Trends of Decline of Douglas Fir in Lithuania: Dendroclimatological Approach

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Abstract

Dendroclimatological research on Rocky Mountains Douglas fir (*Pseudotsuga menziesii* var. *glauca* (Beissn.) Franco) and Green Douglas fir (*Pseudotsuga menziesii* (Mirb.) Franco) – introduced trees in Lithuania has been discussed in the article. Multiple regression analysis has shown positive and significant influence of air temperature at the end of winter – beginning of spring on the radial growth of Douglas fir, while the strong positive impact of precipitation in June prevails in eastern Lithuania. Analysis on pointer years of the radial growth has indicated that decreases in the radial growth of Douglas fir are driven by colds in winter – spring and droughts in summer. Increases in the radial growth are connected to warm winters and humid summers. Our research indicates that the importance of winter colds as the limiting factor for the radial growth of Douglas fir at the end of the 20th century has decreased, while summer droughts gain greater importance. According to the trends on the global climate change it is supposed that summer droughts will remain the main limiting factor for the survival of Douglas fir in Lithuania in the beginning of the 21st century. Conditions more favourable for the growth of Douglas fir are likely to be in the regions of West Lithuania: seaside lowlands and Žemaičiai Uplands.

Key words: climate, Green Douglas fir, pointer year, radial growth, Rocky Mountains Douglas fir

Introduction

Climate of the Earth is under the pressure of anthropogenic activity provoking global climate change, degradation of ecosystems and forest decline (Goudie 2000, Lamb 1995, Parmesan and Yohe 2003, Rebetez 2002, Root *et al*. 2003). The relationships between the radial growth of trees and climatic conditions have been investigated since the beginning of the 20th century – research of A.E. Douglass. Due to global climate change investigations on tree rings have acquired greater importance at present (Beniston 2002, Cherubini 2000, Hanson *et al*. 2001, Leslie 2005, Roig *et al*. 2001, Yohe and Wright 2000).

Green Douglas fir (*Pseudotsuga menziesii* (Mirb.) Franco) and two varieties – Rocky Mountains Douglas fir (*Pseudotsuga menziesii* var. *glauca* (Beissn.) Franco) and Fraser River Douglas fir (*Pseudotsuga menziesii* var. *caesia* (Schwerin) Franco) are introduced trees in Lithuania. Green Douglas fir grows naturally in the western part of northern America between 19° and 55° northern latitudes: from British Columbia along the Pacific coast to California (Den Ouden and Boom 1978, Hermann and Lavenger 1990, Humphries 1995). The habitat of Rocky Mountains Douglas fir extends from Rocky Mountains in Columbia to Central Mexico (Den Ouden and Boom 1978, Hermann and Lavenger 1990, Taylor 1993). Douglas fir was introduced in Europe by D. Douglas in 1825-1827 (Hermann 1987, Humphries 1995) and firstly planted in Lithuania approximately 90-100 years ago together with other introduced trees (Янушкевичюс и др. 1990). According to the inventory data, about 60 sites of mature Douglas fir trees were recorded during the 20th century in Lithuania. Rocky Mountains Douglas fir is more common than Green Douglas fir in them (Januškevičius 2004, Ramanauskas 1973, Snarskis and Galinis 1974, Tauras 1989).

There is only sparse number of sites where mature Douglas fir trees grow in Lithuania at present. Trees have died off due to unknown reasons in several parks, e.g. the Kuršėnai Park, Šereitlaukis Park, Bebrujai forest, Pienionys Park, Vyžulionys Park and several other sites. Mature trees grow mainly in western and central part and are rare in eastern Lithuania (Januškevičius 2004, Ramanauskas 1973, Žeimavičius 1995, Žeimavičius 2002).

The first dendrochronological research on Douglas fir in Lithuania was conducted in 1984. The research has shown strong negative influence of colds in winter and spring on the radial growth of Douglas fir (Žeimavičius 1995, Жеймавичюс и Будрюнас 1990). The investigations at the end of the 20th century have indicated decline and increased mortality of trees (Žeimavičius 2002). Decline of Douglas fir in Lithuania is still not investigated. It is supposed that frequent and long-lasting droughts at the end of the 20th century in Lithuania have triggered decline of domestic conifers (Ozolinčius 1998, Vitas 2004a) and more frequent droughts are possible consequences of the global climate change (Bukantis *et al*. 2001, Hoerling and Kumar 2003).

The aim of research is to investigate the main climatic factors limiting the radial growth of Douglas fir during the 20th century in Lithuania and to evaluate the possible impact of global climate change to the state of Douglas fir in Lithuania.

Materials and methods

For the purpose of research 19 research plots of Douglas fir were selected in Lithuania (Fig. 1). Seventeen plots represent stands of Rocky Mountains Douglas fir and two – stands of Green Douglas fir. Because the earlier research on Douglas fir in Lithuania did not demonstrate any significant differences between the radial growth of Green Douglas fir and Rocky Mountains Douglas fir (Žeimavičius 1999), trees from both

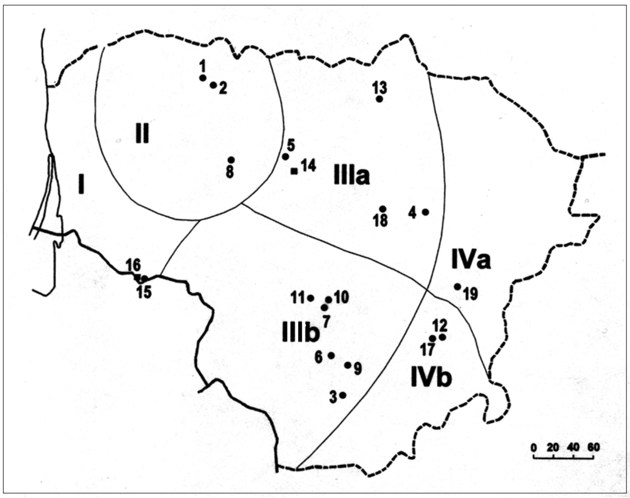

Figure 1. Network of research plots (1-19) on Douglas fir in Lithuania: ● – Rocky Mountains Douglas fir, ■ – Green Douglas fir. Regions of introduction: I – seaside lowland, II – Žemaičiai Uplands, IIIa – northern region of middle lowlands, IIIb – southern region of middle lowlands, IVa – northern region of east Lithuania, IVb – southern region of east Lithuania

species during our investigation were treated as individuals of Douglas fir.

The territory of Lithuania, according to the differences in climate character (Bukantis 1994) is divided into six main regions (Januškevičius 1999): seaside lowlands, Žemaičiai Uplands, northern region of middle lowlands, southern region of middle lowlands, northern region of east Lithuania and southern region of east Lithuania (Fig. 1). The main differences in climate in mentioned regions are the following:

• Seaside lowlands are characterized with the mildest maritime climate conditions: high amount of precipitation, warmest winters (temperature of January -2.8^{o}C) and the longest period of vegetation (200-206 days).

• Climate in the region of Žemaičiai Uplands is distinguished by the highest amount of precipitation and longer lasting spring frosts.

• The smallest amount of precipitation (520-620 mm per year) is characteristic of the northern region of middle lowlands.

• Warmer winters and summers than those in the northern region are indicative for the southern region of middle lowlands.

• The most continental climate conditions with the shortest period of vegetation (185-192 days), coldest winters (-5.0 to -6.8^{o}C) and late frosts are characteristic of East Lithuania.

By using an increment borer, samples were taken at breast height. Tree ring widths were measured within 0.001 mm accuracy. For this purpose the LINTAB tree ring measuring table and TSAPWin 0.30 computer program were applied (F. Rinn Engineering Office and Distribution, Heidelberg). For the dating quality control (Eckstein 1987, Lovelius 1997) we used the COFECHA 3.00P program and for standardization – the CHRONOL 6.00P computer program (R.L. Holmes, Tucson). Each tree-ring series obtained from individual tree were standardized independently. The standardization was carried out of two stages – according to the methods, proposed by Holmes *et al*. in 1986. At first negative exponential curve or linear regression was used and after the spline, preserving 67% of variance at wavelength 21 years, was fitted (Holmes 1994). Each tree-ring width series was averaged into a local chronology of research plot. The biweight robust mean for this purpose was used (Cook 1985, Riitters 1990). Similarity between local chronologies was estimated using correlation coefficients in 1949-1981. This period is covered by the biggest amount of local chronologies: in later periods trees at several research plots were already died. As a result masterchronology for Douglas fir was compiled, which encompasses the radial growth from 15 research plots. We have excluded four local chronologies, the age of which reaches only 23-42 years.

Relationships between the radial growth and climate factors were assessed using the long-term multiple regression analysis and the short-term analysis, well known as detection of event and pointer years (Schweingruber 1990, Schweingruber 1993, Schweingruber *et al.* 1990). The long-term link between the radial growth of Douglas fir and climate (air temperature and precipitation) was ascertained applying response function analysis (Fritts 1987, Fritts and Dean 1992). For this purpose PRECON 5.17B program (H. Fritts, Tucson) was used. Calculations were performed in the period 1940-1990 by using climate variables from September of the previous year to September of the current year. Climate data were selected from the nearest meteorological stations. For the detection of event and pointer years we used method "normalisation in a moving window" (Schweingruber *et al.* 1990). Event years were detected calculating Z_i index values (formula 1).

$$Z_i = \frac{x_i - \text{mean[window]}}{\text{stdev[window]}} \qquad (1)$$

where: Z_i – index value in year i,

x_i – original value (mm) in year i,

mean [window] – arithmetic mean (mm) of the ring width within five-year window x_{i-2}, x_{i-1}, x_i, x_{i+1}, x_{i+2}

stdev [window] – standard deviation of the ring width within five-year window x_{i-2}, x_{i-1}, x_i, x_{i+1}, x_{i+2}

The threshold value of Z_i for negative event years (i.e. years with narrow ring) is ≤ -0.75 and for positive (i.e. years with wide rings) – ≥0.75. Pointer years for each research plot during 1911-2004 were detected using a 50% threshold level of event years. For the calculations we used program WEISER 1.0 (I.G. Gonzales, Lugo) (Gonzales 2001).

For the climatological interpretation of detected pointer years, climate data of the nearest meteorological stations were used. Climate extremes were judged if the differences of air temperature or precipitation from the long term mean exceed the standard deviation (Bukantis 1998). For the estimation of droughts in spring and summer months, a method (Formula 2) proposed by Walter (1974) was used.

$$P_i \le T_i \quad \text{Extreme drought} \qquad (2)$$
$$T_i < P_i \le 2T_i \quad \text{Drought}$$
$$2T_i < P_i \le 3T_i \quad \text{Arid conditions}$$

where: P_i – amount of precipitation (mm) during the month,

T_i – average temperature (°C) during the analysed month.

Results

Nineteen local chronologies on the radial growth of Douglas fir were constructed. Due to low prevalence of Douglas fir, the number of trees in local chronologies fluctuates from 2 to 23. The oldest trees found were 95 years old. The average tree ring widths of Douglas fir are 2-3 mm and the mean sensitivity of local chronologies varies from 0.16 (more complacent) to 0.35 (more sensitive) (Table 1).

Table 1. Characteristics of the radial growth of Douglas fir in Lithuania (R – Rocky Mountain Douglas fir, G – Green Douglas fir)

Research plot		Number of trees	Species	Span, years	Age, years	Ring widths, mm	Mean sensitivity
1	Dabikinė	7	R	1919-2004	86	1.78	0.20
2	Eglėsiai	6	R	1913-2004	92	1.28	0.19
3	Alytus	9	R	1949-2003	55	3.22	0.21
4	Pienionys	5	R	1914-1990	77	2.08	0.27
5	Bebrujai	11	R	1913-1993	81	1.63	0.18
6	Birštonas	7	R	1974-2003	30	4.73	0.17
7	Dubrava	21	R	1963-1985	23	5.72	0.18
8	Gelučiai	2	R	1930-1990	61	4.92	0.35
9	Jundeliškė	3	R	1962-2003	42	2.59	0.33
10	Kauno marios	7	R	1974-2003	30	5.74	0.16
11	Raudondvaris	2	R	1921-1981	61	1.94	0.27
12	Lentvaris	23	R	1910-2004	95	2.05	0.22
13	Berklainiai	11	R	1910-2004	95	1.70	0.22
14	Radviliškis	4	G	1924-1995	72	2.21	0.19
15	Rambynas-R	12	R	1927-2004	78	2.58	0.19
16	Rambynas-G	17	G	1927-2004	78	2.70	0.19
17	Užutrakis	10	R	1916-1995	80	2.17	0.21
18	Užugiris	16	R	1938-2004	67	2.70	0.24
19	Vyžulionys	14	R	1922-1992	71	2.53	0.21

Similarity between local chronologies is high and significant among all pairs. The mean coefficients of correlation among the radial growth of Douglas fir are presented in Figure 2. All coefficients are statistically significant (p≤0.01).

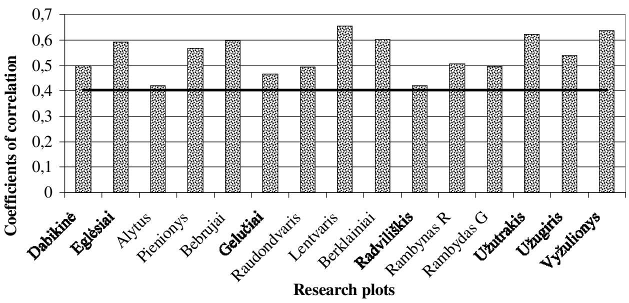

Figure 2. Coefficients of correlation among the local chronologies of Douglas fir in 1949-1981. Horizontal line indicates level of significance at p≤0.01

Masterchronology on the radial growth of Douglas fir encompasses data from 15 research plots (187 trees) (Fig. 3) and spans from 1910 to 2004. Average tree ring width is 2.22 mm and mean sensitivity – 0.16.

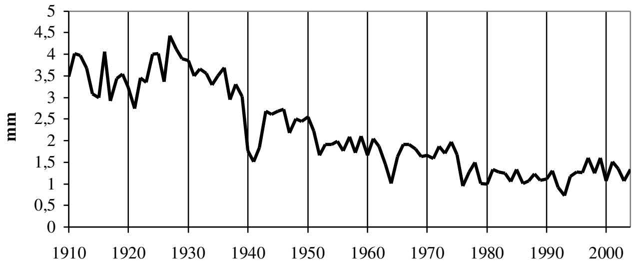

Figure 3. Masterchronology (mm) of the radial growth of Douglas fir covering 187 trees and 15 research plots

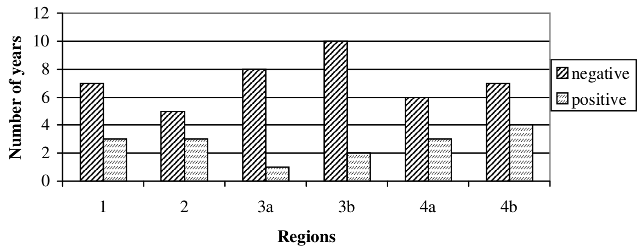

Figure 5. Number of negative and positive pointer years on the radial growth of Douglas fir in regions of introduction (see Fig. 1) in 1911-2004

Analysis of multiple regressions – response function has shown weak links between the radial growth of Douglas fir and climate factors during the autumn of the previous year. Positive links were found with air temperature in spring (February, March) and of the end of summer (August in East Lithuania and September in seaside lowlands region). Positive impact of precipitation in June is strong and significant in East Lithuania (Fig. 4).

of Žemaičiai Uplands). The highest frequency of negative pointer years and the smallest amount of positive pointer years were observed in central Lithuania: northern region of middle lowlands and southern region of middle lowlands. There was found an inverse link between the amount of negative and positive pointer years in individual regions.

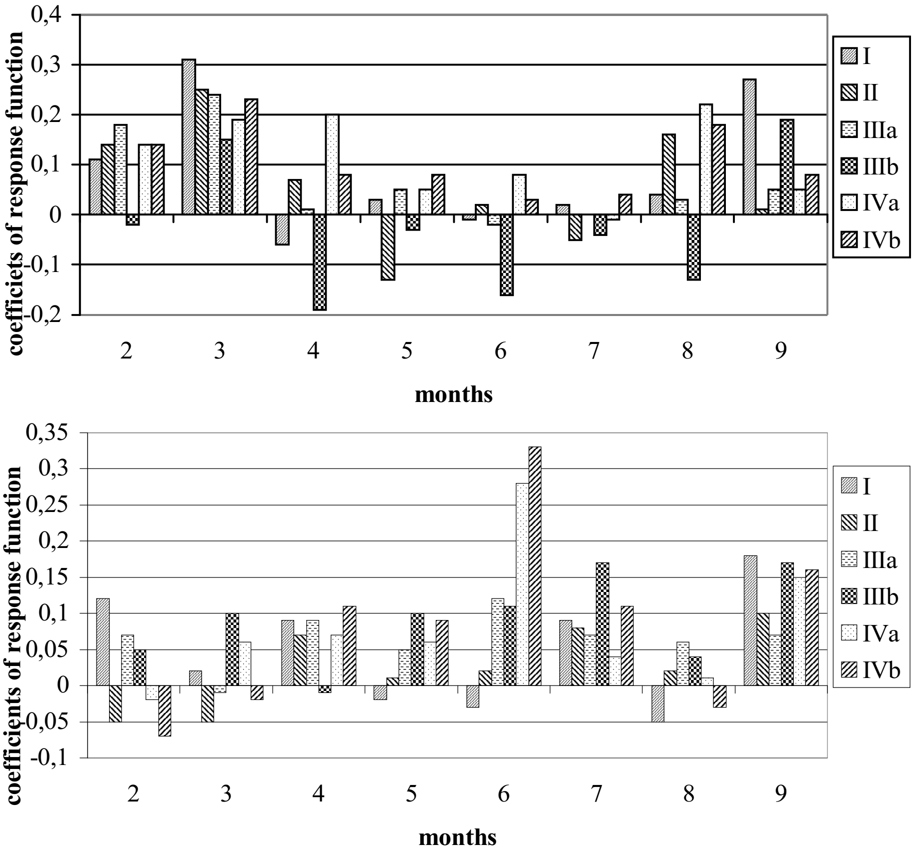

Figure 4. Average coefficients of the response function between the radial growth of Douglas fir and climate factors (air temperature – A and precipitation – B) during February-September in different regions. Asterisk (*) indicates significance (p≤0.05)

Twenty pointer years were ascertained in 1911-2004: fourteen negative (narrow tree rings) and six positive (wide tree rings). The number of detected pointer years in each introduction region is presented in Figure 5. The minimal number of negative pointer years was ascertained in West Lithuania (regions

Negative pointer years could be grouped, according to their spatial distribution, into five categories:

I. Pointer years covered the largest territory of Lithuania and detected in five or six regions: 1964, 1976 and 1993.

II. Pointer years observed in four or three regions: 1937, 1940, 1941, 1952, 1979 and 1980.

III. Pointer years detected in two or one region: 1947, 1956, 1960, 1986 and 1992.

Positive pointer years:

I. Pointer years covered the biggest territory of Lithuania and were found in five regions: 1978.

II. Pointer years detected in three or four regions: 1974 and 1991.

III. Pointer years observed in two or one regions: 1966, 1967 and 1975.

Interpretation of pointer years and climate extremes possibly connected with the decrease and increase in the radial growth of Douglas fir is presented in Table 2. It is evident that four negative pointer years are related to summer droughts. Ten negative pointer years are probably connected with the several inter-connected factors: colds in winter and spring and droughts in summer. Negative pointer years (1992 and 1993) of the radial growth of Douglas fir were caused by droughts in spring and summer.

Table 2. Negative and positive pointer years on the radial growth of Douglas fir in the regions of introduction (I-IVb) (see Fig. 1). Number of trees (%) with observed negative (-) and positive (+) pointer years. Extreme colds in winter (February, March) and spring (April) are expressed as deviations of monthly air temperature (ºC) from the long-term mean. Dry climatic conditions during summer (May-August) are indicated with abbreviations: ED – extreme drought, D – drought, A – arid conditions. Humid conditions during summer (June, July) are shown as deviations of monthly amount precipitation (mm) from the long-term mean

Pointer		Number of trees						Climate extremes						
year		I	II	IIIa	IIIb	IVa	IVb	2	3	4	5	6	7	8
1937	-			70	100		84				A-ED			A
1940	-		71		100		80	-8.6	-4.2	-2.0	A-ED			
1941	-			74	100	86	98			-3.9	A	A-D	A	
1947	-				100	86		-8.8			D			
1952	-	100		72	75				-7.6				A-D	
1956	-	84						-8.2		-2.7	D			
1960	-	88		70							A	A		A
1964	-	82	96	99	100	93	100	-4.4	-4.3		A-D	A-ED	A-ED	A
1966	+					86	73				+58			
1967	+	79							+2.9					+62
1974	+	82	77		76	71		+4.8	+2.5			+58	+58	
1975	+						89		+3.7					
1976	-	100	100	87	80	100	96		-4.1		A	A	A-D	A
1978	+		92	83	72	93	76					+38	+39	+98
1979	-	88	72		81				-3.8		A-D	A-D		
1980	-	73				71	89		-3.5			A		
1986	-			77				-7.0			A	A		
1991	+	80	84				78							
1992	-				87	100					A	D-ED	D	A
1993	-	78	100	83	76		84				A-D		A	

Climate factors determining positive pointer years are connected with warm winters and springs (1975), humid summers (1966, 1978) and integrated effect of both mentioned climate conditions (1967, 1974). The cause of positive pointer year in 1991 remains uncertain.

Discussion

The natural habitat of Douglas fir – North America (Den Ouden and Boom 1978, Hermann and Lavenger 1990, Humphries *et al.* 1995) is characterised by mild and humid climatic conditions (Waring and Franklin 1979). It is established that Douglas fir reaches 1000 years old in favourable growing conditions (Ishii and Ford 2002). Douglas fir in its natural habitat and introduced in Europe suffers from many diseases and pests: *Melolontha melolontha* Linnaeus, *Giletella cooleyi* Gill, *Choristoneura occidentalis* Freeman, *Dendroctonus pseudotsugae* Hopkins, *Dioryctria abietella* Denis and Schiffermüller, *Orgyia pseudotsugata* McDunnough, *Gilletteella cooleyi* Gillette *Oligonychus ununguis* Jacobi, *Rhabdocline pseudotsugae* Sydow and *Phaeocryptopus gaeumannii* (T. Rohde) Petr. (Butin 1996, Forestry compendium 2005, Hadley and Veblen 1993).

Previous research in Lithuania has shown that the radial growth rates of Green Douglas fir are slightly higher than these of Rocky Mountain Douglas fir. It was supposed that Rocky Mountain Douglas fir in Lithuania is more resistant to droughts and colds (Ramanauskas 1973). Later research carried out on the radial growth of Green Douglas fir and Rocky Mountain Douglas fir did not reveal any significant differences (Žeimavičius 1999). A network of our research covered 17 research plots of Rocky Mountain Douglas fir and 2 research plots of Green Douglas fir. We found that the radial growth patterns of both species are very similar (coefficients of correlation reach 0.50) and did not observe any significant differences in response to climatic factors.

Rocky Mountain Douglas fir in the natural habitat (Canada) is very sensitive to climatic conditions, especially to precipitation in spring and air temperature in the beginning of summer (Zhang *et al*. 1999). The radial growth of Douglas fir in Canada (Alfaro *et al*. 1991) synchronizes well with western larch (*Larix occidentalis Nutt.*).

Douglas fir is introduced in the European part of Russia, Parks of Moscow, but dendrochronological investigations on introduced species are absent there (Dr. Andrei Beliakov, personal communication 2004). The similar state with the research is in Latvia. However, scientists in Latvia have also noticed the worsening state of Douglas fir in several old parks of Latvia. This is observed as increased crown defoliation in 1993-1997. A part of Douglas fir trees in Latvia have died off after invasions of pests (Dr. Maris Zunde, personal communication 2004).

E. Feliksik and S. Wilczyński have conducted comprehensive dendrochronological research on Douglas fir in Poland recently (Feliksik and Wilczyński 2004a, Feliksik and Wilczyński 2004b, Feliksik and Wilczyński 2004c, Feliksik and Wilczyński 2004d, Feliksik and Wilczyński 2004e). The research has indicated that the radial growth rates of Douglas fir fluctuate from 0.28 mm to 3.96 mm and the mean sensitivity is between 0.14 and 0.25. The radial growth of Douglas fir is characterized by high similarity between local chronologies (r=0.65-0.80) even if the distance between them reaches 700 km (Feliksik and Wilczyński 2004a, Feliksik and Wilczyński 2004b). The main climate factor limiting the radial growth of Douglas fir in Poland is air temperature in February and March. The influence of precipitation is regional: the inverse link with January and positive with April-July (Feliksik and Wylczyński 2004c, Feliksik and Wylczyński 2004d). It was found that negative pointer years of the radial growth of Douglas fir in Poland are connected with cold winters and droughts during beginning of summer. Increase in the radial growth (positive pointer years) is caused by mild winter conditions and a huge amount of precipitation in summer (Feliksik and Wylczyński 2004e). These results are very close to ours. The most significant differences were observed in the links with precipitation. We did not find any significant links with precipitation in January, but on the other hand we established significant influence of precipitation in June (in the East Lithuania).

A comparison of main climatic factors limiting the radial growth of Douglas fir with the factors strongly connected with other conifer species, which naturally grows in Lithuania have shown that Douglas fir takes the middle position between Norway spruce and Scots pine. The radial growth of spruce is strongly limited by summer droughts (Vitas 2002, Vitas 2004a) and pine is sensitive to low air temperature at the end of winter and spring (Karpavičius *et al*. 1996, Vitas 2004b).

We have noticed that the last two pointer years (1992, 1993) on the radial growth of Douglas fir could be explained only with the effect of summer droughts (Table 2). Because these pointer years were not detected by E. Feliksik and S. Wilczyński in Poland (Feliksik and Wylczyński 2004e) it could be supposed that Douglas fir in Lithuania is more sensitive to droughts than in Poland. The increase in the importance of droughts on the radial growth of trees is connected with global climate change and is observed already from the middle of the 20th century (Breshears *et al*. 2005, Schober 1963). R. Schrober has also suggested that damaged caused to fir by colds reduces, while the effect of precipitation increases in Europe.

Previous research conducted on Douglas fir in Lithuania has indicated the decline of trees from 1988 to 1999. It was found that more than 50% recorded mature trees have died during this period and in 1999 there remained only 59 trees compared to 118 trees in 1988 (Žeimavičius 2002). Trees died off and were cut in three growing places during 1990-2000: the Pienionys Park, Vyžulionys Park and Bebrujai Forest. The growth patterns of Douglas fir in the Vyžulionys Park and Bebrujai Forest (Fig. 6) show a sharp decrease in the radial growth in 1992 compared to 1991. Such decrease in the radial growth of tree persisting for several years is operated by drastic changes in ecophysiological conditions, which inhibit the cambial activity (Schweingruber 1986). The radial growth of several species has shown negative pointer years as a consequence of extreme drought in 1992. This is typical especially of Norway spruce growing in Lithuania (Vitas 2001). This decrease in the radial growth of Douglas fir could be also connected with the invasion of pests. It is well known that the invasion of pests lead to high mortality of trees already declined by extreme climatic conditions (Brubaker 1978, Gedminas *et al*. 2004, Schweingruber 1986). Scarce research on the presence of pests on Douglas fir in Lithuania re-

Figure 6. The radial growth dynamics of Douglas fir in the Vyžulionys Park and Bebrujai Forest in 1980-1992

vealed the existence of at least two diseases: *Rhabdocline pseudotsugae* Sydow and *Phaeocryptopus gaeumannii* (T. Rohde) Petr. (Žuklys 1975).

It is evident that the changes in several climatic parameters of Lithuania at the end of the 20th century (Bukantis 1998, Bukantis *et al*. 2001) lead to the decreased influence of winter colds along with the increased importance of droughts during spring and summer (Vitas 2004a, Vitas 2004b). Similar processes have been observed in other countries and continents (Barbu and Popa 2003, Cook *et al*. 1988). Because the predictions of global climate change forecast more frequent extreme climatic events in the future (Hoerling and Kumar 2003, Hopkin 2004) probably summer droughts will remain as the main limiting factor for the flourishing of Douglas fir at the beginning of the 21st century in Lithuania. Because bigger amounts of precipitation and less frequent droughts are common to the west regions (Bukantis 1994) along with the minimal number of negative pointer years of Douglas fir we forecast more favourite growing conditions for Douglas fir in West Lithuania – seaside lowlands and Žemaičiai Uplands regions in the near future.

Conclusions

1. Analysis of multiple regression has demonstrated the positive impact of air temperature in February and March also with the strong positive influence of precipitation in June (East Lithuania) on the radial growth of Douglas fir.

2. Analysis of pointer years revealed the minimal number of negative pointer years in the seaside lowlands and Žemaičiai Uplands regions. This shows more favourite growing conditions for the Douglas fir in West Lithuania.

3. Increased influence of droughts on the radial growth of Douglas fir, which is demonstrated by negative pointer years in 1992 and 1993, probably is connected with the global climate change.

4. Dry off of Douglas fir at the end of 20th coincides with period of extreme droughts, which have played as a predisposing factor for the decline of Douglas fir.

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ТЕНДЕНЦИИ ОСЛАБЛЕНИЯ ЛЖЕТСУГИ В ЛИТВЕ: ДЕНДРОКЛИМАТОЛОГИЧЕСКИЙ ПОДХОД

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Резюме

В статье обсуждаются результаты дендроклиматического исследования лжетсуги сизой (*Pseudotsuga menziesii* subsp. *glauca* (Beissn.) и лжетсуги мензиса (*Pseudotsuga menziesii* (Mirb.) Franco) – интродуцированных деревьев в Литве. Анализ множественной регресии показал позитивное и статистически достоверное влияние температуры воздуха конца зимы – начала весны на радиальный прирост лжетсуги. Позитивное влияние осадков в июне является важным фактором в восточной Литве. Анализ реперных лет радиального прироста показал, что причиной падения радиального прироста лжетсуги являются зимние морозы и засухи весной и летом. На повышение радиального прироста благоприятно влияют теплые зимы и влажные лета. Наши исследования показали, что значение зимних морозов, как лимитирующего фактора для радиального прироста лжетсуги в конце XX века снизилось, и в то же время возросло значение летних засух. Оценка трендов глобального изменения климата показывает что летние засухи будут одним из основных лимитирующих факторов для сохранения лжетсуги в условиях Литвы в начале XXI века. Самые благоприятные условия для лжетсуги прогнозируются в регионах западной Литвы: приморье и возвышенности Жемайтии.

Ключевые слова: климат, лжетсуга мензиса, лжетсуга сизая, особый год, радиальный прирост