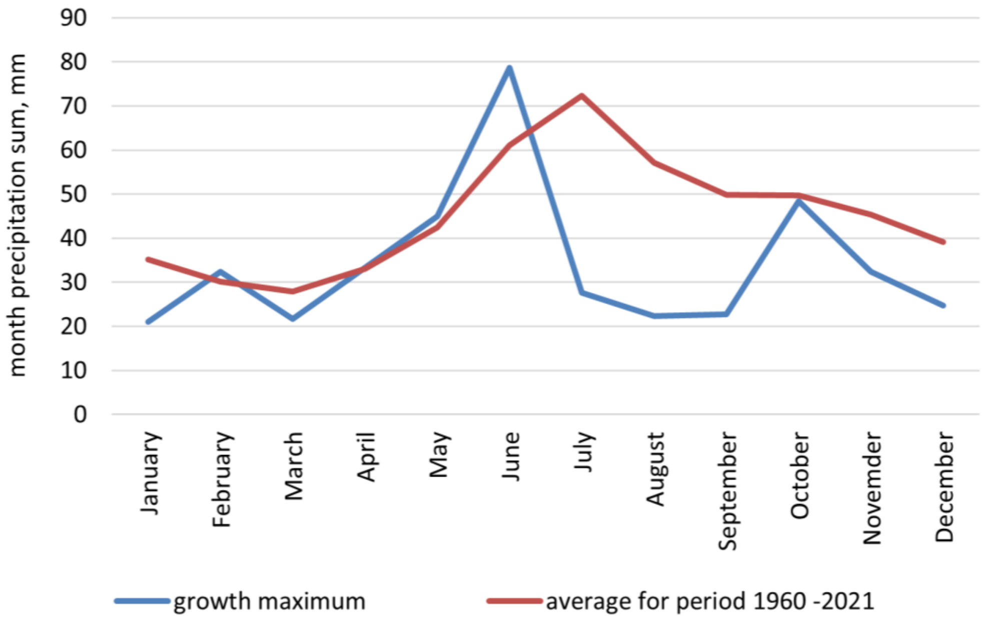

Fig. 5 – The average means of month precipitation sum for yeasr of the radial growth index maximums and for period 1960 - 2021 years

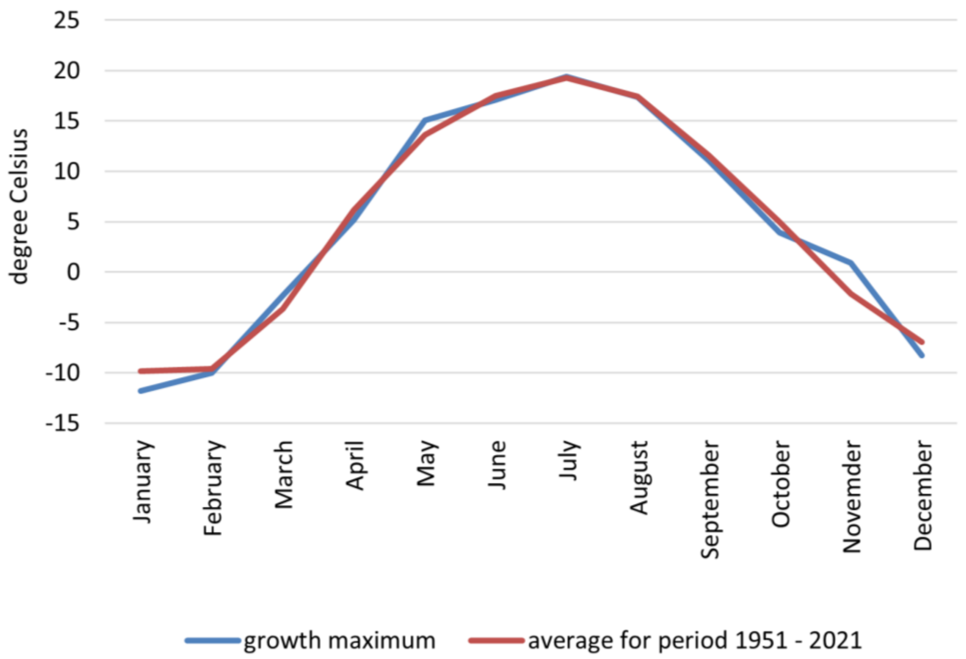

Fig. 6 – The average means of month average air temperature for yeasr of the radial growth index maximums and for period 1960 -2021 years

Analysis of the climatogram by temperature shows that in the years of minimum growth monthly values coincide with the average monthly parameters. This indicates that there is no influence of this parameter on the radial growth in these environmental conditions and coincides with the results of the correlation analysis.

5. Conclusion

According to the results of the research were obtained the following the most important conclusions:

1. The most favorable conditions for the growth of aspen, for the formation by stand the high growth of wood took place in 1942, 1977, 1996, 2004. These years characterized by above average meanths for June precipitation sum and below average meanths for July and August precipitation sum. The meanth for average month air temperatures are close to the average long-term parameters.
2. The high air temperatures in summer of the year preceding the year of tree ring forming has the strong negative impact on the formation of wood in the studied forest stand. Probably it relates with effect of shoot buds' formation and photosintetic product accumulation, wchich determines the biomass of the assimilation surface in the year of the formation of the annual ring.
3. There is a certain periodicity with a period of 11 years for the formation of abnormally narrow rings in aspen trees. But abnormally narrow rings may form non periodically too. This is probably due to the effects of phyllophagous insects.

Conflict of Interest

None declared.

Конфликт интересов

Не указан.

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