Folia Forestalia Polonica, Series A – Forestry, 2022, Vol. 64 (1), 7–14

ORIGINAL ARTICLE

DOI: 10.2478/ffp-2022-0002

Effect of meteorological factors on the radial growth of pine latewood in northern taiga

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Abstract

The purpose of this study is to evaluate the influence of day and night meteorological parameters (air temperatures and dew points, relative humidity, wind speed and precipitation) on the radial growth of pine latewood in northern taiga, in typical conditions of its growth. The study was conducted in the north of the Arkhangelsk region (Russia). A total of 63 cores were selected from seven most representative sites. Meteorological parameters were obtained from the WMR 918 H digital weather station (Huger GmbH, Germany), located directly on the study area and operating in monitoring mode. The analysis used meteorological data for the period 2008–2015. Correlation with night and day air temperature in June and July (0.72–0.77) was revealed in blueberry type. In all the stands studied, a reliable correlation with wind speed was established, direct (0.77–0.88) and inverse (−0.7 to −0.99), but each sample plot had an individual dependence. A reliable correlation with the humidity of August and September (0.64–0.87) and an inverse correlation with precipitation in May and August (−0.63 to −0.75) were established. In general, pine in blueberry, cowberry and pine on swamp types have a similar reaction to the variability of meteorological factors, the most important of which is the temperature regime of air and wind speed.

Key words

latewood, pine, meteorological factors, air temperature, wind speed

Introduction

Latewood (LW) directly determines the physical and mechanical properties of wood. On average, the density of LW is two times higher than earlywood (Jeong et al. 2009; Umit 2012; Kilpeläinen et al. 2003; Pritzkow et al.2014; Peltola et al. 2009). The correlation coefficient of the density and the LW content reaches 0.7–0.75 in the European part of Russia (Polubojarinov 1976) and 0.92 in Central Siberia (Soultson 2018). The above data indicate that the LW content is an important characteristic of wood quality. The formation of LW depends on the weather of the current growing season (Deslauriers et al. 2003; Huang 2011; Zhai et al. 2012). The main limiting factor of radial pine growth for the territory of the European North of Russia is the temperature in June (Feklistov et al. 1997). However, the question of the influence of meteorological factors on the radial growth of LW in this region has not been touched at all.

The aim of the work is to evaluate the role of meteorological factors in the radial growth of LW in north-

Received 23 October 2021 / Accepted 31 January 2022

ern taiga of the European part of Russia (Arkhangelsk region).

Material and methods

The study area is situated in the northern taiga subzone in the Pinezhsky district of the Arkhangelsk region near the southwestern border of the village Pinega (GPS 64°41′07.76″ N, 43°22′09.25″ E). The subject of our research is the common pine (*Pinus sylvestris* L.). In total, seven sample plots (SPs) were laid in 2016 in typical forest types (blueberry, cowberry, on swamp). To determine the radial growth, core samples were taken using an age drill (Haglof, Sweden) at a height of 1.3 m from the root neck in the south–north direction. In total, 9–10 cores were selected at each SP. The LW content was calculated using LINTAB 6 (Rinntech, Germany) with an accuracy of 0.01 mm and the software TSAP-Win (version 4.80, 2012) (Rinn 2003). The taxational characteristics of the studied stands are presented in Table 1.

Table 1. Key characteristics: average values of the sampled stands

Sample plot	Forest type	Stand composition	Mean		Age [years]	Norm
			height [m]	diametr at breast height [cm]		
1	Blueberry pine forest	6P3F1B	18	22	65	0.8
2		10P	12	18	70	0.7
3		9P1B	12	14.2	50	0.8
4		6C4E	18.5	19.7	75	0.7
5		6P4F + B	16	18	80	0.7
6	Cowberry pine forest	9C1F	16	18	60	0.7
7	Pine on swamp	10P	4.5	4.6	62	

P – pine tree, F – fir tree, B – beech tree.

The availability of digital mobile weather stations has allowed not only to increase the number of analysed parameters and reduce the discreteness of measurements, but also to bring the stations as close as possible to the SP. Air temperature (t_{air}), dew point temperature (t_{dp}), relative humidity (H), precipitation (P) and wind speed (WS) were recorded automatically using the WMR 918H digital mobile weather station (Huger GmbH, Germany) from 2007 to 2016 at an altitude of 2 m. The weather station is located in close proximity to the SP. The technical characteristics of the weather stations are presented in Table 2.

Table 2. Specifications of the weather station WMR 918H

Parameter	Measuring range	Resolution
Temperature	−50 to 70°C	0.1°C
Relative air humidity	2–98%	1%
Wind speed	0–56 m/s	0.2 m/s
Annual precipitation	0–999 mm/h	1 mm/h

Discreteness of measurements: temperature – 30 s; pressure – 15 min.

The measurement interval for all sensors was 10 min. The average values of meteorological parameters for May–September are shown in Figure 1.

Due to the fact that at the beginning of the growing season, the night lasts no more than 2 h and by September, it increases to 12 h, for the calculation, we used the duration of the night from sunset to sunrise, calculated for each day.

Pearson correlations (The Python software version 2.7.12, 2016, package SciPy version 0.18.1, 2016) were used to test the effect of meteorological parameters (air temperature and dew point, relative air humidity, wind speed, precipitation) on the radial growth of pine. Significant differences between means were tested ($P < 0.05$).

Results

According to the meteorological parameters, 2010 was not an abnormal year. It differed from the others only by the high air temperature in July, the low dew point temperature in August and the low relative humidity in July (Fig. 1). The dynamics of the radial growth of LW on the studied SPs were similar. The peak of growth was in 2009–2010 and then came the recession. The variation in the growth of LW in pine on swamp was minimal and no significant trends were observed (Fig. 2).

A significant correlation with the July air temperature was found in the blueberry pine in SP3, both with

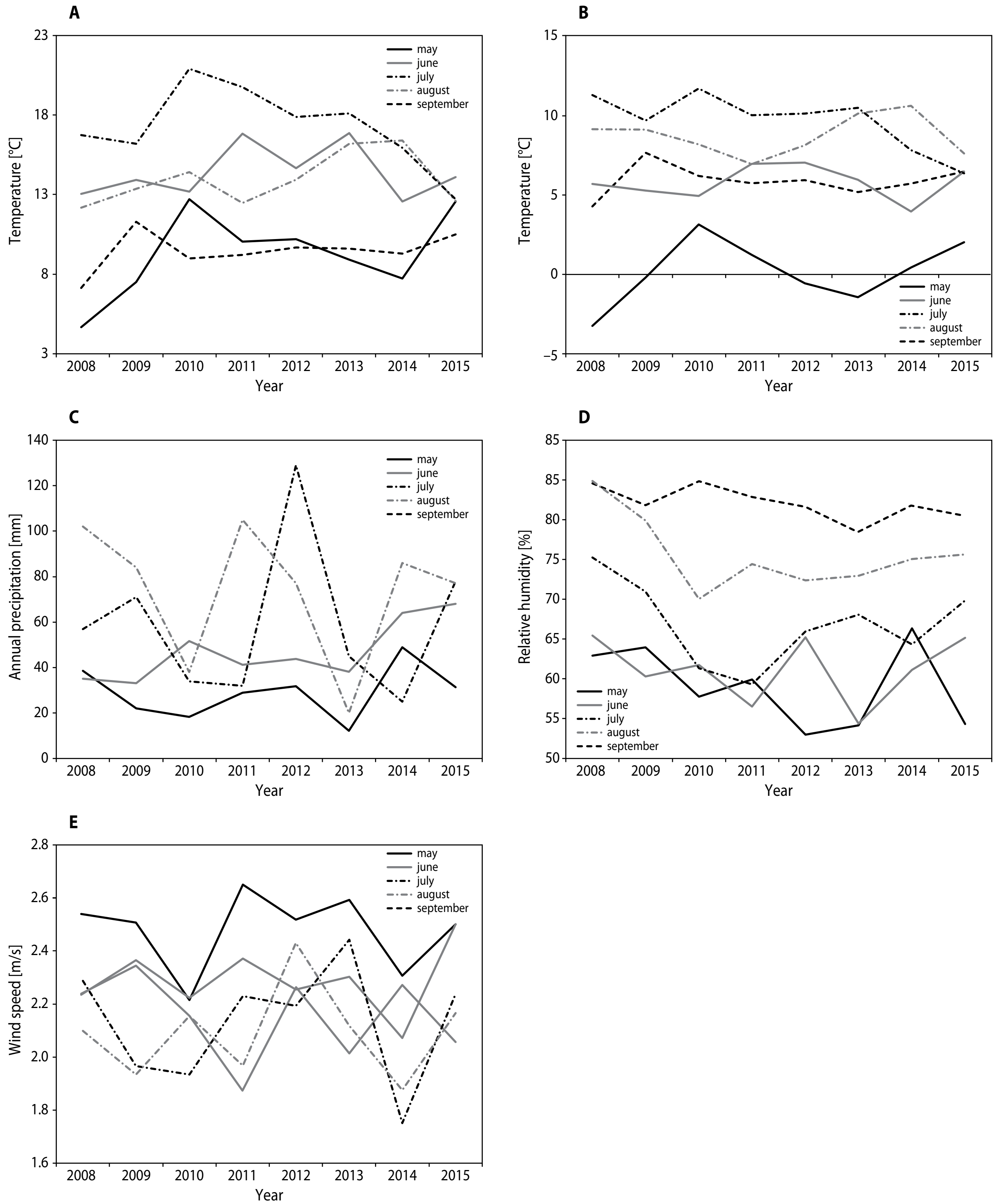

Figure 1. Dynamics of monthly average values of meteorological parameters during May–September in 2008–2015: A – temperature, B – dew point temperature, C – annual precipitation, D – relative air humidity, E – wind speed

Table 3. Pearson correlation coefficient of latewood width and meteorological parameters

		Blueberry pine forest (SP1)					Blueberry pine forest (SP2)					Blueberry pine forest (SP3)				
		May	June	July	Aug.	Sept.	May	June	July	Aug.	Sept.	May	June	July	Aug.	Sept.
t_{air}																
Daily	mean	0.15	0.13	−0.32	0.40	0.14	0.31	−0.12	0.67	0.15	0.21	0.31	0.16	**0.77**	0.13	0.13
Day	max.	0.00	−0.25	−0.27	0.43	0.11	0.30	−0.02	0.67	0.24	0.10	0.24	0.09	**0.72**	0.17	−0.02
	min.	0.02	−0.24	−0.13	0.38	0.11	0.30	−0.02	0.68	0.20	0.06	0.25	0.11	**0.77**	0.16	0.00
Night	max.	0.03	0.30	−0.45	0.17	−0.01	0.48	−0.15	0.62	−0.02	0.44	0.42	0.01	**0.76**	0.01	0.21
	min.	0.05	0.08	−0.46	0.17	0.17	0.48	−0.10	0.62	−0.03	0.28	0.42	0.01	**0.77**	0.00	0.26
t_{dp}																
Daily	mean	0.22	−0.07	−0.57	−0.26	−0.05	0.44	−0.23	−0.14	−0.36	0.49	0.30	−0.04	−0.03	−0.3.1	0.32
Day	max.	0.23	0.20	0.69	0.09	−0.14	0.44	−0.28	0.53	−0.10	0.43	0.30	−0.11	−0.66	−0.13	0.23
	min.	0.19	−0.03	0.60	−0.31	−0.11	0.47	−0.21	0.10	−0.31	0.49	0.30	0.03	0.03	−0.27	0.32
Night	max.	0.21	0.13	0.62	0.21	0.03	0.47	−0.25	0.62	−0.21	0.45	0.36	−0.11	**0.76**	−0.19	0.23
	min.	0.22	0.20	0.65	−0.27	−0.02	0.46	−0.18	0.06	−0.40	0.58	0.33	−0.04	0.20	0.34	−0.42
H																
Daily	mean	0.02	−0.04	−0.18	−0.41	−0.48	0.07	−0.28	−0.68	−0.54	0.32	−0.17	−0.41	−0.60	−0.55	0.21
Day	mean	0.06	−0.01	−0.08	−0.18	−0.36	0.07	−0.24	−0.63	−0.39	0.44	−0.13	−0.40	−0.55	−0.39	0.32
Night	mean	0.13	−0.14	0.21	0.56	0.03	−0.03	−0.22	−0.56	−0.59	−0.24	−0.20	−0.25	−0.54	**−0.70**	−0.08
WS																
Daily	mean	0.42	0.24	0.25	0.15	0.19	0.44	0.25	−0.34	−0.05	0.04	−0.23	−0.12	−0.08	−0.04	−0.14
	max.	0.47	0.36	0.60	0.26	0.38	−0.09	0.39	0.08	0.27	0.38	0.02	0.36	0.00	0.32	0.18
	min.	**0.86**	**0.88**	**0.80**	0.20	**0.80**	−0.65	−0.47	−0.69	**−0.80**	−0.59	−0.01	−0.44	−0.60	**−0.70**	−0.51
Day	max.	0.24	0.44	0.58	0.15	−0.63	−0.45	−0.21	−0.70	−0.10	0.41	−0.36	−0.29	−0.52	0.01	0.32
	min.	−0.16	−0.04	−0.57	−0.36	−0.20	−0.51	−0.51	0.23	−0.31	−0.36	−0.35	−0.35	0.38	−0.16	0.50
Night	max.	−0.27	−0.28	−0.04	−0.27	−0.53	−0.23	0.18	−0.68	−0.14	0.25	−0.11	0.09	−0.48	−0.02	0.09
	min.	−0.45	0.30	−0.25	−0.43	−0.02	−0.17	−0.28	−0.64	−0.39	−0.37	0.02	0.05	−0.39	−0.29	−0.43
P	mean	0.54	0.65	−0.19	0.17		−0.52	−0.23	−0.11	−0.39		**−0.75**	−0.42	−0.11	−0.54	–

Significant correlation coefficients levels ($P < 0.05$) are in bold.

Blueberry pine forest (SP4)					Blueberry pine forest (SP5)					Cowberry pine forest (SP6)					Pine on swamp (SP7)				
May	June	July	Aug.	Sept.	May	June	July	Aug.	Sept.	May	June	July	Aug.	Sept.	May	June	July	Aug.	Sept.
t_{air}																			
0.27	0.30	−0.04	0.63	0.26	−0.29	−0.36	0.06	−0.66	−0.54	−0.54	−0.42	−0.34	−0.55	0.07	0.49	0.24	−0.34	−0.62	0.27
0.14	0.03	0.60	0.26	0.14	−0.31	0.38	0.11	−0.64	−0.17	−0.32	0.07	−0.35	−0.57	0.18	0.47	0.20	−0.36	−0.54	0.34
0.27	0.03	0.65	0.23	0.13	−0.32	0.40	0.07	0.64	−0.25	−0.34	0.05	−0.36	−0.56	0.11	0.45	0.27	−0.35	−0.54	0.34
0.42	−0.13	0.60	0.00	0.42	−0.33	**0.82**	0.20	0.57	0.13	−0.46	−0.47	−0.15	−0.22	0.28	0.35	0.12	0.28	−0.61	0.07
0.42	−0.08	0.61	−0.07	0.45	−0.32	**−0.70**	−0.16	0.56	0.00	−0.46	−0.21	−0.17	−0.21	0.25	0.35	0.16	−0.27	−0.61	0.07
t_{dp}																			
0.42	−0.27	−0.15	−0.33	0.51	0.02	0.15	0.51	0.26	0.50	−0.43	−0.08	0.49	0.44	0.21	0.20	0.66	−0.07	−0.33	0.21
0.40	−0.34	0.9	−0.03	0.44	0.01	−0.50	0.35	−0.17	0.36	−0.43	0.08	0.12	0.12	0.41	0.22	**0.73**	−0.23	−0.67	0.25
0.43	−0.26	−0.11	−0.28	0.52	0.05	−0.17	0.52	0.29	0.27	−0.37	−0.12	0.48	0.46	0.28	0.12	0.62	−0.07	−0.29	0.25
0.46	−0.31	0.59	−0.15	0.42	−0.08	−0.49	0.29	−0.38	0.10	−0.50	−0.29	0.01	−0.03	0.21	0.22	0.64	−0.23	−0.67	0.11
0.44	−0.23	0.04	−0.39	0.58	−0.04	−0.36	0.49	0.29	−0.02	−0.47	−0.37	0.40	0.45	0.07	0.21	0.57	−0.13	−0.27	0.08
H																			
0.05	−0.44	−0.53	0.48	0.21	0.51	0.05	−0.44	0.55	**0.64**	0.42	0.16	0.49	**0.77**	0.21	−0.64	0.24	0.31	0.04	−0.19
0.09	−0.39	−0.57	0.34	0.37	0.49	0.10	0.07	0.64	**0.74**	0.45	0.22	0.56	**0.87**	0.34	−0.68	0.14	0.34	0.11	0.22
0.06	−0.35	−0.56	−0.52	−0.35	0.52	0.12	−0.48	0.14	0.08	0.30	0.05	0.18	0.11	0.47	−0.42	0.53	0.20	−0.26	0.16
WS																			
−0.41	−0.23	−0.33	−0.18	−0.10	−0.52	−0.30	−0.60	−0.63	−0.37	−0.47	−0.44	−0.63	−0.59	−0.3	0.33	**0.77**	0.46	0.31	0.42
−0.15	0.30	−0.13	0.15	0.22	**−0.72**	−0.67	**−0.77**	**−0.70**	−0.37	−0.63	**−0.84**	**−0.99**	**−0.78**	−0.49	−0.42	−0.30	−0.06	−0.13	−0.64
−0.64	−0.47	**−0.70**	**−0.85**	−0.62	**−0.72**	**−0.78**	−0.87	−0.15	**−0.89**	−0.51	**−0.71**	0.06	0.00	**−0.75**	−0.10	−0.03	0.03	0.01	0.02
−0.47	−0.12	−0.66	−0.22	0.40	−0.25	−0.38	**−0.70**	−0.59	0.35	0.03	−0.11	−0.44	−0.17	**0.80**	0.41	0.29	0.20	0.33	0.27
−0.43	−0.45	0.29	−0.29	−0.40	0.30	0.66	0.34	0.06	0.39	0.32	0.14	0.03	0.37	**0.79**	**0.79**	**0.87**	0.68	**0.88**	0.00
−0.19	0.23	0.55	−0.24	0.20	0.28	0.00	0.00	−0.32	0.48	0.46	0.39	0.35	−0.01	**0.80**	−0.37	−0.14	0.29	0.03	−0.02
−0.08	−0.21	0.56	−0.40	−0.48	0.49	0.21	0.17	0.44	0.05	0.55	0.33	0.31	0.50	0.26	0.29	0.51	0.46	0.04	−0.41
−0.63	−0.28	−0.22	−0.46		−0.03	−0.36	−0.20	0.43		0.56	−0.06	0.20	**−0.71**		0.41	0.08	0.42	−0.08	

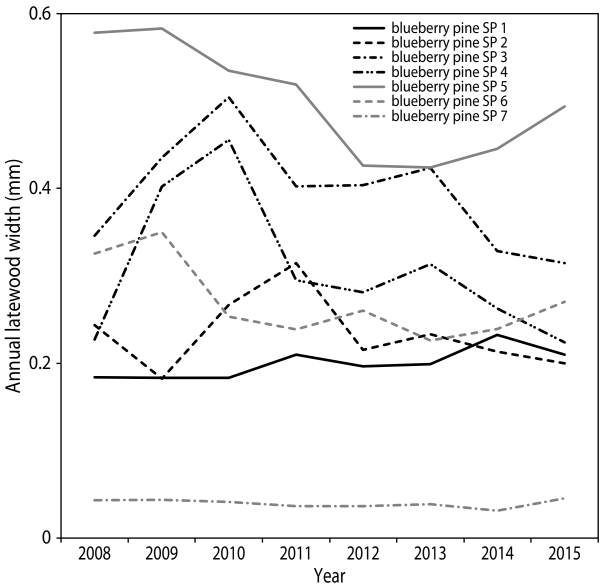

Figure 2. Dynamics of radial growth LW of pine forest for 2008–2015

daytime and nighttime values (0.72–0.77) and in SP5 with night values in June.

Direct (0.77–0.88) and inverse (−0.7 to −0.99) correlation with the minimum and maximum daily values of wind speed was found on all SPs. Moreover, it correlated with the wind speed for the entire growing season in SP5, but the reaction was different in the same type of SP.

A reliable correlation with the humidity of August and September was established in SP 3, 5, 6 (0.64–0.87). Also, at SP 3, 4, 5, an inverse correlation was established with precipitation in May and August (−0.63 to −0.75) (Tab. 3).

Discussion

The wind has a diverse effect on the growth of a tree. Low wind speeds have a positive effect on photosynthesis by reducing the leaf surface temperature, increasing transpiration (Ennos 1997; Grace 1998; Smith and Jarvis 1998) and increasing the gas exchange of CO_2 and O_2, which accelerates enzymatic reactions (Kimmins 1987; Zhu et al. 2000). Stands on SP 1–5 grow in the same type of forest, but blueberries (*Vaccinium myrtillus* L.) grow in broad edaphic conditions, which affects the growth dynamics of pine (Forests of the USSR 1966). The positive and negative correlations of wind speed in the blueberry type are probably caused by the different completeness and composition of stands. From a pine forest in a swamp, the wind has a positive effect on the growth of LW due to increased transpiration.

In general, the radial growth of pine LW in blueberry and cowberry and on swamp forest types have a similar reaction to the variability of meteorological factors, the most important of which is wind speed and air temperature (June–July). Only in pine on swamp, a correlation with relative humidity was also found and there was no correlation with precipitation.

There is an opinion that the proportion of LW is a genotypically determined trait and is not subject to change under the influence of external factors (Shchekalyov et al. 2005; Kosichenko et al. 2011). But most studies refute this opinion and indicate a significant contribution of weather conditions to the growth of LW. So, in Finland, last year's precipitation and the air temperature of July and August of this year are the limiting factors for the growth of LW (Mikola 1950; Leikola 1969; Saikku 1975; Kellomäki 1979; Miina 2000). In Central Siberia, the hydrothermal regime of August–September directly affects the morphometric parameters of the tracheids of LW (Antonova and Stasova 2015).

In the European part of Russia, zonality plays a greater influence on the growth of LW than the local growing conditions (Kiseleva and Sakharova 2014). In the conditions of the forest steppe, the variability of the LW content is insignificant in favourable forest-growing conditions (Kiseleva and Platonova 2016).

In the west of France, LW is more changeable due to weather than early wood. An inverse correlation with July temperature and a direct correlation with precipitation were found for this territory (Lebourgeois 2000). Similar dependencies were obtained for the Crimean peninsula (Koval 2013) and Portugal (Campelo 2007).

In the forests of the Belarusian Poozerie, the lack of precipitation and the high air temperature in July have a negative effect on the growth of late pine wood. The high variability of the width of the LW, compared with the early one, was noted, which is probably due to less favourable weather conditions for its formation (Bolbotunov and Degtjareva 2020).

Conclusion

The radial growth of pine LW in the conditions of the European North of Russia is variable and is largely determined by the weather conditions of the current growing season. Limiting factors of LW growth are air temperature and wind speed.

Acknowledgements

This study was supported by the state assignment no. 122011300380-5 for N.P. Laverov Federal Center for Integrated Arctic Research, Ural Branch, Russian Academy of Sciences.

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