P-11

INFLUENCE OF DROUGHTS TO THE RADIAL GROWTH OF SCOTS PINE (PINUS SYLVESTRIS L.)

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Abstract

Dendroclimatological research on the radial growth of Scots pine in Aukštaitija National Park in north-eastern Lithuania has been conducted. The aim of the study was to estimate the differences of the impact of droughts to the radial growth of pines growing on dry and wet sites. For this purpose event years of the radial growth were estimated. Investigation has revealed that the fluctuations of the ground water level have different effects on the radial growth of pines. Increase of the soil water level stimulates the radial growth on sites with organic soil, but on sites with mineral soil growth is positively affected by the abatement of the water level. It was found that droughts in spring and early summer (May-June) are much more dangerous for the radial growth of pines compared to August. Droughts of three-month duration have been acknowledged to be much more stressful than short one-month droughts. The affect of drought to the radial growth of pines depends on climate conditions before and after the drought. The investigation did not reveal any significant differences between the number of pines with negative event years growing on sites with organic peat and mineral soils.

Introduction

Scots pine (Pinus sylvestris L.) has been one of the most comprehensively investigated tree species in Lithuania and Baltic countries by using dendroclimatological techniques. This is determined by the prevalence of pines in forests of Lithuania (about 36.2 % of the total stands), pine longevity and wide ecological amplitude of its growing sites. Due to high tolerance of Scots pine to different and variable soil moisture conditions [1], previous research has involved wide range of site conditions (from peat bogs to infertile and dry mineral sites). Dendroclimatological knowledge states that drought sensitive trees grow in dry mineral soil [2]. Many studies have proven that pines growing in peat bogs respond to precipitation negatively, especially during summer time [3], but several studies have admitted contradictory results affirming positive, usually insignificant, impact of precipitation on pine radial growth on wet sites [4,5]. Trees may become fewer droughts tolerant after the decrease of water level [6].

This study is aimed to qualify the differences of the impact of droughts to Scots pine radial growth on dry and wet sites.

Material and methods

For the purpose of research eight experimental plots of Scots pine in Aukštaitija National Park were selected. Research plots are located between two small lakes – Žiegžmaris and Ešerinis in Ažvinčiai Forest. Six research plots are located in peat bog with thinner or thicker organic soil layer and two of them – on the periphery of the peat bog with mineral soil and deeper ground water level (up to 226 cm).

Research of soil parameters. The measurements of soil water level have been carried

out research plots from 1997. This is done every ten days from spring to autumn (approximately from mid-April to the beginning of November) in the special soil holes. The acidity of soil water was measured using pH-meter within 0.1 pH value accuracy.

Dendrochronological research. Using increment borer four cores from each tree in each plot were taken at the breast height. Tree ring widths with preciseness of 0.001 mm were measured. For this purpose, LINTAB tree-ring measuring table and WinTSAP 3.0 computer program (F. Rinn Engineering Office and Distribution, Heidelberg) were used. The measured series were cross-dated by visual comparison of ring-width graphs and checked statistically using COFECHA 3.00P computer program (R.L. Holmes, Tucson) [7].

The long-term regression analysis seldom permits to evaluate effect of contrast climate conditions (information is contained in conspicuous single growth rings). For this purpose event year analysis by using method "normalisation in a moving window" proposed by H.F. Schweingruber was performed [8]. For the estimation of droughts in spring and summer, a slightly modified method (Formula 1) proposed by Walter (1974) was used.

$P_i \le T_i$	Extreme drought	
$T_i < P_i \le 2T_i$	Drought	(1)
$2T_i < P_i \le 3T_i$	Arid conditions	

where: P_i – amount of precipitation (mm) during the month; T_i – average temperature (°C) during the analysed month.

Results and discussion

Data of research plots (soil water level (cm) during the vegetation periods of 1997-2005, soil acidity (pH values)) and statistical characteristics of tree-ring chronologies (number of missing rings (%), average tree-ring width, length of compiled chronology) are given in Table 1.

Table 1. Statistical characteristics of research plots and tree-ring chronologies

Plot number	Soil water level cm			pH value	Missing rings %	Tree ring width mm	Length of chronology years
	lowest	average	highest				
1-2o	76	32	4	3.42	0.59	1.09	201
3-4o	70	36	3	3.35	0.13	0.95	187
5m	247	226	201	6.05	0.06	0.98	192
6o	61	37	12	3.45	1.59	0.81	167
7o	80	51	21	3.30	0.48	0.73	163
8o	66	33	12	3.30	0.62	0.54	188
9m	89	72	51	4.35	0.00	0.99	183
10-12o	78	30	7	3.15	0.43	0.70	221

Pine growth in peat bogs is characterised by narrow rings, which often transits into wedging rings on different sides of the stem. During periods with unfavourable conditions in boggy sites missing rings are detected occasionally. Therefore, precise dating of measured tree ring series was successful mainly because of four taken cores per tree. The frequency of wedging and missing rings is directly connected not only to the age of trees, but also depends on growing conditions of pines. The least frequency of missing rings was established among pines growing on mineral soils (5m and 9m), while the biggest – among pines in organic (peat) soils (Table 1).

A surplus of soil humidity common to peat bogs forms unfavourable growing conditions by altering variety of physical, chemical and biological processes [6]. Trees growing on peatlands are highly dependent on depth and fluctuations of the water table, which depth is controlled by precipitation and temperature [9].

Coefficients of correlation between the radial growth of pines and average depth of soil water in April-September at most cases are statistically insignificant ($p \leq 0.05$). This is also connected to quite short time of measurements (9 years). Nevertheless, differences between correlation coefficients at organic and mineral sites are noticeable (Table 2).

Table 2. Coefficients of correlation between the average depth of soil water in April-September and the radial growth of pines at eight research plots during 1997-2005

Months	1-2o	3-4o	5m	6o	7o	8o	9m	10-12o
Apr-May	-0.25	0.13	0.79*	0.38	0.00	0.16	0.32	-0.11
Jun	-0.27	0.43	0.64	0.40	0.06	-0.13	0.42	-0.42
Jul	-0.22	0.03	0.43	0.26	-0.27	-0.39	0.17	-0.20
Aug	0.00	0.16	0.55	0.46	0.58	-0.33	0.33	0.31
Sep	-0.20	-0.05	0.55	0.49	-0.43	-0.53	0.27	0.25

Note: * - indicates significance - 95%

Steady and positive links were found between the soil water depth and the radial growth of pines on mineral sites (Table 2). This indicates that growth of pines is stimulated by deeper water levels (drier periods), and high water table has negative effect on the radial growth. Coefficients between the radial growth of pines and water depth on organic sites are much lower. Negative links have been observed on the wettest plots (1-2o, 7o, 8o and 10-12o). That means that high water table stimulates radial growth on sites with organic soil.

We have analysed years (not inter-connected with winter colds) with droughts during the 20th century. Droughts in May and June are much more stressful than in August and percentage of affected trees at both organic and mineral sites on average is similar (Fig. 1). However, in 1925, 1946 and 1978 droughts in May and June did not cause marked reduction of the radial growth. This may be connected to short duration of droughts and favourable conditions before and after droughts: mild winter in 1925, snowy winter with higher accumulation of water and humid June after drought in 1946, snowy winter and humid April in 1978 before the drought.

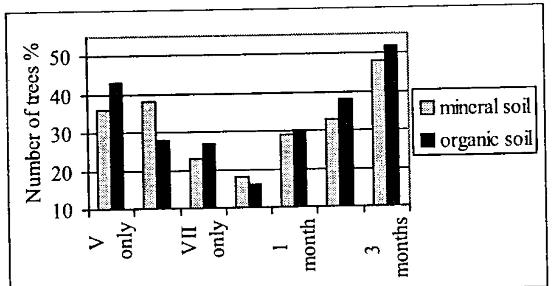

Fig. 1. The average percentage of trees indicating negative event years on mineral and organic sites during droughts.

The duration of droughts is very important factor. First four columns in Figure 1 show average percentage of trees during droughts of one-month duration (May-August), the last three columns indicate percentage of pines with event years during droughts of different length (one month, two months and three months). The most dangerous are droughts lasting three months (on average they cause marked decrease for 48-52 % of pines), while droughts lasting one or two months usually affect respectively about 30 % and 33-38 % of trees only. The average percentage of trees indicating negative event years on sites with organic and mineral soils is similar, differences are statistically insignificant ($p \leq 0.05$).

Conclusions

Investigations have revealed that the fluctuations of soil water level influence the radial growth of pines: increase of water table stimulates the radial growth on sites with organic soil, while on sites with mineral soil high soil water has an inverse effect.

Dendroclimatological research has revealed that droughts in May and June are more dangerous and induce higher number of pines with marked decrease of the radial growth compared to droughts in August.

The most dangerous are droughts of three months duration, while droughts lasting one month usually are not so stressful. The influence of drought, expressed as percentage of pines with event years, depends on climate conditions before and after the drought. Favourable conditions may reduce or even eliminate effect of short one-month droughts.

Significant differences in the response of the radial growth of pines to droughts at sites with organic and mineral soils were not found.

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