DENDROECOLOGICAL PECULIARITIES OF PINUS SYLVESTRIS L. STEM AND ROOT RADIAL GROWTH

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Abstract

Mature *Pinus sylvestris* L. stands growing near the flowless lake Baltys in the Ignalina region of Lithuania have been sampled. The lake has distinct 25-27 yr fluctuations that affect the lakeside pine stands. This study includes an analysis of tree-ring growth dynamics on different parts of trees (stem or roots) as well as different site locations. We have used ITRDB Program Library (COFECHA and ARSTAN programs) of the University of Arizona (Tucson) for crossdating, measurement quality assessing, chronology computation and statistical analysis, and FORMANT program created at the Institute of Mathematics and Informatics (Vilnius) - for the tree-ring growth fluctuation analysis.

The analysis of the precipitation data (1887-1990) exposes relatively stable 28 yr period cyclicity. High water level periods in the lake Baltys usually start several years before the end of 28 yr periodicity of increased precipitation. 24-30, 33-34 and 37 yr period fluctuations have been determined in Scots pine stem tree-ring growth as well as 24-33 and 36 yr period fluctuations - in root radial growth at the lakeside sites.

Tree-ring radial growth reaction to lake water fluctuations of two kinds has been established due to our investigations: positive (mostly) or negative - in roots, and negative - in stems. Diverse fluctuations are conditioned by different intensity of the expression of exogenous factors which impact on radial growth dynamics as well as individual characteristics of every tree, especially of the underground part of a plant. *Pinus sylvestris* root systems react to the changes of environment more sensitively, diversily and not always synchronously.

The stem and root tree-ring growth peculiarities of the lakeside scotch pine stands ascertain extremal limits of the species ecological amplitude and can be applied for prognoses and retrognoses of hydrological regime and water resources.

Introduction

Woody plant growth fluctuations do not distinguish themselves in a strict periodicity. The regular perennial tree-ring radial growth fluctuations in dendrochronology are called cyclic (Shiyatov 1986). The period phase and amplitude of these fluctuations are not constant and change in time and space (Douglass 1936; Siren 1963; Bitvinskas 1974), disappearing and reappearing from time to time (Shiyatov 1986). An individual factor makes only a slight effect on the formation of annual tree-ring, however, its impact increases under simultaneous effect of other factors.

The functions of root system and aboveground organs are strictly differentiated and interdependent and they condition each other, while most stages of growth processes are synchronous (Baitulin 1987).

Materials and methods

Pinus sylvestris L. trees growing near the self-contained 53.25 ha lake Baltys have beensampled. The lake is surrounded by a 25 m height horseshoe-shaped hill with sandy terraces overgrown with forest fragments. Lake water level fluctuations were documented during the period from 1959 to 1989 (Pakalnis 1970, Kriukelis 1995).

Eighteen 90-150 yr *Pinus sylvestris* trees in 4 sites (NR 1, NR 4, NR 5, NR 6) in the nearest and lowest parts to the lake as well as 2 control sites (NR 2 and NR 3) at the higher places were investigated. Cross-sections were collected from the breast height (1.3 m) and the tree base.

The root systems of trees were uncovered by the classical washing method (Böhm 1979; Guz 1981; Kriukelis 1989). Cross-sections of roots were taken from the root base and at a distance of 20 cm from it for a dendrochronological analysis. A total of 54 cross-sections from 18 stems and 267 from roots were measured (Kriukelis 1995).

We used ITRDB Program Library-1.1, Lab. of Tree-Ring Research, University of Arizona. The computer program COFECHA was used for crossdating and measurement quality assessment as well as the program ARSTAN - for detrending, chronology computation and statistical analysis (Holmes 1994). For statistical analysis (dispersive, regressive, etc.) we also used the program STATGRAPHICS-2.0.

The computer program FORMANT was used for the tree-ring growth and precipitation fluctuation analysis (Slivinskas, et al. 1991). Formant is an interactive program to get mathematical models of signal data. The name "Formant" stands for a signal component which can be an exponent, pure sinusoid, polynomial, damped polynomial, quasipolynomial. The signal under investigation is assumed to be represented as a sum of formants (Slivinskas, Shimonyte 1990).

Results and discussion

Formant analysis of the longest known precipitation data in Lithuania (1887-1990) measured at Vilnius meteorological station expose relatively stable 28 yr period fluctuations (Kriukelis 1994).

The fluctuations of lake water level are caused by the changes of climate. In 1864-1967 four periods of a high water level in the lake Baltys were singled out: 1878-1883, 1906-1911, 1930-1938 and 1959-1962 (Pakalnis 1970). Radial growth chronology minima of *Pinus sylvestris* trees growing near the lake Baltys conform with 25-27 yr period lake water level fluctuations and with 28 yr period precipitation cycle in Lithuania (Shshemeliovas 1964; Pakalnis 1970). High water level periods in the lake Baltys usually start several years before the finishing of an increased precipitation period and lasts from 3 to 9 yrs depending on the precipitation amount and summer temperatures (Pakalnis 1970, 1971, 1972). In 1958-1967 period the highest water level of the lake Baltys was registered in 1959. At that time there were flooded three isles and the lowest places of the lakeside stands.

24-28, 30, 33-34 and 37 yr period fluctuations were determined in scotch pine stem radial growth in the lakeside sites as well as 24-25 and 27-28 yr period fluctuations - in control sites. Formant analysis of the horizontal root tree-ring growth data shows 24-33 and 36 yr period fluctuations in the lakeside sites as well as 23, 25-29, 31-32, 34 and 37 yr period fluctuations in the control sites.

In lakeside sites the tree-ring growth fluctuations had higher amplitudes and lower damping coefficients than in the control ones (Fig.). Diverse fluctuations are conditioned by different intensity of the expression of exogenous factors which impact on radial growth dynamics as well as individual characteristics of every tree, especially of the underground part of a plant. The impact of factors can manifest itself in transformations of tree-ring growth dynamics from several months to some years later (Fritts 1976). An intensive competition of trees growing in the stand, making use of both the underground and aboveground space, can decrease the total radial growth and suppress a display of certain fluctuations, especially the long-term ones.

According to our investigation data on 1930-1988 period *Pinus sylvestris* horizontal root radial growth, the decreased growth in long-term dynamics at the lakeside sites was ascertained mostly in 1939-1956 (low lake water level), in 1964-1979 (low water level, low precipitation), increased - in 1960-1963 (high lake water level, high precipitation) and in 1981-1985 (high lake water level, high precipitation). In some root radial growth series from lakeside sites an existence of the opposite reaction to lake water level fluctuations during the same periods was established. Minima in long-term dynamics of the stem radial growth data at the lakeside sites were in 1959-1963 (high Baltys lake water level) and maximums - in 1942-1954 (low lake water level) periods. In the control sites the increased growth was determined in stem as well as in horizontal root radial growth long-term dynamics during the high lake water level and high precipitation periods.

Coincidence of maximum and minimum radial increment periods in roots and stems of trees growing under different ecological conditions sometimes occur due to water level fluctuations in Baltys lake and different intensity of precipitation as well as general effect of summer temperatures on dynamics of lakeside stand growth (Pakalnis 1972). A considerable increase of annual ring-width in a part of root system (e.g. horizontal roots) during high water level periods can be explained by the compensatory growth phenomenon (Baitulin 1987) (Fig.).

Mean sensitivity (MS) measures the ring-width changes among adjacent rings and is influenced mostly by the high-frequency variations in climate (Fritts 1971). Mean sensitivity is 25-38 % higher in roots to compare with stem individual radial series as well as chronologies ($P < 0.01$). MS values at breast height (1.3 m) and at the tree base are lower than in horizontal roots ($P < 0.05$). There is no significant difference in mean sensitivity at both stem heights ($P > 0.40$), between lakeside and control sites ($P > 0.13$). Standard deviation (SD) and mean sensitivity are not equivalent measures because a standard deviation is inflated more than mean sensitivity by long-term variations in climate (Fritts 1971). Standard deviations are 30-40 % higher in lakeside than in control sites. There is no significant difference between SD values at the tree base or breast height of stem chronologies. Tree-ring growth series with high SD frequently have high MS.

Conclusions

1. 24-30, 33-34 and 37 yr period fluctuations were determined on scotch pine stem tree-ring growth in the lakeside sites as well as 24-25, 27-28 and 33 yr period fluctuations - in the sites located on 2-3 m height from the average lake water level (control). Dynamics of the horizontal root tree-ring growth shows 24-33 and 36 yr period fluctuations in the lakeside sites as well as 23, 25-27, 31-32, 34 and 37 yr period fluctuations - in the control sites.

2. In the lakeside sites tree-ring radial growth reaction to high lake water level periods was the following: positive (mostly) or negative - in roots and negative - in stems.

3. The coincidence of maximum and minimum radial increment periods in series of the aboveground and underground parts of trees growing under different ecological conditions sometimes occurs due to the general effect of water level fluctuations in the Baltys lake, different intensity of precipitation and summer temperatures on dynamics of lakeside *Pinus sylvestris* L. growth as well as because of the compensatory growth phenomenon.

4. Root systems react to the changes of environment more sensitively, diversely and not always synchronously. Variability in all frequency ranges (high and low frequency variations) in horizontal root radial growth dynamics of scotch pine is significantly higher than in stems, as well as in the lakeside sites - higher than in control ones.

5. Investigations both on stem and root growth dynamics may increase the information to a considerable extent and help us to ascertain extremal limits of the species ecological amplitude.

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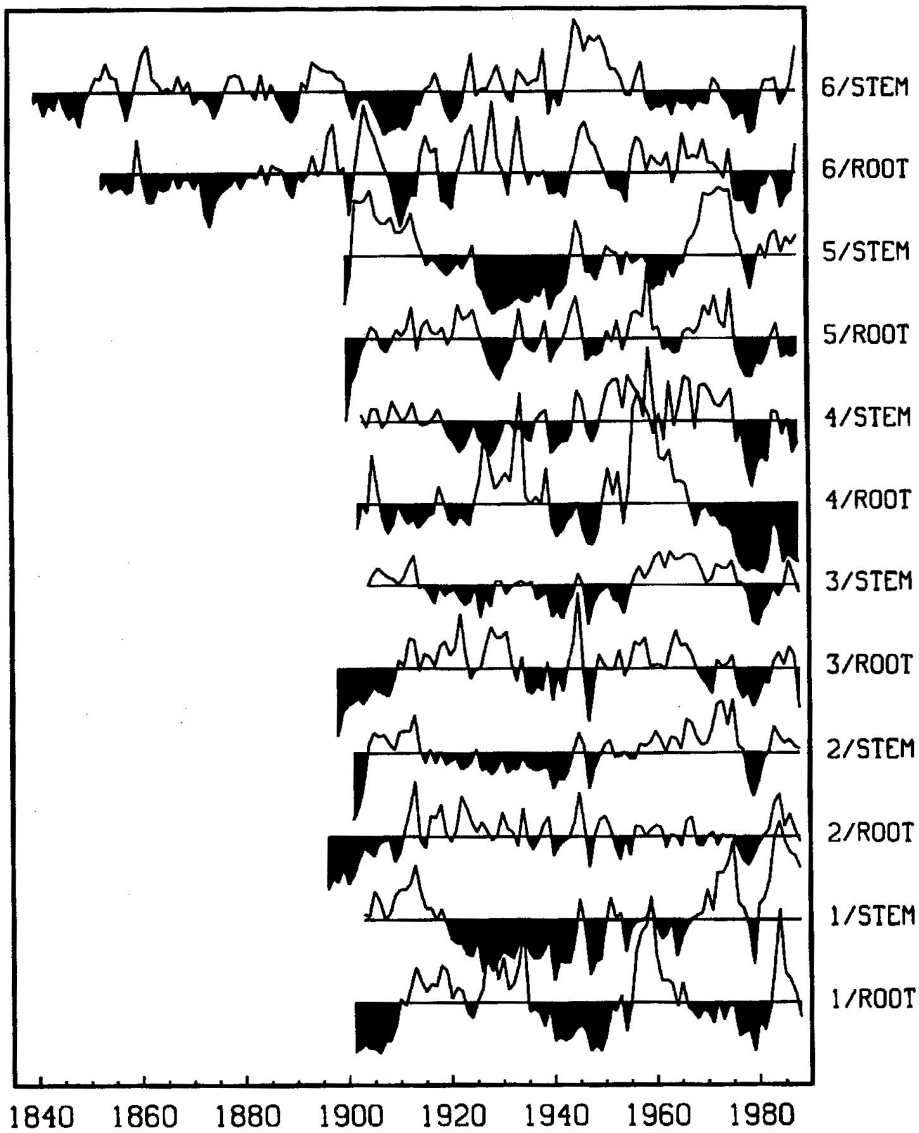

Fig. Plots of Pinus sylvestris L. ring-width index chronologies (/** - site NR/ root or stem chronology).*

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