Dendroclimatological similarities of *Picea abies* (L.) Karsten and *Pinus sylvestris* (L.)

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The results of the dendroclimatological research conducted in 1995-1997 has been discussed in this publication. The dendroclimatological research has been carried out in ten experimental plots located in West and Central parts of Lithuania in mixed conifer forests on different sites. The main dendroecological similarities and differences of Norway spruce (*Picea abies* (L.) Karsten) and Scots pine (*Pinus sylvestris* L.), – the main conifer species in Lithuania have been established. The dynamics of the annual radial increment has been analysed in the period 1711-1997. Carrying out the research, the differences of sensitivities of the annual radial increment, impact of climate (air temperature and precipitation) and extreme ecoclimatic conditions have been analysed.

Key words: annual radial increment, dendroclimatology, extreme ecoclimatic conditions, Pine, Spruce forests.

Introduction

The dendroclimatological research in Lithuania has been carrying out since the middle of the twentieth century. The research on Norway spruce (*Picea abies* (L.) Karsten) and Scots pine (*Pinus sylvestris* (L.)) in Lithuania has been carried out by T. Bitvinskas, V. Stravinskienė, L. Kairiūkštis etc. [3, 4, 7, 12, 13, 14, etc.]. Research was also conducted all over the World by D. Eckstein, F.H. Schweingruber, H. Fritts etc. [5, 11,].

Due to Pine domination in Lithuanian conifer forests, the main part of dendrochronological research was concentrated on pine and only a smaller part on spruce. Spruce was less investigated than pine for some time [10]. The greater part of research was carried out in former times, therefore the impact of present extreme ecoclimatic conditions, in connection to a climate change and forest decline, due to increasing environment pollution was not investigated. Some research was carried out in small parts of Lithuania, e.g. Kaunas region and in a small number of experimental plots [10] and on forest sites, in which the main part of Spruce or Pine forests are located, e.g. research on spruce in *Piceetum oxalidosum*, *Piceetum myrtillo-oxalidosum* types.

Understanding the importance of the previous research, which was carried out in limited opportunities, research results, published in this article covers accumulated experience of research, applied to new technical possibilities.

Materials and methods

For the purpose of our research, Pine and Spruce, growing on various forest sites in mixed conifer forests in the West and Central parts of Lithuania, were used. Owing to the long-life and anatomical structure of the annual radial increment, conifers are one of the most important objects of the dendroclimatological research in Lithuania (Spruce lives to 200- 300, Pine to 500 years) [3].

The main objectives of the research have been achieved as follows:

- Experimental plots in conifer forests in the West and Central parts of Lithuania were selected.
- Dendrochronological material in eleven experimental plots, with Spruce and Pine was collected. Sixty samples have been taken from tree stems (about 600 trees) of each experimental plot (thirty in pine and thirty in spruce) by inserfing an increment borer.
- Using usual methods and taxation characteristics experimental plots were established (forest types were established according to the typology by prof. S. Karazija) [9]. Experimental plots were divided into a dry

(*Pinetum vaccinio-myrtillosum*), moderately wet (*Pinetum myrtillosum, Piceetum myrtillosum, Pinetum myrtillo-oxalidosum, Piceetum myrtillo-oxalidosum*) and wet (*Piceetum oxalidosum, Piceetum oxalido-nemorosum*) forest types.

• Using a "Bengan (Jonson)" device, late, early and annual radial increment was measured.

• PC analysis. Using a computer program "Arstan 40", indexes of chronologies were counted. With a negative exponential curve and linear regression the age curves were eliminated. Meteorological (monthly and yearly precipitation and air temperature) data was interpolated for each experimental plot. Using "Excel 5.0" computer program correlation coefficients were counted.

Results and discussion

A lot of dendrochronological researches affirms that Spruce is more sensitive to the changes of environmental conditions [10, 12, 13]. Spruce is less ecologically plastic than Pine. Spruce does not grow in very dry (*Pinetum* and in more suitable forest sites could change Pine. The anatomical structure of the annual radial increment is different: there is more late increment in Pine rings, which forms at the end of summer and autumn; Spruce rings are not so clear and bright than Pine and the difference between late and early radial increment is not so sharp. The cycles of increment dynamic of Pine are similar to Spruce, especially on dry forest sites. The annual radial increment indexes of Pine and Spruce in the Paštuva forest (*Piceetum vaccinio-myrtillosum)* is shown in Figure 1. Due to a surface root system, Spruce more rapidly and frequently responds intensively to extreme ecoclimatic conditions (especially droughts).

Spruce and Pine differences of sensitivities to environmental changes was found out. Sensitivity was counted for late, early and annual radial increment. Late radial increment is more sensitive than early or annual. Sensitivity of Spruce in all experimental plots was greater than Pine (Table 1).

To show the importance of sensitivity differences of Spruce and Pine, the average value of sensitivity, using

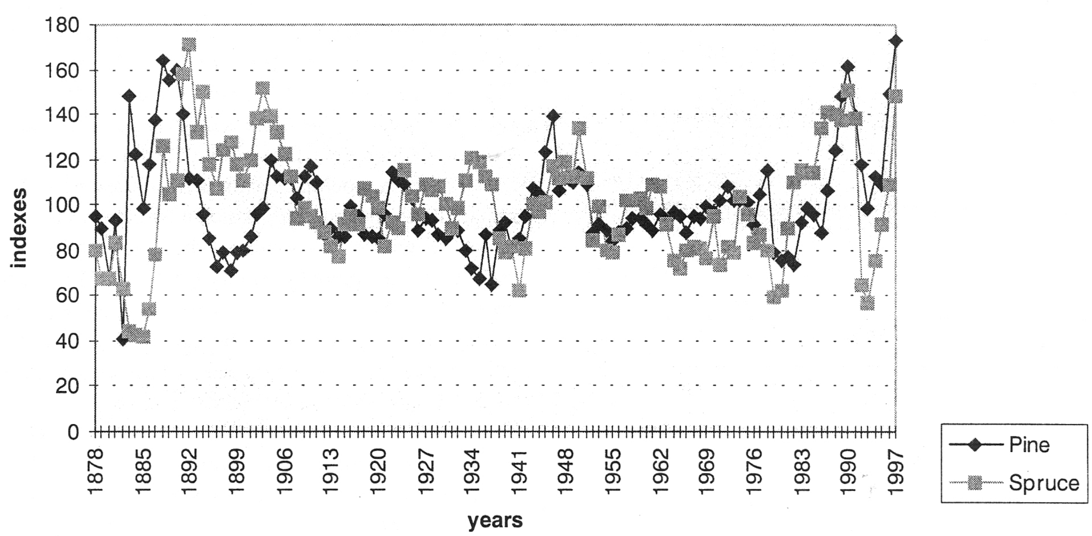

Fig. 1. The annual radial increment indexes of Scots pine and Norway spruce in dry forest site (*Piceetum vaccinio-myrtillosum*) in the Paštuva forest

cladoniosum) and wet (*Pinetum sphagnosum*) forest types. Spruce forests dominate in *Piceetum oxalidosum, Piceetum oxalido- myrtillosum* and Pine forests in *Pinetum vacciniosum, Pinetum vaccinio- myrtillosum* forest types (Spruce grows on rich and wet and Pine on dry or moderately dry and not rich forest sites) [15].

Spruce, growing with Pine in mixed forests, usually is younger than Pine, because spruce tolerates thickets

Table 1. Sensitivity of Scots pine and Norway spruce the annual radial increment in different forest sites

Forest site		Sensitivity			
		late	early	annual	**average**
dry	Pine	0.19	0.14	0.13	**0.15**
	Spruce	0.22	0.17	0.15	**0.18**
moderately wet	Pine	0.19	0.16	0.14	**0.16**
	Spruce	0.20	0.18	0.15	**0.18**
wet	Pine	0.16	0.14	0.12	**0.14**
	Spruce	0.18	0.14	0.12	**0.15**
average	**Pine**	**0.18**	**0.15**	**0.13**	0.15
	Spruce	**0.20**	**0.16**	**0.14**	0.17

a mathematical statistics was verified. The hypothesis of an average comparison was used.

$$t_e = \frac{x_1 - x_2 \; (n_1 n_2 (n_1+n_2-2))^{1/2}}{(S_1^2(n_1-1)+S_2^2(n_2-1))^{1/2} \cdot (n_1+n_2)^{1/2}} = 2.34$$

t_c=2,04, because $t_e > t_c$, there is an average difference (sensitivity of Spruce and Pine is different).

There is a high correlation between early and annual radial increment of Pine and Spruce (separately) 0,94 – 0,99, more poorly between late and annual 0,52 – 0,92, and late and early 0,34 – 0,85. Pine shows better correlation.

There is reliable correlation in some experimental plots between the annual radial increment of Spruce and Pine to 0,61, but in some only -0,12...0,05. Better correlation was obtained on dry forest sites (Table 2).

Table 2. The correlation between Pine and Spruce annual radial increment (l-late, e-early, a-annual increment)

Forest site		l-e	e-a	l-a	l-l	e-e	a-a
dry	Pine	0.60	0.97	0.74	0.30	0.18	0.23
	Spruce	0.59	0.94	0.71			
moderately wet	Pine	0.61	0.98	0.75	0.16	0.11	0.16
	Spruce	0.50	0.95	0.69			
wet	Pine	0.72	0.98	0.81	0.15	0.06	0.11
	Spruce	0.62	0.96	0.82			
average	**Pine**	**0.57**	**0.95**	**0.74**	**0.20**	**0.12**	**0.17**
	Spruce	**0.64**	**0.98**	**0.72**			

The correlation between the annual radial increment of Pine and Spruce and climate has these peculiarities.

Dry forest sites (Fig. 2, 3).

Similarities:

• Positive impact of precipitation of June,

• Negative impact of precipitation of January, March and December,

• Positive impact of air temperature of a year

Differences:

• Negative impact of air temperature in June-August on Spruce,

• Positive impact of air temperature in June-August on Pine.

Wet forest sites.

Similarities:

• Positive impact of air temperature in January-April,

• Positive impact of air precipitation in November-December.

Differences:

• More significant positive impact of air temperature on Pine in July-September and yearly.

The main dendroclimatological differences of Spruce and Pine corresponds to the conclusions obtained by D. Eckstein in 1989 in Northern Germany [5]. He affirms that spruce positively responds to wet and cool summer.

At the end of the XXth century it was detected that the Earth climate began to change. Concern is also expressed by the United Nations and scientists all over the World: "In the last 100 years following the Industrial Revolution, the temperature of the Earth has risen from 0.3 to 0.6 °C. Data on the ice cores suggest we are living in the warmest century in a period of 600 years. The last two decades of the XXth century are hottest on the record, according to the Intergovernmental Panel on Climate Change (IPCC) a body of 2,500 scientists".

The main ecoclimatic extremes influencing the annual radial increment and under which impact forms the pointer years are: winter frost, summer droughts and heat. In the middle of the twentieth century (1922-1955) there was a greater impact of cold winters, while at the end of the XXth century the importance of summer droughts and heats rises. Pointer years of Spruce and Pine radial increment was after the cold winters of 1940-1941, 1978-1979. Negative impact has, in particular, summers of 1992 and 1994, which causes considerable reduction of the annual radial increment, especially on dry forest sites. Scientists notice, that more narrow tree rings formed already in 1981 under the impact of cold winter of 1979-1980 and increasing environment pollution. Consequenctly an outbreak of *Ips typographus* in spruce forests began [12].

Having detected the impact of extreme ecoclimatic conditions in 1992 and 1994 we counted also the correlation between the meteorological data and annual radial increment indexes from 1992.

After six years (in 1998) the impact of extreme ecoclimatic conditions on the annual radial increment could be evaluated and a conclusion drawn, comparing

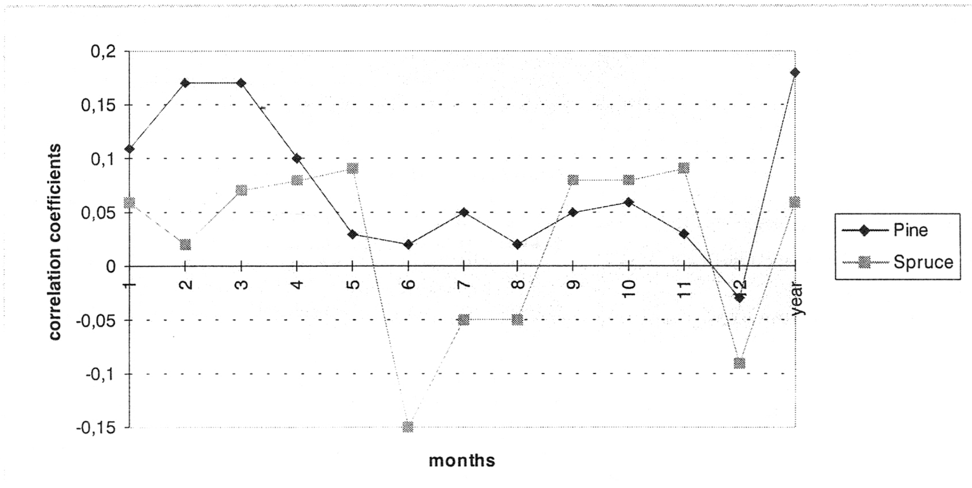

Fig. 2. The correlation between the annual radial increment of Scots pine and Norway spruce and precipitation in dry forest sites

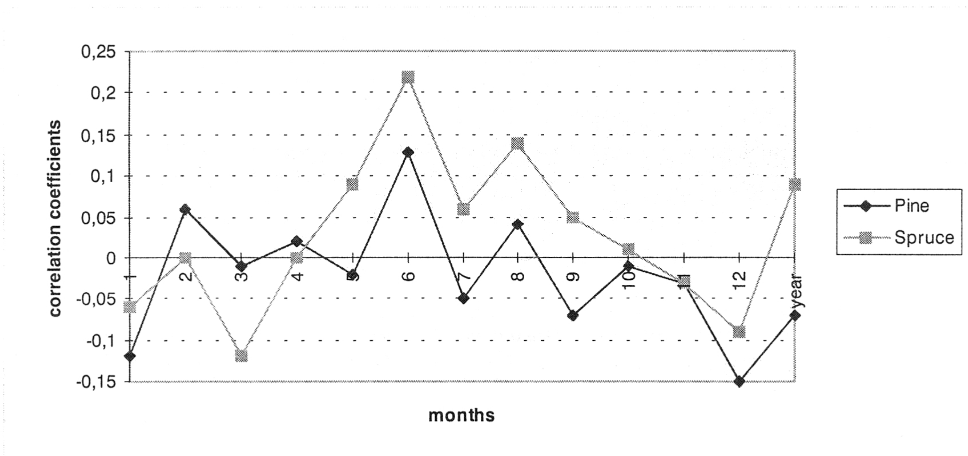

Fig. 3. The correlation between the annual radial increment of Scots pine and Norway spruce and air temperature in dry forest sites

the impact of changes in climate in the whole period of tree growth.

The impact of extreme ecoclimatic conditions (summer droughts and heat in the last decade of the XXth century) on Spruce and Pine annual radial increment was investigated counting the correlation between the annual radial increment and air temperature and precipitation since 1992.

By comparing correlation coefficients from 1992 year with the whole period of tree growth, were found out these peculiarities.

1. On dry forest sites. With air temperature.

• Negative impact of January appears,

• Positive impact of August disappears,

• Negative impact of December and year on the annual radial increment of Spruce appears.

2. With precipitation.

• Instead of a positive correlation with June, appears with May-June.

3. On wet forest sites. With air temperature.

• Positive impact of February appears,

• Instead of positive impact of July-September on the annual radial increment of Pine, positive effect of June-September appears.

4. With precipitation.

• Positive impact of June-August appears,

• Negative impact of September-November on the radial increment of Spruce and positive effect on that of Pine are observed.

Conclusions

1. In spite of Spruce and Pine similarities, which is displayed in similar increment dynamic rhythms, researching impact of climate on the annual radial increment was found out differences.

2. Air temperature of spring and year positively affects the annual radial increment of Spruce and Pine. There is positive impact of summer and negative influence of spring, and autumn precipitation on Spruce and Pine.

3. Pine is more resistant to extreme ecoclimatic conditions (especially to droughts) and responds to them later, e.g. Pine Pointer year of increment minimum was in 1993 and Spruce mainly in 1992 (especially in dry forest sites). It has been found that on dry forest sites in a period of an extreme ecoclimatic conditions, positive impact of summer precipitation, a negative impact of warm August and warm year appear.

4. Research results could be used in ecological prognosis and reconstruction of the impact of the past ecological conditions on the forest ecosystems.

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ДЕНДРОКЛИМАТОЛОГИЧЕССКИЕ СХОДСТВА ЕЛИ ОБЫКНОВЕННОЙ (*PICEA ABIES* (L.) KARSTEN) И СОСНЫ ОБЫКНОВЕННОЙ (*PINUS SYLVESTRIS* L.)

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Резюме

В этой публикаций дискутируются результаты дендроклиматологичесских исследований проведённых в 1995-1997 годах. Дендроклиматологичесские исследование проведены в десяти пробных площадей в западной и центральной частях Литвы в смешанных хвойных лесах и разных типах лесов. Установлены основные дендроэкологичесские сходства и различия обыкновенной ели (*Picea abies* (L.) Karsten) и обыкновенной сосны (*Pinus sylvestris* L),- основных сосновых насаждений. Динамика годичного радиального прироста анализированна в периоде 1711-1997 годах. В исследований анализированно: чувствительность годичного радиального прироста сосны и ели и также влияние климата (температуры воздуха и осадок) и экстремальных экоклиматичесских ycсловий на радиаьный прирост.

Ключевые слова: годичный радиальный прирост, дендроклиматология, еловые леса, ель, сосна, условия экоклиматичесских экстремумов