Sensitivity of Diameter Growth to Annual Weather Conditions in Scots Pine Provenances at a Central Siberian Location

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Summary

Eight tree-ring characteristics (tree ring width, latewood and earlywood widths and densities, maximum and minimum densities and latewood percentage) were measured densitometrically in 16 Scots pine provenances in the southern taiga, Central Siberia. Age trends were excluded by standardization. It was found that the sensitivity coefficient of latewood width, latewood and maximum densities and latewood percentage has a tendency to decrease in relation to the increasing latitude of seed sources. Northern provenances utilise only the energy resources (heat and light) during the first half of the growing season effectively. The correlation of tree ring series between the local provenance and the other provenances decreases in relation to the increasing latitude difference between seed origins. As a whole, the values of the normalized Euclidean distance, correlation and synchronicity coefficients between the local provenance and the other provenances prove that, for most of the provenances, the interannual variability of the chosen tree ring characteristics reflects the prevailing climate conditions.
influence of weather conditions (even for the populations from the northern taiga and forest-tundra zone). The variability of weather conditions determines up to 85% the variability of radial growth and wood density.

Key words: annual ring, weather sensitivity, climate tolerance, latitudinal transfer, environmental change.

Introduction

Several general models of global climate change predict very rapid warming due to an increase in atmospheric concentrations of CO₂ and other greenhouse gases (BRIFFA et al., 1998; PLANCHON et al., 1998) and it is believed that the effects of global warming could have a substantial impact on tree species distribution (JOYCE et al., 1990; ROBERTS, 1989). However, there are no sure answers to the general question: how will global and regional climate changes affect trees; their growth rates; their survival in natural ecosystems; and their succession processes? (BEUKER, 1994; STETTLER et al., 1994). KAUHY and POSCH (1988) have predicted increases in larch productivity in northern boreal forests in response to climatic warming. Their model assumes that the trees will adapt to the new climate. Estimates of the effects of climate change on tree growth are important because trees, with their long life spans, are least able to respond in a short time by migration or genetic selection (e.g. DAVIS, 1990; DAVIS and ZABINSKI, 1992; NANCE et al., 1993; MATYS, 1994). MATYS (1992) proposed that one effective way to reveal the ability of trees to adapt genetically and to document the response of a tree species to climatic change would be the analysis of provenance trials.

The results of provenance trials have shown that if seed sources are moved slightly northwards, populations out perform local sources. However, if seed sources are moved too far to the north, trees suffer cold damage and may not perform as well as those from the original source. If moved to the south, trees also may not perform as well because of heightened sensitivity to disease (WELLS and WAKLEY, 1966; WRIGHT, 1978). Several authors have also noted that there is a reduction in tree growth, if northern seed sources are moved too far south (IROSHNIKOV, 1977, SHUTAYEV et al., 1990; KUZMINA, 1999).

VAGANOV et al. (1994) have found that tree ring data can supply comprehensive information on weather influences during the growing season. COOK et al. (1990) have proposed that the densitometric method provides an appropriate analytical tool for comparing the response of tree growth to different climatic conditions.

The objective of this study is to evaluate the response to annual weather conditions of Scots pine (Pinus sylvestris L.) through testing sixteen provenances in the southern taiga, Central Siberia using densitometry measurements of tree rings.

Material

In the years 1974 to 1976 throughout the former USSR, a series of provenance trials on Scots pine were established by the state Forestry Committee (SHUTAYEV et al., 1998) with 113 provenances planted on over 33 planting sites. The program was prepared by the late YE.I. PROKASON from the Forest Seed Laboratory of the All-Union Forest Research Institute (VNIIILM), Pushkin, near Moscow. The present paper is based on the study of Scots pine trees from one of the provenance trial, which was included in this program and was established in the Krasnoyarsk region (Boguchany), Central Siberia (58° 23'N, 97° 26'E). The Laboratory of Forest Genetics and Plant Breeding of the Institute of Forests (A.I. IROSHNIKOV, L.I. MILYUTIN, N.A. KUZMINA) raised seedlings in 1974 and a field trial of 3-year-old plants was established in 1977. Details of the establishment and design of the test has been described more recently by N. KUZMINA (1989). A total of 405 increment cores from 16 pine provenances were collected from the Boguchany test site. The area is classified as southern taiga and sub-taiga, zone of pine and larch forests (KOROTKOV, 1994). The Boguchany plantation lies on a large flat area of 9 hectares, on the site of a former open pine forest with dark grey forest soil. The climate is typically continental, with a cold winter (average January temperature is -20°C to -21°C), summer temperatures average +23°C in July. The average annual temperature is between -2.3°C to -3.6°C. More than 50% of the annual precipitation falls in the three summer months, with spring usually being the driest season. Average annual precipitation is about 350 mm to 400 mm. The locations of all the seed sources and their forest types are given in table 1.

Table 1. - Data of the 1974 Scots pine provenance trial. Provenances are listed in order of decreasing latitude of origin.

<table>
<thead>
<tr>
<th>Provenance</th>
<th>Latitude (°N)</th>
<th>Longitude (°E)</th>
<th>Number of trees analysed</th>
<th>Forest type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pechenga</td>
<td>69° 40'</td>
<td>31° 17'</td>
<td>20</td>
<td>Forest-tundra ecotone</td>
</tr>
<tr>
<td>Turekhansk</td>
<td>65° 51'</td>
<td>68° 04'</td>
<td>20</td>
<td>Northern taiga</td>
</tr>
<tr>
<td>Yaboktuk</td>
<td>62° 11'</td>
<td>129° 37'</td>
<td>22</td>
<td>Middle taiga</td>
</tr>
<tr>
<td>Pryazha</td>
<td>61° 45'</td>
<td>33° 40'</td>
<td>19</td>
<td>Middle taiga</td>
</tr>
<tr>
<td>Severe-Ven</td>
<td>60° 27'</td>
<td>93° 04'</td>
<td>21</td>
<td>Middle taiga</td>
</tr>
<tr>
<td>Boroglay</td>
<td>58° 23'</td>
<td>97° 26'</td>
<td>15</td>
<td>Southern taiga</td>
</tr>
<tr>
<td>Revda</td>
<td>56° 47'</td>
<td>58° 54'</td>
<td>20</td>
<td>Southern taiga</td>
</tr>
<tr>
<td>Ayan</td>
<td>56° 26'</td>
<td>138° 13'</td>
<td>22</td>
<td>Northern taiga</td>
</tr>
<tr>
<td>Kurovskoye</td>
<td>55° 35'</td>
<td>38° 55'</td>
<td>23</td>
<td>Pine forests</td>
</tr>
<tr>
<td>Mininorsk</td>
<td>53° 43'</td>
<td>91° 45'</td>
<td>17</td>
<td>Forest-steppe</td>
</tr>
<tr>
<td>Niko'f'k</td>
<td>53° 42'</td>
<td>46° 04'</td>
<td>18</td>
<td>Hardwood-coniferous trees</td>
</tr>
<tr>
<td>Aveyan</td>
<td>53° 35'</td>
<td>57° 32'</td>
<td>20</td>
<td>Northern steppe</td>
</tr>
<tr>
<td>Zaudinskii</td>
<td>51° 45'</td>
<td>108° 50'</td>
<td>19</td>
<td>Forest-steppe</td>
</tr>
<tr>
<td>Svolodyay</td>
<td>51° 28'</td>
<td>128° 04'</td>
<td>21</td>
<td>Light-coniferous taiga</td>
</tr>
<tr>
<td>Belgazyan</td>
<td>50° 58'</td>
<td>95° 10'</td>
<td>22</td>
<td>Steppe</td>
</tr>
<tr>
<td>Kyakhta</td>
<td>50° 28'</td>
<td>106° 30'</td>
<td>20</td>
<td>Forest-steppe</td>
</tr>
</tbody>
</table>

The seed sources are distributed across a wide climatic, range, between approximately 50°N to 70°N and 31°E to 129°E, and distributed along four meridional transects including: European, Urals, East Siberian and Far Eastern transects. For each provenance, 20 to 25 trees were sampled (Table 1). We selected the widest trees in the plots. Cores were taken in two directions at approximately 50 cm above ground to avoid mechanical influences at the stem base. This height above the base represents a loss of about 8 years growth in relation to total tree age. Analysis was carried out on tree rings formed in the age period from 8 to 22 years.

Methods

Cores were analysed densitometrically with a DENDRO-2003 densitometer (SCHWEINRUBER, 1988; ESCHBACH et al., 1995; KIRDIYANOV, 1999). Tree ring width, earlywood width, latewood width (radial growth chronologies), minimum and maximum densities, density of early and latewood (density chronologies) and percentage latewood were measured and crossdated (KIRDIYANOV, 1999; SAVVA et al., in press). Chronologies of all these eight tree ring parameters were obtained for each tree (and for each provenance by averaging the individual
chronologies) showing interannual weather related reactions and age trends. In studies of ring-width variability associated with climate, it is usually most convenient to estimate the systematic changes in ring width associated with age and to remove them from the measurement (Fritts, 1987). The indices generally have no linear trend; (their mean value is one); and the large variability in ring-width of a provenance would be comparable to the lower variability in the ring-width of the another provenance. In a previous study of the provenances it was found that the individual variability of all tree ring parameters was one to four times greater than the chronological variability due to weather (Savva, et al., in press). To exclude age trends and differences within the provenance, the radial growth, minimum and earlywood density chronologies were standardized using a 3rd degree polynomial function (Figure 1A). Linear functions were used for standardising the latewood and maximum density chronologies (Figure 1B); and a 2nd degree polynomial function was used for standardising the latewood percentage chronologies. Then indices (Figure 1, curve 3) were calculated by dividing the measured parameter (Figure 1, curve 2) by the expected value obtained from the fitted curve (Figure 1, curve 1) (Cook et al., 1990). The interannual variability due to weather influence can be determined from the indices curves, with a mean of 1.0 and a relatively constant variance.

Fig. 1. - Examples of excluding the age trend in tree-ring characteristics for Avyan provenance: A) TRW - tree ring width; B) MAX - maximum density (1 - calculated curve, 2 - measured data, 3 - index curve).

The coefficient of sensitivity was calculated to evaluate the radial growth variations quantitatively. Once the sensitivities had been calculated it was possible to ascertain to what extent the growth of population was influenced by weather conditions (Schweingruber, 1988). The following formula was used to calculate the coefficient of sensitivity:

\[ K_s = \frac{n^2}{n-1} \frac{\sum_{t=1}^{n} (x_{t+1} - x_t)^2}{\sum_{t=1}^{n} x_{t+1} + x_t}, \]

where \( x_t \) is the relative index in year \( t \), and \( n \) is the number of observations (Shiyatov, 1986).

The coefficient of synchronicity (\( K_s \)) (Huber, 1943) was calculated to evaluate the conformity between the local, Boguchany, and the other provenances’ dendrochronological curves. The degree of synchronicity reveals the similarity of growth rhythm of two populations (Shiyatov, 1986). This is expressed as:

\[ K_s = \frac{n^2 \cdot 100}{n-1}, \]

where \( n^2 \) is the number of segments from radial growth curves having the same directional tendency and \( n \) is the length of the compared period (in years).

To estimate the similarities in interannual variability between the local (Boguchany) and the other provenances, the normalised Euclidean distances were calculated (Aivazyan et al., 1987). We chose statistically independent parameters of radial growth and density (coefficient of correlation between them: \(<0.85\)): tree-ring width, latewood and earlywood densities and latewood percentage (Savva et al., in press). The Euclidean distance is expressed as:

\[ d_p(X, X') = \frac{1}{p} \left( (x_{1}^{(i)} - x_{1}^{(j)})^2 + (x_{2}^{(i)} - x_{2}^{(j)})^2 + \ldots + (x_{p}^{(i)} - x_{p}^{(j)})^2 \right)^{\frac{1}{2}}, \]

where \( x_{1}^{(i)}, \ldots, x_{p}^{(i)} \) are the coefficients of synchronicity between the local provenance and the \( i \)-th transformed provenance (\( i = 1-16 \)) for the: (1) tree-ring width, (2) earlywood density, (3) latewood density, (4) latewood percentage; \( x_{1}^{(j)}, \ldots, x_{p}^{(j)} \) are the coefficients of correlation between the local provenance and the \( i \)-th provenance for the same tree ring characteristics; \( x_{1}^{(i)}, \ldots, x_{p}^{(j)} \) are the coefficients of synchronicity and correlation between the local provenance and the \( j \)-th provenance (where \( j \)-th provenance is the local provenance (Boguchany)), with being equal 1 correspondingly. According to this, \( p = 8 \).

**Results**

Table 2 demonstrates the mean values of tree ring width and latewood portion. It was found that the values of tree ring width decrease, but the values of latewood portion increase in relation to increasing latitude of seed origins.

<table>
<thead>
<tr>
<th>Provenance</th>
<th>Tree ring width, mm</th>
<th>Latewood ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pechenga</td>
<td>2.38</td>
<td>0.215</td>
</tr>
<tr>
<td>Turukhansk</td>
<td>2.72</td>
<td>0.206</td>
</tr>
<tr>
<td>Yakutsk</td>
<td>2.91</td>
<td>0.180</td>
</tr>
<tr>
<td>Pryazha</td>
<td>3.69</td>
<td>0.198</td>
</tr>
<tr>
<td>Severo-Yeniseisk</td>
<td>3.50</td>
<td>0.192</td>
</tr>
<tr>
<td>Boguchany</td>
<td>3.55</td>
<td>0.170</td>
</tr>
<tr>
<td>Revda</td>
<td>3.54</td>
<td>0.164</td>
</tr>
<tr>
<td>Ayan</td>
<td>3.17</td>
<td>0.176</td>
</tr>
<tr>
<td>Kurovskoye</td>
<td>3.87</td>
<td>0.174</td>
</tr>
<tr>
<td>Minusinsk</td>
<td>3.33</td>
<td>0.175</td>
</tr>
<tr>
<td>Nikol'sk</td>
<td>3.72</td>
<td>0.173</td>
</tr>
<tr>
<td>Avzan</td>
<td>2.80</td>
<td>0.185</td>
</tr>
<tr>
<td>Zaudinskii</td>
<td>3.74</td>
<td>0.165</td>
</tr>
<tr>
<td>Svobodnyi</td>
<td>3.87</td>
<td>0.169</td>
</tr>
<tr>
<td>Balgazyn</td>
<td>2.93</td>
<td>0.182</td>
</tr>
<tr>
<td>Kyakhta</td>
<td>3.12</td>
<td>0.175</td>
</tr>
</tbody>
</table>
given in Table 3 show that radial growth chronologies are more sensitive than density chronologies.

- The sensitivity coefficient of latewood width is higher (0.20 to 0.36) than that for earlywood width (0.09 to 0.17), showing that latewood formation is more influenced by weather conditions.

- Range of variation of the sensitivity coefficient for latewood density (0.05 to 0.10) are higher, than for earlywood density (0.03 to 0.04).

- However, tree ring characteristics are not highly sensitive, according to S.G. Shvarts’s (1985) classification of sensitivity, with one exception from the Svobodnyi provenance (Amurskaya obl.) where the sensitivity coefficient for latewood width is 0.36.

Table 3. – Sensitivity coefficients of the tree ring characteristics for different provenances (TRW – mean tree ring width, EWOT – earlywood width, LWOT – latewood width, PLW – latewood percentage, MAX – maximum density, LWAD – latewood density, MIN – minimum density, EWAD – earlywood density).

<table>
<thead>
<tr>
<th>Provenance</th>
<th>TRW</th>
<th>EWM</th>
<th>LWAD</th>
<th>PLW</th>
<th>MAX</th>
<th>LWAD</th>
<th>MIN</th>
<th>EWAD</th>
<th>DENSITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pechenga</td>
<td>0.17</td>
<td>0.17</td>
<td>0.20</td>
<td>0.12</td>
<td>0.04</td>
<td>0.05</td>
<td>0.04</td>
<td>0.03</td>
<td></td>
</tr>
<tr>
<td>Turukhanik</td>
<td>0.13</td>
<td>0.12</td>
<td>0.19</td>
<td>0.15</td>
<td>0.04</td>
<td>0.05</td>
<td>0.04</td>
<td>0.03</td>
<td></td>
</tr>
<tr>
<td>Yakutsk</td>
<td>0.10</td>
<td>0.08</td>
<td>0.20</td>
<td>0.13</td>
<td>0.03</td>
<td>0.07</td>
<td>0.07</td>
<td>0.03</td>
<td></td>
</tr>
<tr>
<td>Slyudyanka</td>
<td>0.20</td>
<td>0.20</td>
<td>0.22</td>
<td>0.23</td>
<td>0.07</td>
<td>0.07</td>
<td>0.07</td>
<td>0.03</td>
<td></td>
</tr>
<tr>
<td>Severo-Vysotsk</td>
<td>0.13</td>
<td>0.12</td>
<td>0.32</td>
<td>0.18</td>
<td>0.09</td>
<td>0.05</td>
<td>0.05</td>
<td>0.03</td>
<td></td>
</tr>
<tr>
<td>Boguchany</td>
<td>0.10</td>
<td>0.09</td>
<td>0.25</td>
<td>0.17</td>
<td>0.07</td>
<td>0.08</td>
<td>0.07</td>
<td>0.04</td>
<td></td>
</tr>
<tr>
<td>Revda</td>
<td>0.01</td>
<td>0.09</td>
<td>0.25</td>
<td>0.17</td>
<td>0.09</td>
<td>0.09</td>
<td>0.03</td>
<td>0.03</td>
<td></td>
</tr>
<tr>
<td>Ayansk</td>
<td>0.13</td>
<td>0.12</td>
<td>0.20</td>
<td>0.14</td>
<td>0.06</td>
<td>0.07</td>
<td>0.03</td>
<td>0.03</td>
<td></td>
</tr>
<tr>
<td>Karuksky</td>
<td>0.16</td>
<td>0.06</td>
<td>0.23</td>
<td>0.18</td>
<td>0.07</td>
<td>0.08</td>
<td>0.07</td>
<td>0.04</td>
<td></td>
</tr>
<tr>
<td>Minusinsk</td>
<td>0.14</td>
<td>0.12</td>
<td>0.28</td>
<td>0.22</td>
<td>0.19</td>
<td>0.09</td>
<td>0.06</td>
<td>0.04</td>
<td></td>
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<tr>
<td>Nikfak</td>
<td>0.11</td>
<td>0.11</td>
<td>0.22</td>
<td>0.19</td>
<td>0.09</td>
<td>0.09</td>
<td>0.05</td>
<td>0.03</td>
<td></td>
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<tr>
<td>Ayram</td>
<td>0.12</td>
<td>0.12</td>
<td>0.26</td>
<td>0.21</td>
<td>0.18</td>
<td>0.10</td>
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<td>0.04</td>
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<td>Zadonsk</td>
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<td>0.10</td>
<td>0.28</td>
<td>0.19</td>
<td>0.08</td>
<td>0.08</td>
<td>0.06</td>
<td>0.03</td>
<td></td>
</tr>
<tr>
<td>Slyudyanka</td>
<td>0.16</td>
<td>0.13</td>
<td>0.36</td>
<td>0.26</td>
<td>0.07</td>
<td>0.06</td>
<td>0.05</td>
<td>0.04</td>
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<td>0.10</td>
<td>0.30</td>
<td>0.22</td>
<td>0.10</td>
<td>0.19</td>
<td>0.08</td>
<td>0.04</td>
<td></td>
</tr>
<tr>
<td>Kyakhta</td>
<td>0.14</td>
<td>0.14</td>
<td>0.25</td>
<td>0.20</td>
<td>0.07</td>
<td>0.07</td>
<td>0.04</td>
<td>0.03</td>
<td></td>
</tr>
</tbody>
</table>

Table 3 shows the conformity in interannual variability between the local Boguchany and other provenances expressed by correlation and synchronicity coefficients. Except for latewood percentage, tree ring parameters from all the provenances from Revda and southward are highly correlated with Boguchany (with R values mostly between 0.7 to 0.9), with the notable exception of R = 0.45 for Svobodnyi. The correlation coefficients are a little lower for the northern provenances, with exceptionally low correlations for Pechenga (forest-tundra) provenance, with R = 0.44 for latewood density, and in the Severo-Vysotsk and Turukhanik provenances with R = 0.44 and 0.37 respectively for tree ring widths. The synchronicity coefficients for the latewood percentages for about half of the provenances are below 0.7 and the earlywood densities for five out of the 16 provenances are also low.

As a whole, the values of the correlation and synchronicity coefficients show that, for most of the provenances, the interannual variability of the chosen tree-ring characteristics reflects the prevailing weather conditions, with the variability of conditions mainly determining the variability in radial growth and wood density. The analysis of the parameters interannual variability shows that the directional response to weather changes is the same in most provenances (Figure 2). The synchronicity coefficient for tree ring width indices is >0.71 and for latewood density it is >0.54. For example, Figure 2A shows that the years of maximum and minimum radial growth coincide in all the provenances, with an especially abrupt marked decrease in maximum density in 1991 (Figure 2B).

The sensitivity of tree ring characteristics was also considered in relation to seed origin. There is a significant negative correlation (p < 0.05) between the sensitivity coefficient and the latitude of seed origin for all latewood parameters (for maximum density and for latewood percentage R = -0.68, for latewood density R = -0.65 and for latewood width R = -0.65).

The correlation and synchronicity coefficients of the independent dendrochronological characteristics were used to compare the radial growth parameters of Boguchany with the other provenances. The lowest Euclidean distance (dE = 0.06) connects Boguchany to Revda provenance (southern taiga), its nearest neighbour. The Euclidean distance increases for the northern taiga provenances (Figure 4). The highest Euclidean distance (dE = 0.15) separates Boguchany from its most remote northern provenance, Pechenga (forest-tundra).

Discussion

The analysis of the provenances correlation and synchronicity coefficients and their generally close relationship with Boguchany provenance demonstrates that the local weather conditions mainly influence the interannual variability of the tree ring characteristics. The influence of the local weather conditions decreases with the increase in the distance from the seed origin (Figure 4). Trees growing in subarctic and high latitude regions are highly sensitive to summer temperature variations (Vaganov et al., 1999). However, if northern seed sources are moved southward, their tree ring parameters do not exhibit as high a sensitivity as in their native environmental conditions.

The main environmental parameters determining growth response differences among provenances are heat sum, precipitation and photoperiod (latitude). In the subarctic regions of Siberia (forest-tundra and the northernmost parts of the northern taiga) the temperature of the two summer months: June and July is the main limiting factor. In the middle taiga, interannual growth variability depends on the June-July temperature and winter precipitation (Vaganov et al., 1996). Kira

Table 4. – The correlation and synchronicity coefficients of the tree ring width and density chronologies between the local (Boguchany) and the other provenances.

<table>
<thead>
<tr>
<th>Provenance</th>
<th>Correlation coefficient (R)</th>
<th>Synchronicity coefficient (R*)</th>
<th>R</th>
<th>X</th>
<th>mean</th>
<th>mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pechenga</td>
<td>0.66</td>
<td>0.34</td>
<td>0.57</td>
<td>0.42</td>
<td>0.79</td>
<td>0.79</td>
</tr>
<tr>
<td>Turukhanik</td>
<td>0.54</td>
<td>0.44</td>
<td>0.57</td>
<td>0.69</td>
<td>0.46</td>
<td>0.58</td>
</tr>
<tr>
<td>Yakutsk</td>
<td>0.47</td>
<td>0.29</td>
<td>0.50</td>
<td>0.33</td>
<td>0.45</td>
<td>0.79</td>
</tr>
<tr>
<td>Slyudyanka</td>
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(*) the lowest correlation and synchronicity coefficients, p < 0.05
DYANOV et al., 1996) and in the forest-steppe the major factors are April to June temperatures and June to July precipitation (VAGANOV, 1989).

The growth limiting factors for the studied provenances from the forest-tundra and northern taiga that were transplanted to the southern taiga differ greatly, while those for seedlings transplanted from the forest-steppe and steppe differ much less. This is due to the increase of the heat sum which is used by the northern provenances and to the decrease of the heat sum for the steppe and forest-steppe provenances planted in the conditions of the southern taiga.

We have shown that the sensitivity of latewood decreases with increases in the latitude of seed origins. This is because trees at higher latitudes have adapted to maximally exploit the earliest available heat sum (MIKOLA, 1962; LEIKOLA, 1969; VAGANOV et al., 1994; HUGHES et al., 1999). The conditions of the second half of the growing season therefore have less effect on radial growth characteristics. The southern provenances use the energy resources (heat and light) effectively during the whole growing season. Latewood formation mainly depends on the conditions of the second half of the growing season. Northern provenances show an earlier cessation of growth and transition to dormancy. If these trees are transplanted to the
south, they lack the ability to compete with southern provenances which are adapted to use the energy resources across the whole growing season (Table 2).

The values given by the normalised Euclidean distance show that the differences between tree-ring parameters from the northern provenances and those from the southern taiga provenances differ by less than 15%, while the provenances from the middle taiga and forest-steppe zone differ by 6% to 11%. The larger part (85%) of the variability in tree ring characteristics is due to differences in current local weather conditions even in the northern provenances.

Tree ring characteristics of different provenances integrates the complex processes of wood formation such as cell division, radial extension and cell wall deposition (Larson, 1994). On the one hand this is controlled by the genetical program of xylem differentiation, while on the other hand environmental factors influence these processes (directly or indirectly) (Xylem, 1981; Savidge, 1996). The analysis of densitometrical tree ring characteristics might be considered as a tool to evaluate genetical control of xylem differentiation under current environmental conditions. Significant differences in tree rings sensitivity were detected between the provenances. These differences prove the existence of genetical control of wood formation if trees moved to new environment. The evaluation of Euclidean distances between the provenances show that the genetical control is not strong. Nevertheless densitometrical parameters and their dynamic characteristics such as sensitivity to weather conditions might be used for evaluation of genetical differences between the provenances. They do, however, summarize the influences of climatic conditions over a long period of time.

In the context of global and regional climatic changes the results show that the northern provenances are more conservative by utilizing only the energy resources of the first half of the growing season effectively. Moving of the northern border of the Pinus sylvestris natural habitat will not be very rapid, especially if the other competitive species (for example, larch) turn out to be more adaptive to use heat effectively.

Conclusions

1. Northern provenances, planted in the southern taiga, retain their ability to use only the energy resources (heat and light) of the first half of the growing season effectively.
2. Latewood is more sensitive to weather conditions than earlywood.
3. Including the northern provenances, large part (up to 85%) of the variability in tree ring characteristics is due to local weather conditions.

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References