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Impact of climatic fluctuations on radial increment of English oak (*Quercus robur* L.)

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The effect of variation in climatic factors on the radial increment of English oak (*Quercus robur* L.) stands was analysed over a 200-year period. For this purpose, 27 sample plots were established in oak stands on normally irrigated and temporarily overmoistured sites on rich, very rich and very rich with ash trees sandy loam and clay soils. The results showed that over the last 50 years (1952–2002) the response of the English oak stands to mean air temperature of a hydrological year (from past October to September of the coming year) and mean monthly air temperatures of February, March, April and August was more positive than late in the 18th and in the early 19th centuries. This may indicate a positive response of oak stands to the warming climate. Radial increment of the oak stands on the temporarily overmoistured sites was negatively correlated with the precipitation sum in May and the precipitation sum for the preceding two hydrological years (r = –0.3 – (–0.47); $p < 0.05$), possibly because of a negative effect of water excess on the radial increment of oak stands on the above-mentioned sites. Over the last century, the growth of oak stands on well-drained sites with coarse-textured soils was the best during moist summers, whereas on well-drained sites on fine or coarse-on-fine textured soils it was the best during moist and warm summers.

Key words: climate change, oak, precipitation, radial increment, temperature, site type

INTRODUCTION

Variations of the annual rings of trees may be used for describing climatic fluctuations over a certain period of time (Fritts, 1987; Eckstein, 1989; Schweingruber, 1989; Stravinskienė, 2002; Juknys, Vencloviené, 1998; Kairiūkštis, Vencloviené 2000; Битвинскас, 1965). Dendrochronology may also be used to assess the effect of climatic conditions on annual rings.

In addition to the above-mentioned factors, the radial increment of trees is affected by the tree age, biological and genetic properties, pests, site conditions, stocking and humans. According to the most of the relevant studies, such important environmental extremes as winter frosts, summer droughts and heat markedly affect the variation of radial increment of forest stands over time (Bitvinskas, 1974; Shweingruber, 1989; Juknys, Vencloviené, 1998; Stravinskienė, 2002; Karpavičius, 2004 et al.). Recent studies showed that the variation of radial increment of forest stands over time is also strongly affected by the depth to the water table (Kairaitis, Karpavičius, 1996; Cater et al., 1999; Hatic et al., 2000; Cater, Cater, 2002). Oak stands often exhibit a stand-specific variation of radial increment.

According to Wazny et al. (1991), Kairaitis, Karpavičius (1996), etc., oak stands show the most uniform growth on clay soils with the depth to the water table exceeding 5 m. Stands on soils with a low depth to the water table (1.2–1.5 m) also are characterized by a uniform growth course regardless of the soil texture. However, Kairaitis and Karpavičius (1996) stressed that more studies are needed to confirm these findings. Earlier, the effect of the climatic conditions on the properties of the annual rings of oak trees had been studied without assessing the effects of the periodic means. This did not allow more explicit conclusions on the effects of climatic change (*e.g.*, climatic warming) on the radial increment of oak stands over a longer period of time. The process of global warming was noted by many studies (Sneyers, 1998; Kairiūkštis, 2000; Bukantis et al., 2001; Misson, Rasse et al., 2002; Broadmeadow et al., 2005).

The objective of this study was to assess the dynamics of the radial increment of oak stands and the

Fig. 1. Location of the oak stands studied

possible effect of climatic conditions and climatic change on the growth of oak stands.

MATERIALS AND METHODS

The studies were carried out in English oak stands on *hepatico-oxalidosa* (normally irrigated very rich), *oxolidosa* (normally irrigated rich), *oxalido-nemorosa* (temporarily overmoistured very rich) and *aegopodiosa* (temporarily overmoistured very rich with ash) site types. The oak stands were located in the forests of 12 state forest enterprises and were representing 3 eco-climatic regions of Lithuania (Fig. 1). Most of the sample plots (86%) were established in mature or overmature oak stands where an admixture of other tree species was less than 20%. Thirteen and 14 sample plots were established in temporarily overmoistured and normally irrigated sites, respectively. The classifications of forest types by Karazija (1988) and site types by Vaičys (1983) were used. In each sample plot, 1 m deep soil profiles and 5 m deep water wells were established to determine the soil type and the depth to the water table. The depth to the water table below 5 m was judged according to water level in the landscape depressions. Based on the recommendations of E. R. Cook (Cook, Kairiūkštis, 1989) and Stravinskienė (1994), increment cores were sampled from oak trees of the first and second Kraft classes. In each sample plot, 20–30 trees were randomly selected for the sampling of increment cores based on the selection methods developed by V. Hubert (1987), T. Bitvinskas (1974), E. R. Cook, L. A. Kairiūkštis (1989), V. Stravinskienė (1994), etc. The width of the annual rings was measured with the Eklund tool with the precision of 0.1 to 0.01 mm. The standard dendrochronological methods were used to calculate the annual radial increment indices (Bitvinskas, 1974; Stravinskienė, 1994). The increment norm was estimated by expressing the annual ring width as a percentage deviation from the mean value for the current 11-year period. Air temperature and precipitation records of climatic stations over 80–100 (225) year-long periods were used. The data from the Kairaitis (1978) study was used for calculation of the long-term radial increment indices of the oak stands (reaching 225 years). Data from the sample plots No. 1 to 8 were collected by J. Grigaliūnas. The radial increment indices over the period from 1850 to 2001 were calculated according to our data. The radial increment indices over the period from 1776 to 1974 were calculated according to the data of Kairaitis (1978) (Fig. 2). Thus, there was a 124-year long overlapping period between these two index series. The coefficient C_x (Bitvinskas, 1974) was used to assess the correspondence between these two index series during the overlapping period. The coefficient shows the percentage of the annual rings of the corresponding increment direction (increase or decrease) in both index series.

The coefficient of correspondence and the coefficient of correlation between the indices of the two series were high (C_x = 91% (t = 5.41) and $r = 0.89$ ($p < 0.05$)). The similarity of the two index scales over the overlapping period of 1850–1974 is also confirmed by the fact that the same climatic factors were significantly correlated with the I_{zr} values and there is less than 10% difference between 97% of the correlation coefficients. This similarity allowed merging the two series of the oak radial increment indices into the time scale of 225 years. This long-term index scale allowed to assess the effect of climatic conditions on the growth of oak stands over the last two centuries. The effect of climatic factors

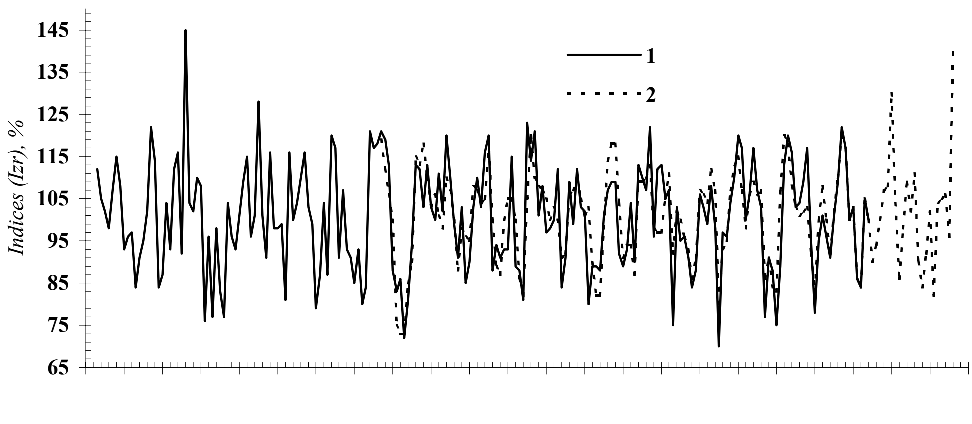

Fig. 2. Comparison of radial increment indices calculated from our data for the period 1850–2001 (curve 1) and from data of Kairaitis (1978) for the period 1775 to 1974 (curve 2)

on the oak stands growing in different site types was compared by using our data only. The Statistica for Windows 4.3 statistical software was used for data analysis.

RESULTS AND DISCUSSION

Effects of soil and hydrological conditions on radial increment of oak stands
In this section, the response of radial increment of oak stands on different soils and irrigation regimes to climatic factors over the period from 1925 to 2002 will be described (explicit climatic data were available for this period only). Based on the reaction of oak trees to site-specific hydrological properties described by Kairaitis and Karpavičius (1996), the sites were subdivided into the following three groups:

1. Fine-textured soils or coarse on fine textured soils with a shallow water table (depth of 0.60–2.0 m). According to the site type classification, these are temporarily overmoistured sites on very rich soils (Lds, Ldp indices). There were 12 such sample plots.

2. Coarse-textured soils with a deep water table (5–6 m). According to the site type classification, these are normally irrigated sites on rich soils (index Ncl). There were 3 such sample plots.

3. Fine-textured soils or coarse on fine textured soils with deep water table (depth of 4–7 m). According to the site type classification, these are normally irrigated sites on very rich soils (Ndp, Nds indices). There were 12 such sample plots.

As is shown in Fig. 3, the oak stands in the above-described site groups differently respond to climatic conditions. Radial increment of the oak stands that grow in the temporarily overmoistured sites on fine or coarse-on-fine textured soils with a shallow water table was negatively correlated with the precipitation sums over May and over the two preceding years (r = –0.33 to –0.47; $p < 0.05$) and positively correlated with the mean air temperatures of March, May, July, August, summer and annual means (r = 0.21 to 0.53; $p < 0.05$). This indicates that oak stands on the temporarily overmoistured sites are suffering from the surplus of moisture. Therefore, they negatively react to the precipitation in May, which decreases the

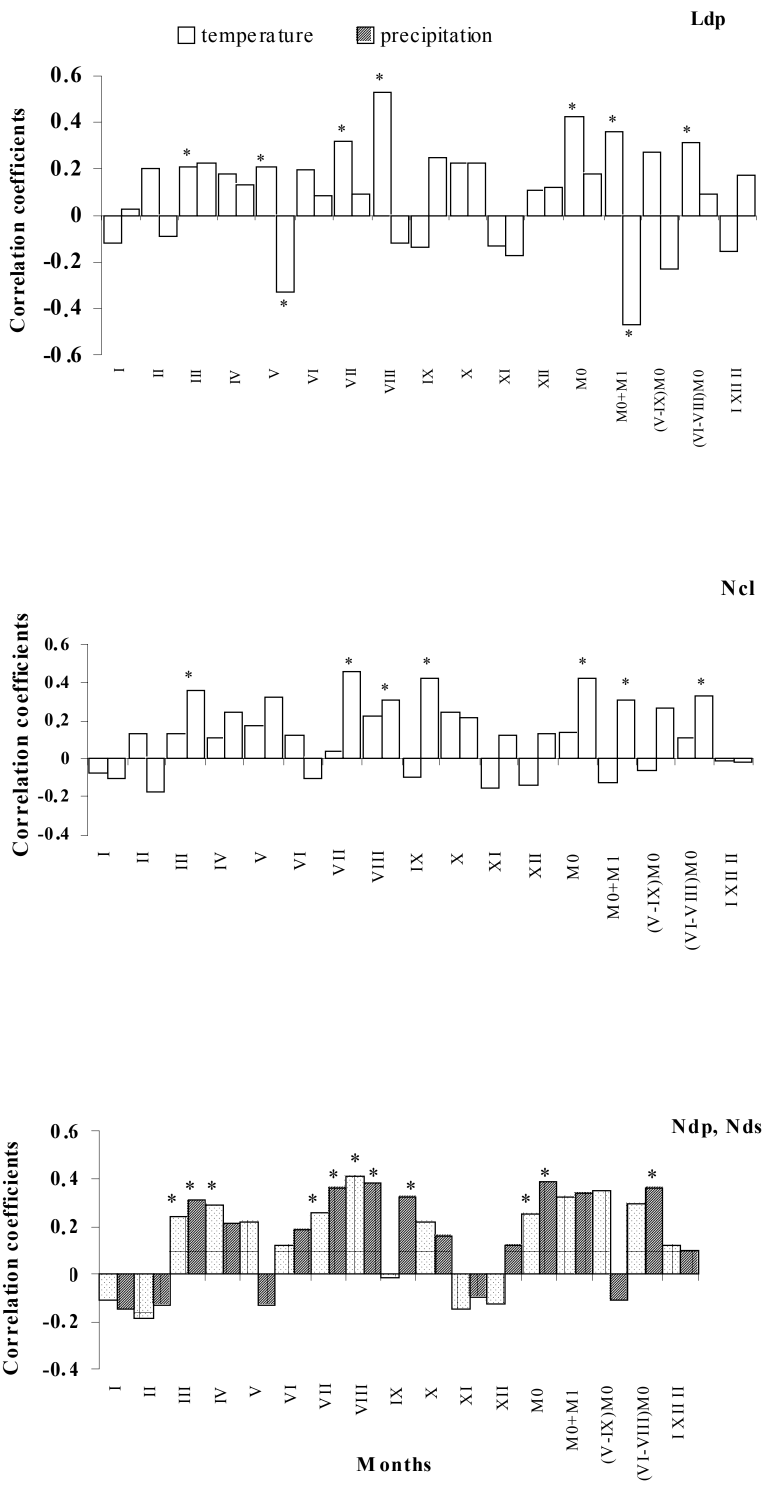

Fig. 3. Coefficients of correlation between the radial increment of oak stands and mean air temperatures (white bars) and precipitation sums (filled bards) over certain periods of time. The coefficients were calculated separately for temporarily overmoistured sites on very rich soils with coarse-on-fine soil texture (upper plot; site index Ldp), normally irrigated sites on rich, coarse-textured soils (Ncl) and for normally irrigated sites on very rich soils with fine and coarse-on-fine soil texture (Ndp; Nds). The arrows point at the coefficients that were significant at 0.05 level, where (M_0) is the hydrological year (from past October to September of the next year); (M_1) is the previous (earlier) hydrological year

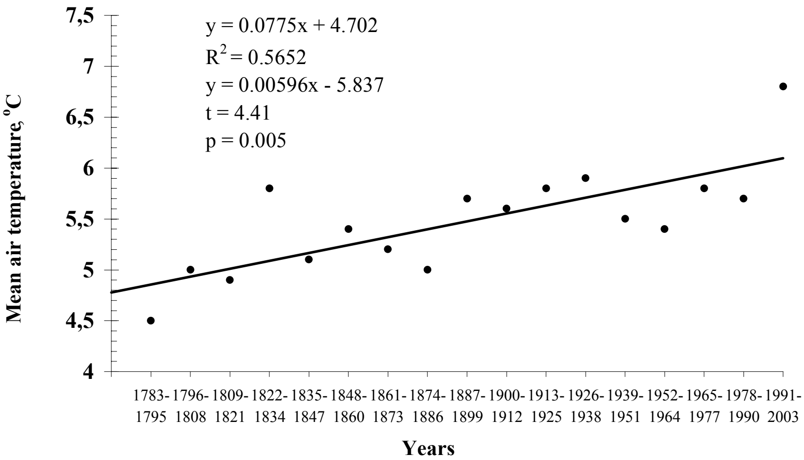

Fig. 4. Variation in mean annual temperatures averaged over 13 year periods during 1783–2003 (data from Vilnius Climatic Station)

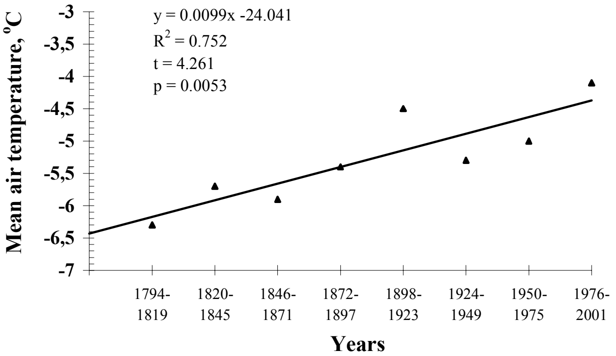

Fig. 5. Variation in mean winter temperatures (December, January, February) averaged for 26 year periods during 1785–2001

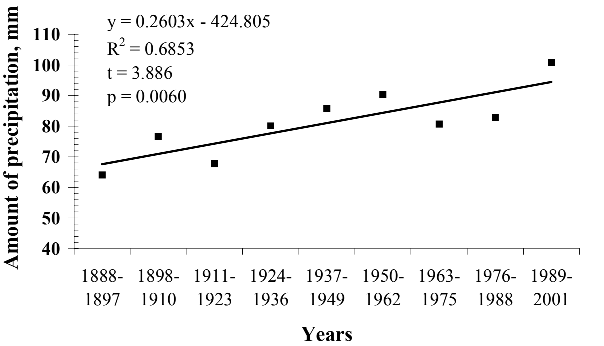

Fig. 6. Variation of the amount of precipitation in March and April averaged over 13 year periods during 1887–2001

depth of the water table at the start of the growth period, as well as to the wet periods over a couple of years leading to a lower depth to the water table at the time of the growth period. The negative effect of excess moisture on oak stands on the temporarily over-moistured sites is confirmed by the fact that these stands positively react to drainage (Ruseckas, 1997).

Radial increment of oak stands on coarse-textured soils with a deep water table (depth > 4 m) was weakly correlated with the mean monthly and seasonal temperatures (r = –0.01 to + 0.22) (Fig. 3), but the radial increment was strongly related to the mean precipitation amount in July, August, September and annual mean. This indicates that the oak stands grown on the above-mentioned sites are negatively affected by the lack of water and positively react to the precipitation which increases soil moisture during the growth period. A number of other studies confirmed a positive response of oak stands on coarse soils to precipitation during the growth period (Bauch, Eckstein, 1975; Kairaitis, Karpavičius, 1996; Smelko, Scheer, 2000 et al.).

Radial increment of oak stands on fine-textured soils with a deep water table (depth 4–7 m) was positively correlated with the monthly precipitation amounts in March, July, August, September and annual precipitation amount (the correlation coefficients between radial increment and precipitation amounts over the above-mentioned periods were significant at a 0.05 level and ranged between 0.32 to 0.39) (Fig. 3). In addition, the radial increment of the oak stands on fine textured soils with deep water table was positively correlated with the monthly temperatures of March, April, July, August and mean annual temperature (r = 0.24–0.35; p < 0.05).

These data indicate that on well drained fine-textured soils, growth of oak stands is best during warm and wet summers and, according to our earlier studies, such stands may reach a maximum wood yield index (Ruseckas, 1997).

Effects of climatic change on radial increment of oak stands

With the aim to assess the variation of climatic factors of potential significance to the radial increment of trees, we have prepared the fluctuation diagrams and developed the fluctuation equations of the mean values for the 13 to 26 year-long periods of annual mean temperatures (data for 1781 to 2003) and precipitation amounts (data for 1888–2001) (Figs. 4, 5 and 6).

At the end of the 20th century, the periodic average of the annual air temperatures over a period of 13 year was by 1.0–1.6 °C higher and the periodic average of winter temperatures over 26 years was by 1.4–2.2 °C higher than at the end of the 19th century (Figs. 4 and 5). Meanwhile, over the past 200 years, the mean air temperature during the active growth period (mean for April through September) was rising 2–3 times more slowly than the mean winter temperature, *i.e.* on the average 0.1–0.2 °C per 50 years. Though there is a noticeable tendency of gradually warmer summers, analysis of periodic mean air temperatures during summer over the period since 1975 to 2003 gave no firm proof of the rise of air temperature during summer (R^2 = 0.082–0.44; p = 0.103–0.49). Analysis of variation of mean monthly temperatures over the period from 1777 to 2003 showed that in the past the air temperature was warmer in January (R^2 = 0.67; t = 3.48), March (R^2 = 0.62; t = 3.07), April (R^2 = 0.60; t = 3.03), May (R^2 = 0.56; t = 2.77), October (R^2 = 0.69; t = 3.26), November (R^2 = 0.75; t = 4.22), and December (R^2 = 0.89; t = 7.10). Over the period from 1777 to 2003, the highest rate of increase of the mean monthly air temperature was observed in December (0.016 ˚C per year) and a somewhat lower increase was observed in April and May (0.005 ˚C per year). However, there is also a firm evidence (R^2 = 0.568; t = –2.8; p = 0.03) of a decrease in the mean monthly air temperature of August over the past 200 years (0.0032 ˚C per year). As regards the summer months (June, July and August), there was no proof of a consistent change in monthly mean air temperatures (no significant trend in temperature variation over the 200-year period was observed). Bukantis et al. (2001) obtained similar results by analysing a shorter period (1778–1997), using a specific method of moving averages over a 30-year period.

Analysis of the long-term variation (1888–2001) in annual precipitation averaged for 13-year-long periods and recorded at the Vilnius climatic station revealed a new finding of a reliable trend of increase in precipitation amount over March and April (R^2 = 0.685; t = 3.88; p = 0.006) (Fig. 6) at a rate 0.26 mm per year. A less significant but reliable trend of increase of the mean monthly precipitation amount was also observed for September (R^2 = 0.5038; t = 2.662; p = 0.03). The rate of increase of the mean monthly precipitation amount in September over the period from 1888 to 2001 was 0.21 mm per year. However, the monthly precipitation amount

Table 1. **Coefficients of correlation between the radial increment index and mean temperatures over certain periods of time in the second half of the 18th and 20th centuries and the first half of the 19th century. M_0 is mean for the current hydrological year (from past October to September of the next year)**

Months, years	1773–1799	1800–1850	1952–2002	r value over the last fifty years, in comparison with earlier fifty years: increased (+), decreased (–), practically unchanged (o)
I	–0.0825 p = 0.722	–0.1316 p = 0.357	–0.0718 p = 0.706	o
II	–0.1865 p = 0.418	–0.1316 p = 0.357	0.4122* p = 0.012	+++
III	–0.0881 p = 0.704	–0.0242 p = 0.866	0.2245* p = 0.035	+++
IV	–0.1394 p = 0.547	–0.1566 p = 0.272	0.2235 p = 0.235	++
V	0.1061 p = 0.707	0.2819* p = 0.045	0.4139* p = 0.023	+
VI	0.1068 p = 0.645	–0.2048 p = 0.149	0.0692 p = 0.716	+
VII	0.186 p = 0.209	–0.0816 p = 0.569	0.2141* p = 0.021	+
VIII	0.1887 p = 0.204	–0.1142 p = 0.425	0.545* p = 0.036	+++
IX	0.1095 p = 0.362	–0.1951 p = 0.170	–0.2049 p = 0.277	o
X	–0.1087 p = 0.639	0.2009 p = 0.158	0.1894 p = 0.316	o
XI	–0.1086 p = 0.639	0.0452 p = 0.753	0.1466 p = 0.440	+
XII	0.1504 p = 0.274	–0.1714 p = 0.229	–0.0434 p = 0.820	–
M_0	0.0501 p = 0.829	–0.1588 p = 0.266	0.4327* p = 0.017	+++
(VI–VII)M_0	0.1296 p = 0.317	–0.1746 p = 0.220	0.2396* p = 0.2046	+
(V–IX)M_0	0.1792 p = 0.2220	–0.1036 p = 0.469	0.2778 p = 0.048	+
I, XII, II	0.0197 p = 0.932	–0.1616 p = 0.257	0.214 p = 0.255	+

* Data are statistically reliable.

in August, which is the driest summer month, when plants may lack water (August was especially dry in 1994, 1996 and 2002), decreased by 30.9 mm with the annual rate of 0.30 mm over the period from 1888 to 2001 (R^2 = 0.52; t = 2.74; p = 0.029).

Based on the data presented above, we have raised a hypothesis that the variation in the annual, seasonal and monthly temperatures and precipitation amounts over the period from 1778 to 2003 may have affected the radial increment of the oak stands. Table 1 shows that this hypothesis may be true, as the radial growth of the oak stands in response to certain climatic variables has markedly changed. For instance, the mean temperature of the hydrological years (from September to August of the next year) at the end of the 18th and the beginning of the 19th century had no marked effect on the radial increment of oak stands. However, over the last 50 years (1952–2002), the mean temperature of hydrological years positively affected the radial increment of oak stands (the r values between I_{zr} and mean temperatures of hydrological years over the periods from 1773 to 1799 and from 1800 to 1849 ranged between 0.05 to –0.15 with the p value larger than 0.05; whereas, the corresponding r value for the period from 1952 to 2002 was 0.43 with the p value less than 0.05). In comparison with the late 18th century and early 19th century, over the last 50 years, a more positive reaction of oak stands to the mean monthly temperatures of February, March, April and August was observed (Table 2; $\Delta r = r_2 - r_1 \approx 0.24–0.54$, where r_1 is the correlation coefficient between the radial increment (I_{zr}) and mean monthly temperatures over the periods from 1773 to 1799 and from 1800 to 1849, and r_2 is the correlation coefficient between the radial increment (I_{zr}) and mean monthly temperatures over the period from 1952 to 2002). In addition, over this comparably warm period of the last 50 years (it was the warmest period over the last 200 years, Fig. 4) there was no marked decrease of radial increment of comparably old oak trees (over 100 years), which indicates an increase in the increment of the stand basal area. Similar results were obtained by Bednarzkij (1987) and Grigaliūnas (1997). According to Grigaliūnas (1997), presently the increment of the basal area of oak stands is twice as high as 120 years ago. According to Bednarzkij (1987), there was no marked reduction in the increment of oak stands, despite the increased pollution in the study region.

The results presented above lead to a conclusion that, generally, the reaction of oak stands to a warmer climate in Lithuania is positive and that the recent droughts had no marked effect on the growth of oak stands. However, it is worth noting that climate warming coincides with increased levels of CO_2 in the atmosphere and that the increase of CO_2 to the currently observed level has a positive effect on plant growth (Ciesla 1995; Broadmeadow et al., 2005). According to Šlapakauskas (1990), photosynthesis in plants starts when the air CO_2 concentration is 0.008–0.01% and is the most active when the CO_2 concentration reaches 0.2–0.3%, *i.e.* is 10 times higher than the naturally occurring level. It would be impossible to separate the effects of CO_2 level and air temperature on the growth of oak stands in the field conditions. However, the oak species is recognised as a xero-mesophytic species, it performs well in forested grasslands and, therefore, it is possible that the positive reaction of the growth of oak stands to the increase in annual temperatures may

Table 2. **Coefficients of correlation between the radial increment index and precipitation sums over certain periods of time in the first and second half of the 20th century. M_0 is precipitation sum for the current hydrological year (from past October to September of the next year)**

Months	Temporarily overmoistured sites		*r* value during the latter fifty years, in comparison with earlier fifty years: increased (+), decreased (–), unchanged (o)	Normally irrigated sites		
	1900–1950	1951–2001		1900–1950	1951–2001	*r* value during the latter fifty years, in comparison with earlier fifty years: increased (+), decreased (–), practically unchanged (o)
I	0.0121	0.021	o	0.060	–0.068	o
II	–0.043	–0.060	o	–0.042	–0.033	o
III	0.229	0.232	o	0.351*	0.365*	o
IV	0.121	0.146	o	0.241	0.225	o
V	–0.149	–0.305*	– – –	0.042	0.035	o
VI	0.053	0.069	o	0.227	0.117	o
VII	0.030	0.077	o	0.042	0.395*	+++
VIII	0.043	–0.112	o	–0.312*	0.211	– – –
IX	0.112	0.263	+	0.05	0.419*	+++
X	0.092	0.284	+	0.114	0.264	+
M_0	0.142	0.195	o	0.000	0.359*	+++

* Data are statistically reliable.

be linked with their tolerance of xero-mesophytic conditions.

A comparison of response of radial increment of oak stands on temporarily overmoistured and normally irrigated sites to a long-term variation (100 years) in the precipitation amount (data from 10 sample plots closest to the Vilnius and Kaunas climatic stations containing the long-term records) showed that for the oak stands on normally irrigated sites, the effect of monthly participation amounts of July, August-September and mean for a hydrological year was positive and especially increased over the last 50 years (Table 2; $\Delta r = r_2 – r_1 =$ 0.34–0.36, where r_1 is the correlation coefficient between the radial increment (I_{zr}) and mean monthly precipitation sums over the period from 1900 to 1950, and r_2 is the correlation coefficient between the radial increment (I_{zr}) and mean monthly precipitation sum over the period from 1951 to 2001). This finding may be associated with the water deficiency which over the last 50 years was mainly noted at the end of July, beginning of August or September in Lithuania. The sensitivity of forest stands to variations in precipitation under climatic warming was reported in numerous studies (Lasch, Badeck Lindner, Suckow, 2002; Misson, Rasse, Vincke, Aubinet, Francois, 2002).

Over the last 50 years, there was a noticeable lack of water in forest stands on normally irrigated sites during July and August (especially in 1964, 1965, 1970, 1971, 1975, 1983, 1991, 1996, 1999 and 2002). Evaporation in July and August of the above-mentioned years was 4–11 times higher than the precipitation. This, as is shown by our earlier studies (Ruseckas, 2002) may lead to a marked decrease of moisture in the uppermost soil layers and inhibit the takeup of water.

Analysis of the response of radial increment of the oak stands on temporarily overmoistured sites to the variation in the precipitation amount (Table 2) showed that the negative effect of monthly participation amount in May has increased twice over the last 50 years (the correlation coefficient between the radial increment and the precipitation amount in May over the period 1900 to 1950 was –0.148; $p > 0,5$, whereas for the last 50 years it was equal to –0.305 with $p < 0.05$). This negative effect may be explained by the observation that with the constantly earlier start of the growth period, oak stands become more sensitive to the soil moisture regime, which on wet sites turns to worse because of gradually increasing precipitation during March and April.

CONCLUSIONS

1. Late in the 20th century and early in the 21st century, the average of the annual mean air temperatures over the last 13-year period was by 1.0–1.6 ˚C higher and the mean air temperature in winter (mean for December, January and February) was by 1.4–2.2 ˚C higher as compared to the end of the 18th century.

2. Over the period from 1773 to 2002, there was a trend of a decrease of precipitation in the driest month of August (on the average 0.3 mm per year; $R^2 = 0.52$; $t = 2.74$; $p = 0.029$) and a trend of precipitation increase in March and April (on the average 0.26 mm per year; $R^2 = 0.685$; $t = 3.88$; $p = 0.006$).

3. Over the last 50 years (1952–2002), the reaction of oak stands to mean air temperatures for hydrological years (from past October to September of the next year) and mean monthly air temperatures of February, March, April and August was more positive than at the end of the 18th and the beginning of the 19th centuries. This may indicate a positive reaction of oak stands to the warming climate.

4. Radial increment of oak stands on temporarily overmoistured sites with fine-textured or coarse-on-fine-textured soils (site indices Lds, Ldp) was negatively correlated with the precipitation sum in May and precipitation sum for the preceding two hydrological years (r = –0.33 – (–0.47); $p < 0.05$). This indicates that the oak stands on the above-mentioned sites are suffering from water excess.

5. Over the last century, growth of the oak stands on well-drained sites with coarse-textured soils (Ncl site index) was best during moist summers, whereas the growth of oak stands on well-drained sites on fine or coarse-on-fine-textured soils was best during moist and warm summers.

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KLIMATINIŲ FLUKTUACIJŲ ĮTAKA PAPRASTOJO ĄŽUOLO (*QUERCUS ROBUR* L.) RADIALIAJAM PRIEAUGIUI

Santrauka

Analizuojama meteorologinių veiksnių bei klimato kaitos įtaka ąžuolų (*Quercus Robur* L.) radialiajam prieaugiui. Dėl to *Nc* (*oxalidosa*), *Nd* (*hepatico-oxalidosa*), *Lf* (*aegopodiosa*), *Ld* (*oxalido nemorosa*) augavietėse su įvairių uolienų (*l* – lengvų, *s* – sunkių ir *p* – dvilyčių) dirvožemiais iš viso buvo išskirta 27 tyrimo bareliai. Nustatyta, kad dėl klimato pašiltėjimo per pastarąjį penkiasdešimtmetį (1952–2002 m.), palyginti su XVIII a. pabaiga bei XIX a. pradžia, ąžuolynai pradėjo teigiamiau reaguoti į hidrologinių metų bei II, III, IV, VIII mėnesių vidutines temperatūras ($\Delta r = r_2 - r_1 \approx 0{,}24$–$0{,}54$; čia r_1 – radialiojo prieaugio (I_{zr}) ir II, III, IV, VIII mėnesių vidutinių temperatūrų ($t_{mėn.}$) koreliacija 1773–1799 bei 1800–1849 m.; r_2 – minėtų dydžių koreliacija 1952–2002 m.). Tai rodo, kad ąžuolynų reakcija į klimato šiltėjimą yra teigiama.

Ąžuolynų, augančių laikinai užmirkstančiuose dirvožemiuose su sunkiomis ir dvilytėmis (lengvos ant sunkių) uolienomis (*Lds; Ldp* augavietės), radialusis prieaugis neigiamai koreliuoja su gegužės mėnesio bei dviejų iš eilės hidrologinių metų kritulių sumomis ($r = -0{,}33 - (-0{,}47)$, $p < 0{,}05$), o tai rodo, kad medynai, augdami minėtuose dirvožemiuose, kenčia dėl drėgmės pertekliaus.

Ąžuolynai, tarpstantys gerai drenuotų lengvų uolienų dirvožemiuose (Nc_l augavietė), pastarąjį šimtmetį geriausiai augo drėgnomis vasaromis, o tarpstantys gerai drenuotuose, sunkių ir dvilyčių (lengvos ant sunkių) uolienų dirvožemiuose (Nd_p; Nd_s augavietės) – drėgnomis ir šiltomis vasaromis.

Raktažodžiai: ąžuolas, radialusis prieaugis, meteorologiniai faktoriai, klimato kaita, augavietė, dirvožemis