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EFFECT OF THE THERMAL REGIME ON RADIAL GROWTH OF TREES IN THEIR DIFFERENT HABITAT CONDITIONS

L. G. Polozova and S. G. Shiyatov

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The article presents the results of a quantitative analysis of the relations between the indices of the width of the annual rings of larch and spruce growing near the northern timber line in different types of habitat conditions and certain indices of the thermal regime of the vegetative period (sum of active temperatures, mean July temperature, etc.). It is shown that to obtain the most reliable dendroclimatologic series with respect to larch the model trees should be taken from dry habitats and with respect to spruce from copiously and running wet habitats.

The relation between the variation of climatic elements and amount of annual growth of trees growing at the northern timber line has been studied by many, especially Scandinavian, authors (Erlandsson, 1936; Eidem, 1942-43; Giddings, 1943; Hustich, 1945; Schove, 1950; Mikola, 1962). They unanimously note that under conditions of the Far North the increment of wood depends mainly on the thermal regime of the vegetative period of the current year and to some extent the previous year. A positive correlation is found between the indices of the annual increase of wood and average air temperature of all summer months, but the highest relation between them is observed in July (the correlation coefficient reaches +0.7-0.8). A sufficiently high correlation is obtained also with such indices as the average maximum air temperature and sum of active temperatures. As a rule the correlation increases with a decrease of the distance between the region of collecting the wood samples and the meteorological station. The use of generalized dendroclimatologic series and disregard of secular trends also increases the correlation between the investigated quantities (Erlandsson, 1936; Schove, 1950).

Having a general idea about the character of the effect of individual climatic elements on the annual growth of trees, we still know little about how various tree species react to a change of the climatic situation and in what types of habitat conditions the limiting effect of climatic factors is manifested maximally. Such information is needed for obtaining more reliable dendroclimatologic series.

This article presents the results of an analysis of the relations between the indices of the width of the annual rings of the Siberian larch (Larix sibirica) and Siberian spruce (Picea obovata) growing near the northern timber line and certain indices of the thermal regime of the vegetative period. For the analysis we used six dendroclimatologic series obtained on the basis of studying the annual rings of presently living old trees in the lower course of the Taza River (polar region of Western Siberia) and 7-10 km north of the village Sidorovsk. The region of taking samples of the wood is located within the southern part of the forest-tundra zone. Model trees were taken in three types of habitat conditions: dry, fresh, and copiously and running wet (Table 1).

The copiously and running wet habitats were confined to river floodplains and stream banks. They are characterized by rich alluvial soils, low permafrost level, brief inundation by flood waters, and copious and running-water wetting of the ground during the greater part of the vegetative period. A forbs rediny* of spruce, larch, and birch grows on such habitats.

*Translator's note: A rediny is a plant formation of the northern forest-tundra characterized by singly scattered stunted trees against the tundra background.

A. I. Voeikov Main Geophysical Observatory. Institute of Plant and Animal Ecology, Ural Scientific Center, Academy of Sciences of the USSR. Translated from Ékologiya, No. 6, pp. 30-35, November-December, 1975. Original article submitted March 10, 1975.

TABLE 1. Brief Characteristics of the Dendroclimatologic Series

Type of habitat conditions	Larch			Spruce		
	no. of series	duration, years	no. of models used units	no. of series	duration, years	no. of models used, units
Copiously and running wet	1	1633—1969	29	4	1671—1969	21
Fresh	2	1624—1969	22	5	1675—1969	15
Dry	3	1681—1969	22	6	1604—1969	22

The fresh habitats are located in the middle and lower parts of sloping elevations, and also in shallow sinkholes. The soils are comparatively rich, of the podzolic type. The plants do not experience a soil moisture deficit. Green moss—larch—spruce open woodlands grow on the fresh habitats.

The dry habitats are found only in the upper parts of hills, primarily on southern slopes. The soils are poor, weakly developed, their wetting occurs only due to precipitation. In dry periods the plants experience a lack of soil moisture. Lichen—larch and spruce—larch open woodlands grow here.

According to the scheme of the climatic regionalization of the USSR (Alisov, 1969), the region of investigations is located in the continental area of the subarctic belt, near its southwestern boundary. There are no meteorological stations with long observation series within this area. The nearest station, Sidorovsk, located 7-10 km from the place of collecting the wood samples, has an observation series only since 1949.

The Turukhansk station, located in the northeastern part of the continental West Siberian area of the temperature belt, has a long observation series (since 1881). Since the Sidorovsk and Turukhansk stations are located near the boundary dividing the climatic regions indicated above, there should be no significant differences between them in climatic characteristics, especially in their fluctuations from year to year. For example, during 20 years (from 1949 to 1969) an asynchronous source of the change of the mean July temperature at these stations was observed only twice (in 1958 and 1960), despite the fact that they are about 300 km apart.

In establishing the dendroclimatologic relations we used mainly the long series of the Turukhansk station, as a result of which it was possible to obtain a more reliable correlation. The coefficients of correlation between the mean July temperature and the generalized indices of larch and spruce growth proved to be equal respectively to $+0.56 \pm 0.07$ and $+0.58 \pm 0.07$ for Turukhansk and to $+0.52 \pm 0.18$ and $+0.51 \pm 0.18$ for Sidorovsk. Despite the considerably greater distance of Turukhansk from the region of collecting the wood samples, the correlation coefficients in the first case were higher and the root-mean-square error half as much.

The coefficients of synchronism and correlation were used for estimating the measure of the relation between the dendroclimatologic and climatic series. The coefficient of synchronism shows what percent of the segments of the compared curves have the same trend (Liese, 1970). The correlation coefficient characterizes the closeness of the linear relation between two statistical quantities. In calculating the correlation coefficient the secular trends were not eliminated from the investigated series, although this operation also increases the indices of the relation (Erlandsson, 1936). For the analysis we used such characteristics of the thermal regime as the sum of active temperatures of the vegetative period, mean July temperature, sum of the mean daily and maximum temperatures of different gradations and their duration, and sum of the average decade (10 day) temperatures during the period from June 20 to August 10.

Before proceeding to an analysis of the relations between the climatic factors and tree growth, we will examine the degree of synchronism and similarity between the dendroclimatologic series of larch and spruce of the three types of habitats (Table 2).

As we see from Table 2, there is a high degree of synchronism and correlation between the dendroclimatologic series obtained for the different tree species and different types of habitat conditions. The highest indices are obtained on comparing series for one tree species. In addition, the series for larch of different habitats are similar to one another to a greater degree than those of spruce.

Of the aforementioned characteristics of the thermal regime, the mean July temperature and sum of average decade temperature for the period from June 20 to August 10 gave the highest synchronism and correlation with the growth indices (Table 3). For the generalized series of larch and spruce (all types of

TABLE 2. Indices of the Synchronism and Correlation between the Investigated Dendroclimatologic Series (see the No. of the series in Table 1)

No. of series	1	2	3	4	5
			Coefficient of synchronism (1800-1969), %		
2	85	—	—	—	—
3	86	88	—	—	—
4	73	72	74	—	—
5	73	70	71	79	—
6	75	72	76	81	82
			Coefficient of correlation (1882-1969)		
2	+0,87±0,03	—	—	—	—
3	+0,88±0,03	+0,87±0,03	—	—	—
4	+0,63±0,07	+0,60±0,07	+0,72±0,06	—	—
5	+0,42±0,09	+0,61±0,07	+0,53±0,08	+0,70±0,06	—
6	+0,65±0,06	+0,69±0,06	+0,76±0,05	+0,82±0,04	+0,80±0,04

habitats) the relation of the growth indices with the July temperature is about the same (coefficient of synchronism 74 and 75%, correlation coefficient 0.56 and 0.58). But if we analyze how the indices of the relation change in different types of habitats, then we find a considerable difference. Larch shows the highest synchronism (75%) and correlation (0.60) on dry habitats, whereas spruce on copiously and running wet habitats (80% and 0.61). The lowest dependence of tree growth on the mean July temperature was obtained for fresh habitats (both for larch and spruce).

Approximately the same regularities are observed for the sum of mean daily and decade temperatures. In the majority of cases the maximum values of the correlation coefficient are obtained for larch from the dry habitats and for spruce from the copiously and running wet habitats (Table 3). However, the change of the coefficient of synchronism does not obey this rule. The highest synchronism of the growth indices with the sum of the mean decade temperature between June 20 and August 10 is observed for the generalized larch and spruce series.

The dissimilar climatic significance of the series in different types of habitat conditions can be explained by comparing the ecological and biological characteristics of the investigated tree species. Spruce is a more moisture-loving species and has a surface root system. Therefore it does not experience a moisture deficit only in copiously and running wet habitats. Larch has a deeper root system and is more drought-resistant, in connection with which it is provided with a sufficient amount of moisture also on dry habitats. Moreover, larch on waterlogged habitats apparently suffers from an excess of moisture. From this follows that when constructing the temperature dendroclimatologic series with respect to the northern timber line it is necessary to take into account both the water supply of the habitats and the ecological and biological characteristics of the trees..

To reconstruct the climatic conditions of the past it is important to establish the relation between tree growth and characteristics of the thermal regime during the longest possible time intervals — the entire summer season, the vegetative period. As the calculation showed (Table 3), the correlation decreases with a decrease of the limit of the active temperature of the vegetative period included in the sum (or the sum of the mean daily temperatures). The interval of the most active temperatures* — from 15 to 20° — is distinctly revealed by the correlation coefficient. Both a decrease (< 10°) and an increase (>20°) of these limits lessens the relation with growth. Here it turns out that the relation with the sum of temperatures above 15° for spruce especially increases, reaching a significant relation (0.64) in copiously and running wet habitats, whereas for larch in dry habitats the relation is moderate (0.48).

The question arises, nevertheless why is the highest correlation obtained with the mean July temperature and not with the sum of temperatures above 15°? Here, apparently, not only the value of the sum of temperatures but also the continuity of the effect of this factor (at its highest level) on plant growth plays a role. Under continental conditions July is the main month of the vegetative period, when long periods with an average daily temperature above 15° are most probable.

*Similar results were obtained by Erlandsson (1936) in an investigation of the relation between growth and number of days with a certain maximum temperature in Scandinavia.

TABLE 3. Coefficients of Synchronism and Correlation between Tree Growth Indices and Characteristics of the Thermal Regime for the Turukhansk Station

Characteristics of thermal regime	Larch				Spruce			
	type of habitat conditions							
	dry	fresh	copiously and running wet	all types	dry	fresh	ccpiously and running wet	all types
	Coefficient of synchronism, %							
Average July temperature during 1881-1969	75	72	69	74	74	72	80	75
Sum of average decade temperatures between June 20 and August 10 during 1921-1969	73	73	77	79	77	81	77	83
	Coefficient of correlation (r ± e)							
Average July temperature during 1881-1969	+0,60±0,07	+0,49±0,08	+0,53±0,08	+0,56±0,07	+0,52±0,08	+0,40±0,09	+0,61±0,07	+0,58±0,07
Sum of average decade temperatures between June 20 and August 10 during 1921-1969	+0,52±0,10	+0,41±0,12	+0,49±0,11	+0,48±0,11	+0,48±0,11	+0,36±0,12	+0,66±0,07	+0,56±0,10
Sum of mean daily temperatures during 1921-1969:								
above 5°	+0,22±0,14	+0,20±0,14	+0,27±0,13	+0,25±0,13	+0,18±0,14	+0,20±0,14	+0,32±0,13	+0,26±0,13
above 10°	+0,39±0,12	+0,31±0,13	+0,42±0,12	+0,32±0,13	+0,31±0,13	+0,22±0,14	+0,42±0,12	+0,41±0,12
above 15°	+0,48±0,11	+0,40±0,12	+0,43±0,12	+0,40±0,12	+0,43±0,12	+0,37±0,12	+0,64±0,08	+0,53±0,10
above 20°	+0,33±0,13	+0,32±0,13	+0,34±0,13	+0,33±0,13	+0,34±0,13	+0,31±0,13	+0,42±0,12	+0,41±0,12

In conclusion, we need stress that the generalized series, i.e., the series obtained by combining the models from all types of habitats, show rather high values of the coefficient of correlation with the July temperature (from +0.56 to +0.58). This indicates that in the forest-tundra zone model trees in different types of habitat conditions can be taken for constructing rather reliable dendroclimatologic series.

A comparison of the correlation coefficients obtained by us and other investigators shows that our coefficients do not reach the values given for other regions. This can apparently be explained by different climatic conditions, the considerable distance of the meteorological station from the region of collecting the wood samples, and by the circumstance that the secular trend in the investigated series was not eliminated.

Thus, in the region of the Taza forest-tundra the dendroclimatologic series for spruce and larch reflect fluctuations of the thermal regime of the warmest month (July) and almost to the same extent the warmest period in the given region (from the third decade of July to the first decade of August). To obtain the most reliable temperature series for larch the model trees should be taken from dry habitats and for spruce from copiously and running wet habitats.

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