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DENDROECOLOGICAL CHARACTERIZATION OF DOUGLAS FIR (*PSEUDOTSUGA MENZIESII* FRANCO) IN THE WIELKOPOLSKA REGION

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ABSTRACT

Dendroclimatological analysis of Douglas firs growing in six different sites located from the east to west of the Great Poland Lowland area allowed us to determine that the factors that influenced the variability of annual wood increments were winter temperatures and the rainfall of spring and summer. The tree-ring width was positively influenced by higher than average temperatures in February and March and high amounts of rainfall from April to July. On the other hand, the increment was negatively influenced by high temperatures in May when the increment was formed and in the previous September. At sites further to the east, the more continental the climate the more pronounced was the impact of winter temperature on the tree-growth. Douglas fir within a radius of approximately 100 km were characterized by a similar rhythm of annual variability of tree-ring width, which was determined mainly by thermal conditions. Pluvial conditions, on the other hand, were the factor that diversified tree-ring chronologies. The similarity of chronologies decreased with the increase of the distance between the sites. The area of the Great Poland Lowland can be considered as dendrochronologically homogenous.

Key words: dendroclimatology, dendrochronology, dendrochronological regionalism, dendroclimatological regionalism, *Pseudotsuga menziesii*

INTRODUCTION

Douglas fir, which was introduced to Poland, has gained a permanent place in the Polish forest. Dendroclimatological research on this species conducted so far indicates that it actively reacts to pluvial and thermal conditions of the local climate [6, 7, 8]. It also seems to be a good indicator of climatic differences between even small areas, particularly in the mountains [9, 11]. In the mountainous areas, the annual rhythm of increment variability reflects the changes of thermal and pluvial conditions which follow the changes of altitude [10, 12].

Considering the findings of research conducted so far, we decided to investigate the influence of the main climatic factors on wood formation of Douglas fir growing in the lowlands with a relatively small spatial diversification of thermal and pluvial conditions. We also aimed to determine the size of the area with a homogenous rhythm of increment variability of this species. In the future, this would enable us to create a dendroclimatological regionalization of Douglas fir growing in Poland.

RESEARCH MATERIALS AND METHODS

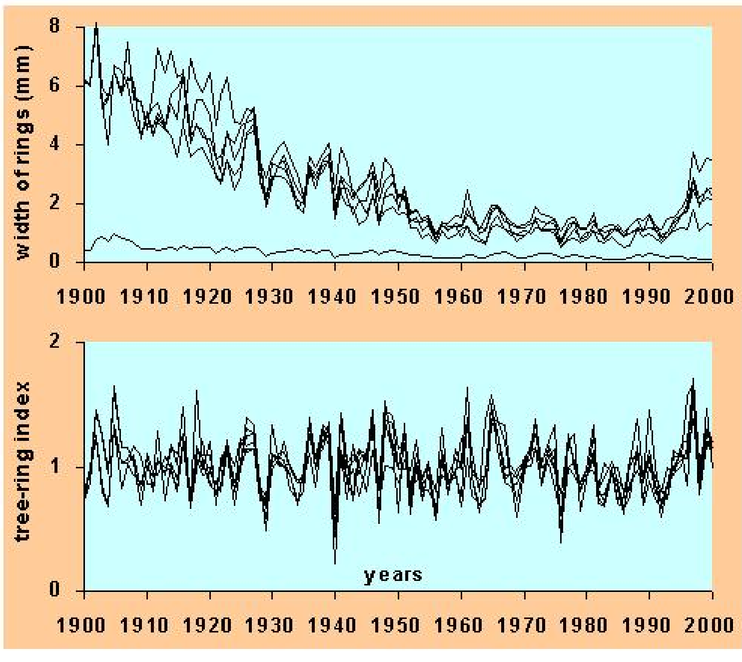
We took two samples from healthy, dominant trees selected from the six research stands containing Douglas firs in the area of The Great Lowland (Table 1, Fig. 1). The trees were cored by means of the Pressler bore at the height of 130 cm above the ground. The samples were used to measure the width of tree rings. We obtained two sequences of values known as dendroscales for each tree. Next, the dendroscales underwent the process of synchronization [14] and indexation [4]. We calculated the average tree-ring widths and average index values for 20 trees from each stand. In this manner we obtained chronologies of tree-ring widths and indexed chronologies representing the annual variability of the average increment for each research site (Fig. 2).

Table 1. Characteristic of surfaces forest stands

Forest District Division Compartment	Site code	Latitude (N) Longitude (E)	Forest site type	Soil	Species composition	Age of trees (years)
Lubsko Jeziory Dolne 24i	LBK	51° 53' 14° 44'	Fresh mixed broadleaved forest	Haplic Luvisol	4 Douglas fir, 4 oak, 2 beech	120
Nowa Sól Mirocin 176h	NSL	51° 52' 15° 29'	Fresh mixed broadleaved forest	Albi-Distric Cambisol	4 Db, 3 Douglas fir, 2 Pine, 1 larche	90
Sława Śląska Stare Strącze 331l	SLW	51° 54' 16° 05'	Fresh broadleaved forest	Haplic Cambisol	7 Douglas fir, 2 spruce, 1 oak	90
Kościan Olejnica 256h	KSC	51° 57' 16° 17'	Fresh mixed broadleaved forest	Haplic Podzol	7 Douglas fir, 2 oak, 1 pine	100
Łopuchówko Wojnowo 169c	LPC	52° 36' 17° 01'	Fresh broadleaved forest	Distric Cambisol	6 Douglas fir, 4 pine	105
Jarocin Cielcza 180a	JRC	51° 55' 17° 24'	Fresh mixed broadleaved forest	Albic Luvisol	9 Douglas fir, 1 oak	100

Fig. 1. Map of Poland: location of the study sites (circles) and meteorological stations (squares)

Fig. 2. Tree-ring chronologies of the six study sites: tree-ring widths (top) and tree-ring indices (bottom)



The aim of indexation was to eliminate from the dendroscales the long-term variability caused by non-climatic factors that influenced the tree's growth [13].

The indexes (I_i) were calculated according to the following formula:

$$I_i = R_i / Y_i$$

where: R_i - is the width of the tree-ring in year i, Y_i - is the value of the curve in the year i

In order to discover the factors which determine the relationship between increment sizes (variables) and the chronologies (objects), we used the principal component analysis [15]. It allowed us to estimate the homogeneity of growth reactions of the tree populations under research.

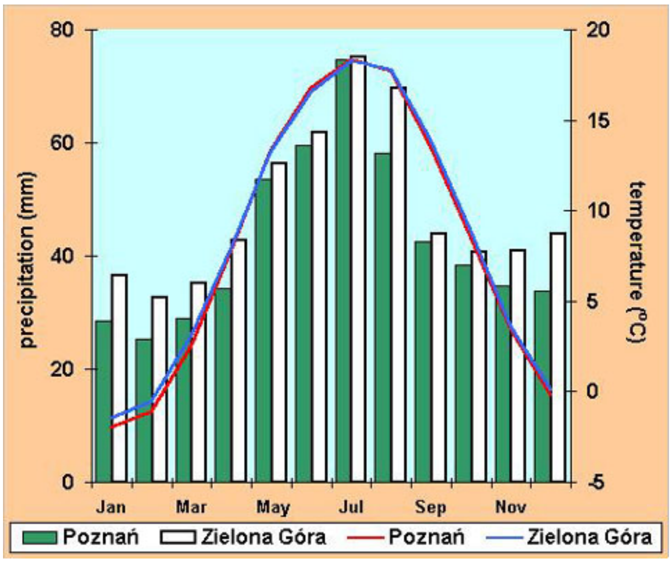
The degree of similarity among chronologies with regard to the convergence of the annual variability of the tree-ring width was estimated by calculating the convergence indicator GL [5, 17]. It was calculated according to the following formula:

$$GL = 100\ m / (n-1)\ (\%)$$

where: m - is the amount of converging sections of compared chronologies, n - is the analyzed years

In the analysis of the relationship between the size of annual increment and temperature and rainfall, we used the response function method [13, 15], in which the indexes of the years 1931-2000 played the role of dependent variables (n=70), while the values of mean monthly temperatures and monthly rainfall totals from September of the previous year to September of the year of increment formation were the independent variables.

Fig. 3. Climatic diagrams of the stations of Zielona Góra and Poznań for the years 1920-2000. Bars – mean rainfall totals, line – mean temperatures



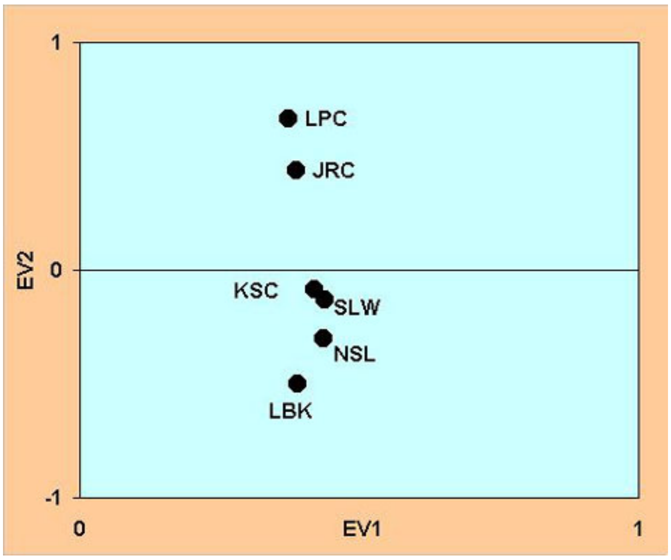
Temperature and rainfall data necessary for dendroclimatological analyses and for the creation of diagrams characterizing the regional climate were obtained from the Meteorological and Hydrological Institute station in Zielona Góra and Poznań (Fig. 3).

RESULTS

The objects of the principal component analysis were the tree-ring index chronologies of Douglas fir. We assumed that the degree of homogeneity among chronologies is a reflection of the similar reaction of trees growing in different sites to external factors.

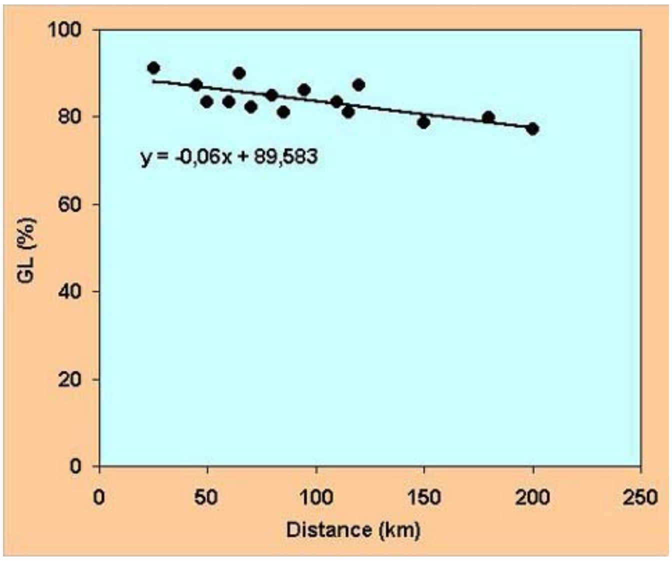
After we had transformed the variables (increment indexes) into a new set of variables (principal components), we found that the first component explains the majority (72%) of the chronologies' common variability. It correlates most strongly with the indexes of increment sizes which were formed in years when the average temperatures of February and March were very low or relatively high. The second component accounts for approximately 10% of the chronologies' common variability. It correlates most strongly with the indexes of increments formed in years with very dry or very wet vegetation seasons. The dispersion of chronologies with regard to the first or second eigenvector (Fig. 4) indicates that it was the thermal factor that integrated the chronologies, while the pluvial factor diversified them.

Fig. 4. Principal component analysis: dispersion of chronologies with regard to the first (EV1) and the second (EV2) eigenvector



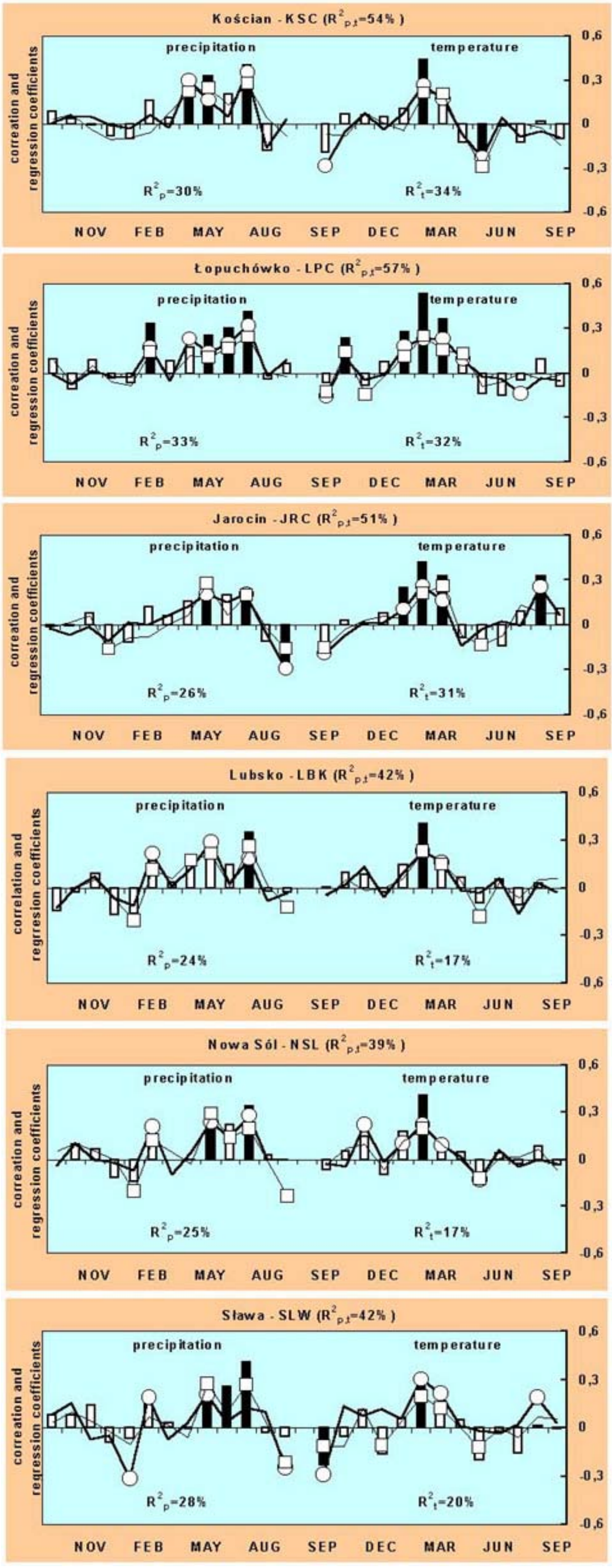
The role of the thermal factor as determining the degree of homogeneity of the increment variability in the Great Lowland is confirmed by a similar course and high values of the chronologies' convergence indicator (GL) (Fig. 2, 5). The GL indicator for the chronologies of the sites located nearest to each other (Nowa Sól – Łopuchówko: distance between sites is about 25 km) is 91.1 and it gradually decreases as the distance between research sites increases. The value of the indicator is 77.2% for chronologies from Lubsko (LBK) and Łopuchówko (LPC) which are 200 km apart. The highly significant indicator of convergence ($p<0.001$) also characterizes chronologies from sites that are even 200 km apart (Fig. 5). It indicates a convergent rhythm of annual variability of thermal conditions on large areas of the Polish lowlands and their clear, strong impact on the life processes of the trees under research. We can, therefore, regard the area where Douglas firs grow in the Great Poland Lowland within the radius of 100 km as dendrochronologically homogenous.

Fig. 5. Coefficient of convergence plot for the six site tree-ring chronologies for the common interval from 1920 to 2000



Dendroclimatological analyses conducted by means of the methods of straight-forward correlation and multifactor regression enriched our knowledge about the thermal and pluvial conditioning of the size of annual increments of Douglas fir. We found that in all research sites the tree-ring width was mainly dependent on the thermal conditions of the winter (January-March) preceding the wood formation. It also depended on the availability of rainfall during the vegetation season (April–July) (Fig. 6).

Fig. 6. Response functions and simple correlations of radial increments of Douglas fir. Coefficients of correlation – white bars; black bars - coefficients statistically significant ($p<0.05$). Coefficients of multiple regression with 13 values each of monthly precipitation and temperature – thin line, significant values ($p<0.05$) – white squares. Coefficients of regression with 13 values of monthly precipitation respectively and with 13 values of monthly temperature, respectively – bold line, significant values ($p<0.05$) – white circles. $R_{p,t}^2$ – coefficient of determination for regression with temperatures and rainfall, R_p^2 – rainfall only, R_t^2 – temperatures only



Warm winters positively influenced the trees' increments. In all research sites, low temperatures of February and March had a particularly negative effect on tree growth. The role of the thermal conditions of the winter period clearly increased towards the east. The increments from sites in the eastern part of the Lowland (Jarocin (JRC), Łopuchówko (LPC)) were limited not only by low temperatures in February and March but also by those in January and even April (Fig. 6).

In most cases, the formation of wide tree-rings was positively influenced also by low temperatures in September of the previous year and by the temperatures in May of the formation year. Rainfall was an important factor that shaped the size of annual increments (Fig. 6).

The diversity of the Douglas fir's requirements with regard to the amount of rainfall in particular seasons in different sites was not the same. Everywhere, the trees required high amounts of rainfall in May and July and, in most cases, also in February. The Douglas fir's water requirements increased with the worsening of the pluvial conditions in the eastern direction (Fig. 3). In research sites located far in the east, the formation of large increments depended not only on May and July rainfall but also on that of April and June (Fig. 6). The increments of Douglas firs (especially those growing in the western part of the Lowland – research sites of Sława (SLW), Lubsko (LBK), Nowa Sól (NSL)) were negatively influenced by high amounts of rainfall occurring in January and during the end of the vegetation season (September) (Fig. 6).

The role of the temperature (R_t^2) in the tree-ring width variability ranged from 17% - 34% and it increased with the longitude of the sites (Fig. 6). The role of precipitation (R_p^2) in shaping increment variability was from 24%-33% and it increased in the eastern direction.

The results of the regression analysis allowed us to determine that thermal and pluvial conditions of the Great Poland Lowland had a significant impact on the life processes of the trees under research. Their combined role in the annual variability of increments is expressed by the indicators of determination ($R_{p,t}^2$). The values of these indicators are 43% - 57% and they increase in the eastern direction (Fig. 6).

DISCUSSION

The annual changes in tree-ring widths a record of the meteorological conditions of a given region. Discovering these relations permits understanding the climatic requirements of tree species of in their habitat [3, 13, 22, 23].

Results of hitherto conducted dendroclimatological research on Douglas fir in Poland indicate that the main factor which limits their growth in width was thermal conditions of the winter season preceding the period of tree-ring formation. The role of rainfall in the process of xylem formation was visible mainly during the period of the greatest cambial activity and was conditioned by local features of the pluvial climate and by the soil's retentive capability [6, 7, 10].

The Douglas fir's sensitivity to frost has been known and confirmed many times since the species was introduced to Europe [2, 16, 19, 21]. Young Douglas firs often freeze and die [18, 20]. The species' resistance to low temperatures increases with age, however, long and severe frosts damage the needles, inhibit the functioning of the hormonal system and delay the activity of formative tissue consequently leading to a small annual increment. A similar role can be ascribed to low temperatures of March. It is during that time that the formation of vascular tissue begins and it is normally accompanied by the tree's decreased tolerance to temperature drops [1].

Douglas firs from all research sites within the Great Poland Lowland were characterized by a shorter or longer period of water requirements during the time of intensified cambial activity (spring and summer). This phenomenon is physiologically justifiable. The range of the tree's rainfall requirements was, at that time, probably related to the pluvial climate of the habitats and also to the retentiveness of the soil. The positive influence on increment of high amounts of February rainfall can be connected to the Douglas fir's sensitivity to very low temperatures. In winter, heavy precipitation is brought to Poland by warm, oceanic masses of air and the resulting overcast effectively reduces radiation, thus decreasing the time and frequency of severe frosts.

The course of tree-ring chronologies from individual research sites reflected the diversification of thermal and pluvial requirements which is a result of the eastbound continentality of climate. This diversification is noticeable even among sites located not very far from each other.

The results obtained confirmed that the factor that regulates the homogeneity of the Douglas fir's increment chronologies in Poland was, first of all, the thermal conditions of winter, especially those of February and

March. A similar rhythm of this factor's variability determines, therefore, the range of convergence among chronologies from various sites [7, 10]. In the case of the Great Poland Lowland, the convergence of chronologies was statistically highly significant, even when the distance between sites was 200 km. The Great Poland Lowland can therefore be considered to be a dendrochronologically homogenous area. The dendroscales of Douglas firs growing in this region can become a part of a regional chronology which reflects the standard rhythm of changes in Douglas firs' increment sizes in the area.

CONCLUSIONS

1. The Great Poland Lowland can be considered as dendrochronologically homogenous. The Douglas fir growing in this region were characterized by a similar rhythm of annual growth variability which decreased with increasing distance between sites.
2. The main factors that determined the homogeneity of the Douglas fir's increment were the thermal conditions at the end of winter. The factor that diversified the incremental rhythm was rainfall during the vegetation season.
3. The size of the radial increments was positively influenced mainly by higher-than- average temperatures in February and March and by high amounts of rainfall from April to July. Negative influence of high temperatures in May of the current year and in September of the preceding year was also observed.
4. The Douglas firs' requirements changed with increasing continentality of the climate in the eastern direction. The requirements changed even with a relatively small increase in the longitude: the increments were increasingly more affected by winter temperature and rainfall in spring and summer.

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REFERENCES

1. Bellon S., Tumiłowicz J., Król S. 1977. Obce gatunki drzew w gospodarstwie leśnym. [Foreign tree species on forest – farms]. PWRiL, Warszawa [in Polish].
2. Białobok S., Chylarecki H., 1965. Badania nad uprawą drzew obcego pochodzenia w Polsce w warunkach środowiska leśnego. [Investigation on growing foreign trees in polish forests]. Arbor. Kórnickie 10, 211-277 [in Polish].
3. Briffa K.R., Cook E. 1990. Methods of response function analysis. (In:) Cook E., Kairiukstis L. Methods of dendrochronology. Applications in the Environmental Sciences. Dordrecht. Kluwer Acad. Publ., Boston, pp. 240-247.
4. Cook E.R., Holmes R.L. 1986. Users manual for computer program ARSTAN. (In:) Holmes R.L., Adams R.K., Fritts H.C. Tree ring chronologies of western North America: California, eastern Oregon and northern Great Basin. Chronology Ser. 6. Univ. of Arizona, Tucson, pp. 50-56.
5. Eckstein D., Bauch J. 1969. Beitrag zur Rationalisierung eines dendrochronologischen Verfahrens und zur Analyse seiner Aussagesicherheit. [Contribution to the rationalization of a dendrochronological procedure to the analysis of confidence]. Forstwiss. Centralbl. 88, 4, pp. 230-250 [in German].
6. Feliksik E., 1997. Wpływ warunków meteorologicznych na szerokość sloów Jedlicy zielonej (*Pseudotsuga menziesii* Franco) z Beskidu Żywieckiego. [Influence of meteorological condition on the tree-ring width in Douglas fir (*Pseudotsuga menziesii* Franco) occurred in Beskid Żywiecki Mountains]. Pamiętnik Puławski, Prace IUNG, pp. 163-170 [in Polish].
7. Feliksik E., Wilczyński S. 1997. Klimatyczne uwarunkowania przyrostów rocznych drewna Jedlicy zielonej (*Pseudotsuga menziesii* Franco) z wybranych stanowisk w Polsce. [Climatological conditions of the Douglas fir (*Pseudotsuga menziesii* Franco) radial incremants from selected sites in Poland]. Acta Agr. Silv. ser. Silv. 35, pp. 3-16 [in Polish].
8. Feliksik E., Wilczyński S. 1998a. Dendroclimatological research on the Doulas fir (*Pseudotsuga menziesii* Franco) from northeastern Poland. Zesz. Nauk. AR w Krakowie 344, ser. Leśnictwo 27, pp. 49-57.
9. Feliksik E., Wilczyński S. 1998b. Wpływ temperatury powietrza oraz opadów atmosferycznych na przyrost drewna jedlicy zielonej (*Pseudotsuga menziesii* Franco) z Karkonoszy. [The influence of air temperature and atmospheric precipitation on the wood increment in Douglas fir (*Pseudotsuga menziesii* Franco) from the Karkonosze Mountains]. Sylwan 142, 11, pp. 55-62 [in Polish].
10. Feliksik E., Wilczyński S. 2000. Wpływ warunków klimatycznych na przyrost grubości jedlicy zielonej (*Pseudotsuga menziesii* Franco) z Beskdu Średniego. [The influence of climatic conditions on the incremant width of the Douglas fir (*Pseudotsuga menziesii* Franco) from the Beskid Średni Mountains]. Probl. Zagosp. Ziem Gór. 46, PAN, pp. 87-96 [in Polish].
11. Feliksik E., Wilczyński S. 2001. The influence of temperature and rainfall on the increment width of native and foreign tree species from the Istebna Forest District. Folia Forestalia Polonica. Ser. A- Forestry 43, pp. 104-114.

12. Feliksik E., Wilczyński S. 2002. Sygnał klimatyczny w słojach drewna deglezji zielonej (*Pseudotsuga menziesii* Franco) z Sudetów. [The climatological signal in tree-rings of Douglas fir (*Pseudotsuga menziesii* Franco) from the Sudety Mts]. Acta Agr. Silv. Ser. Silv. 40, pp. 17-30.
13. Fritts H.C. 1976. Tree Rings and Climate. Acad. Press, London, pp. 567.
14. Holmes R.L. 1986. Quality control of crossdating and measuring. Users manual for computer program COFECHA. (In:) Holmes R.L., Adams R.K., Fritts H.C. Tree rings chronologies of western North America: California, eastern Oregon and northern Great Basin. Chronology Ser. 6. Univ. of Arizona, Tucson, pp. 41- 49.
15. Holmes R.L. 1994. Dendrochronology Program Library. Univ. of Arizona, Tucson, pp 41.
16. Holubcik M. 1968. Cudzokrajne dreviny w lesnom hospodarstvie. [Foreign tree species on forest – farms]. Slov. Vyd. Podohosp. Lit., Bratislava [in Slovak].
17. Huber B. 1943. Über die Sicherheit jafringchronologischer Datierung. [About the confidence of tree-ring dating]. Holz als Roh- und Werkstoff 36, pp. 263-268 [in German].
18. Lacaze J.F. 1964. Note sur la résistance au froid du Douglas suivant l'orgine des graines. [Information of relate resistance onto cold daglezji in dependence from origin of seeds]. Rev. For. Franc. 3, pp. 225-227 [in France]
19. Maciejowski K. 1951. Egzoty naszych lasów. [Foreign species in our forest]. PWRiL, Warszawa [in Polish].
20. Suchocki S. 1926. Pseudotsuga Douglasi. Dotychczasowe wyniki jej aklimatyzacji w Poznańskiem. [Results of investigation on Pseudotsuga Douglasi from Poznań region]. Poznań [in Polish].
21. Schwappach A. 1920. Beiträge zur Kenntnis der Wachstumsleistungen von Pseudotsuga Douglasi. [Contributions to our knowledge of the growth potential of Pseudotsuga Douglasi]. Mitt. d. DDG [in German].
22. Wilczyński S. 1999. Dendroklimatologia sosny zwyczajnej (*Pinus sylvestris* L.) z wybranych stanowisk w Polsce. [Dendroclimatology of Scots pine (*Pinus sylvestris* L.) from selected sites in Poland]. Diss., Zak. Klimat. Leśnej, AR w Krakowie [in Polish], pp. 85.
23. Zielski A. 1997. Uwarunkowania środowiskowe przyrostów radialnych sosny zwyczajnej (*Pinus sylvestris* L.) w Polsce Północnej na podstawie wielowiekowej chronologii. [Enviromental conditions of radial growth of Scots pine (*Pinus sylvestris* L.) in northern part of Poland on the base of long-term chronology]. Praca habilit. Uniw. M. Kopernika w Toruniu [in Polish], pp. 127.

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