THE EFFECT OF AIR TEMPERATURE AND PRECIPITATION ON THE SIZE OF ANNUAL GROWTH RINGS IN A WILD-GROWING FORM OF THE ELDERBERRY (*Sambucus nigra* L.) IN THE ŚWIĘTOKRZYSKI NATIONAL PARK

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A B S T R A C T

Dendroclimatic analysis was used to estimate the effects of air temperature and precipitation on the size of annual rings of the elderberry (*Sambucus nigra* L.). Two bushes were chosen for the study. They were each about 35 years old, and were found growing on brown alluvial soil in a *Fraxino-Alnetum* community in the Świętokrzyski National Park.

Air temperature and rainfall had a significant effect on the growth of the vascular cambium during the growing season. This effect could be accurately estimated from the size of the annual rings of the bushes. The widest rings were produced in years preceded by a warm autumn in which the spring was cold, June was dry, July was wet and warm, and August was warm. Winter weather conditions did not affect the growth of annual rings produced in the following year.

Key words: *Sambucus nigra*, dendroclimatology, dendrochronology, climatic condition, tree-ring width

INTRODUCTION

The elderberry (*Sambucus nigra* L.) belongs to the family *Caprifoliaceae,* and grows throughout Europe, as well as in northern Africa and Asia Minor (Hultén and Fries, 1986). In Poland, it can be encountered everywhere up to 1200 m above the sea level (Tomanek, 1997). The elderberry is a large shrub which can grow to even 10 m in height. The blossoms appear in June, and the fruits begin to ripen in August or September, depending on the locality.

The elderberry grows in forests, on river banks, in old parks or near buildings (Ellenberg, 1988). Although it is not considered to be a fastidious species, it grows and bears best in fertile soils rich in nitrogen and phosphorus (Rackham, 1986). It prefers moist soils and abundant sunshine (Atkinson and Atkinson, 2002).

The bark, roots, leaves, blossoms and fruit of the elderberry have medicinal properties, and are a source of antioxidants, anti-tumor agents, and many macro- and microelements (Abuja et al., 1998; Moszczyński, 1996; Obidowska, 1998; Oszmiański and Lamer-Zarawska, 1995; Waźbińska et al., 1998; Waźbińska and Puczel, 2002). The fruits are highly appreciated for their taste and nutritional value, and are used to produce delicious jams and jellies (Waźbińska et al., 1996).

The aim of this study was to determine the effect of air temperature and precipitation on the activity of the vascular cambium of the elderberry as expressed by the size of annual growth rings. This was the first time dendroclimatic investigations were carried out on the elderberry in Poland.

MATERIAL AND METHODS

Two elderberry bushes were chosen for the study. They were each about 35 years old, and were found growing on very fine, brown, sandy alluvial soil in a *Fraxino-Alnetum* community in Bodzentyn in the Świętokrzyski National Park. Because the elderberry rarely lives long, finding healthy specimens over thirty years old is very difficult, and no other bushes in the area lent themselves to dendroclimatic analysis.

Two cores were taken from the stem of each bush, 1.3 m above ground level. Annual growth rings were measured. The data were checked using the COFECHA computer program (Holmes, 1986), and were indexed using the ARSTAN computer program to eliminate bias and long term fluctuations (Cook and Holmes, 1986). Agreement between the chronology based on temperature and precipitation data and the indexed chronology was estimated using the coefficient of convergence (GL) (Huber, 1943; Eckstein and Bauch, 1969).

The relationship between weather conditions and the size of annual growth rings was analyzed with the help of methods commonly employed in dendroclimatic studies, such as linear correlation, multiple regression, the response function, and analysis of signal years (Fritts, 1976; Lough, unpublished; Holmes, 1995; Schweingruber et al., 1990, 1991). Weather data for the period from 1976 to 2003 were provided by the meteorological station in Bodzentyn, at which the Institute of Meteorology and Water Management has been recording weather data since 1955.

The analyses were carried out in several stages. First, the coefficients of linear correlation between mean monthly air temperature and total monthly precipitation and the standardized size of the growth rings were calculated (Cook and Holmes, 1986). For analysis of the effect of temperature and precipitation on annual growth rings development in a given season, meteorological data were taken for a period from September of the year preceding the ring growth until September of the year when the ring growth was completed. In the next three stages, the coefficients of multiple regression were calculated to yield the response function. Regression analysis was performed using the following independent variables: mean monthly air temperature (13 months), total monthly precipitation (13 months), and both combined (26 independent variables). In each case, the coefficient of multiple correlation and the coefficient of determination of multiple regression were calculated. The significance of coefficients of multiple regression was estimated using the F test.

Multiple regression, the response function, and linear regression were used to assess the quality of the regression models based on mean monthly air temperature, total monthly precipitation, and growth ring size. Computations were performed with the help of the RESPO computer program (Holmes, 1995).

Weather conditions prevailing in signal years were also analyzed. A signal year is a year in which either exceptionally wide or exceptionally narrow tree rings are produced.

RESULTS

Annual ring size strongly decreased from 1976 to 1986, after which it leveled out (Fig. 1). Fluctuations in ring size were small from 1976 to 1989, and very large from 1990 to 2003. The dynamics of annual ring size indicate that external factors which change from year to year strongly influence cambium growth. Indexing eliminated the trend toward decreasing growth ring size due to the increasing age and size of the bushes and accentuated the annual variation in growth ring size. The chronology based on temperature and precipitation data is in complete agreement with the indexed chronology, with a coefficient of convergence (GL) of 100%.

The coefficients of linear correlation and multiple regression indicate that there is a significant relationship between air temperature and precipitation during the growing season and the size of annual growth rings (Fig. 2). There was a positive ($p<0.01$) relationship between precipitation in July, temperature in July, and temperature in August of the year the ring was formed and ring size. There was a negative ($p<0.01$) relationship between precipitation in June, temperature in April, and temperature in May of the year the ring was formed and ring size. There was also a positive ($p<0.05$) relationship between temperature in November of the year before the ring was formed and ring size (Fig. 2).

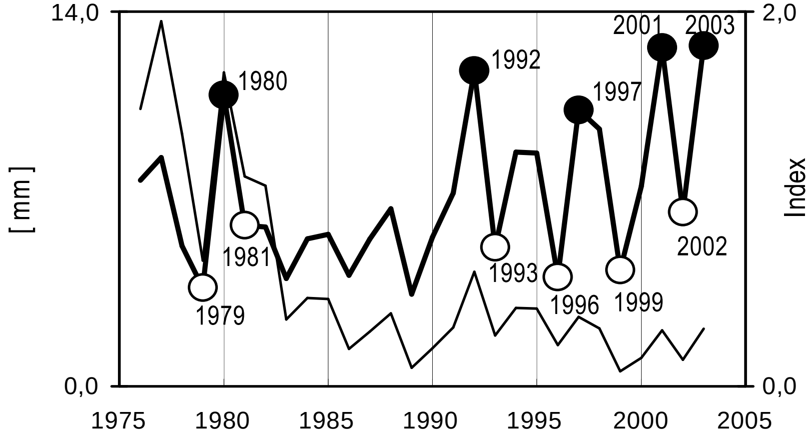

Figure 1. Chronology of the size of annual growth rings. Thin line: observed chronology. Thick line: indexed chronology. Black circles: years when exceptionally wide rings were formed. White circles: years in which exceptionally narrow rings were formed

T a b l e 1 . Relationships between mean monthly air temperature and total monthly precipitation the standardized size of annual growth rings and on the basis of multiple regression, the response function, and linear regression

Independent variables considered in equation of multiple regression	Coefficient of correlation (R), and of determination (R^2) of multiple regression and results of test (F)			Coefficient of linear correlation	Coefficient of convergence
	R	R^2 [%]	F	r	GL [%]
Temperature	0.794	62.9	3.8 p<0.008	0.791 p<0.001	81.5 p<0.001
Precipitation	0.687	47.3	3.7 p<0.010	0.668 p<0.001	74.1 p<0.010
Temperature and precipitation	0.968	93.8	11.0 p<0.002	0.968 p<0.001	96.3 p<0.001

p – significance level

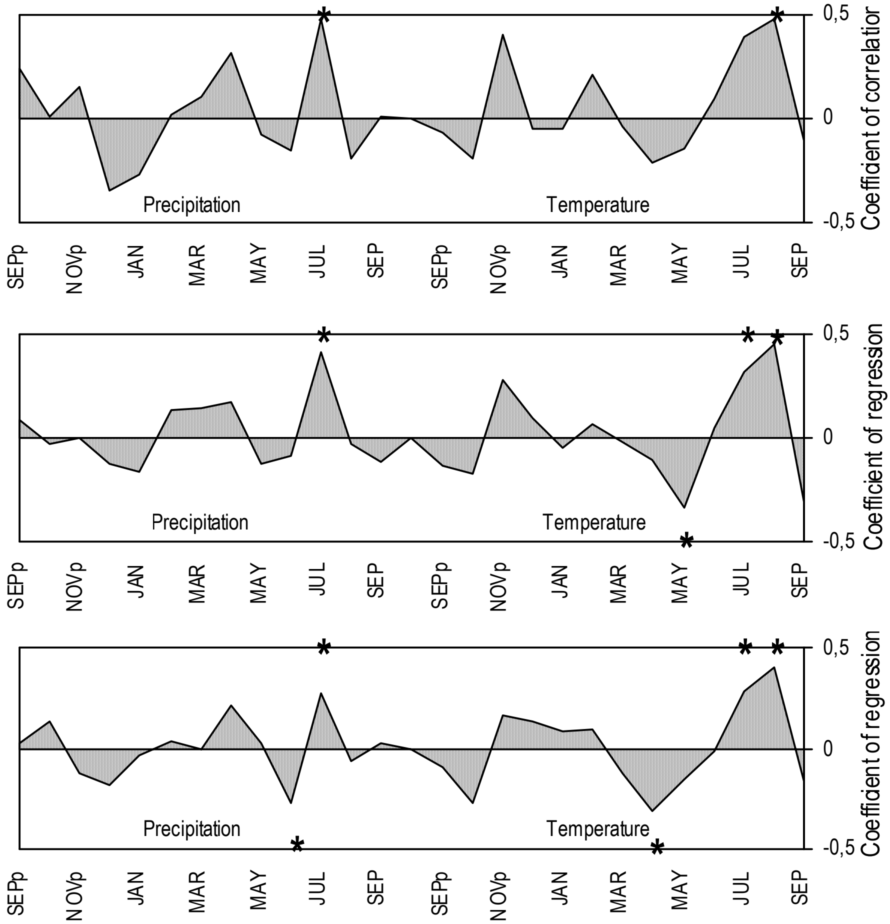

Figure 2. Top: coefficients of linear correlation between mean monthly air temperature and total monthly precipitation and the size of annual growth rings

Middle: coefficients of multiple regression computed for temperature and precipitation separately

Bottom: coefficients of multiple regression for temperature and precipitation taken together. The data presented cover a period from September of the previous year (SEPp) to September of the current year (SEP). Values significant at $p \leq 0.01$ are marked with a star

The coefficients of correlation and convergence presented in Table 1 and the observed and indexed chronologies presented in Figure 3 demonstrate that growth ring size can be accurately predicted on the basis of temperature alone or precipitation alone, although the most accurate predications can be

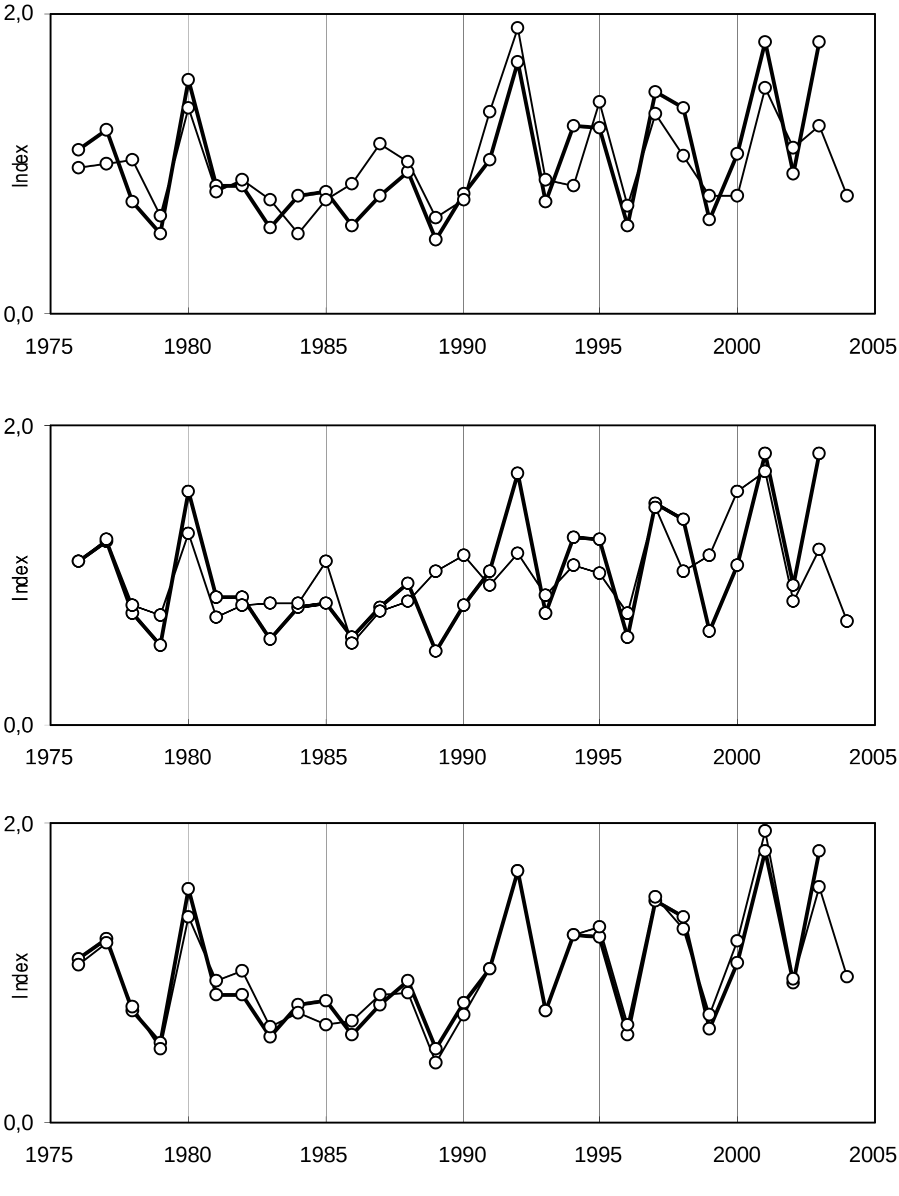

Figure 3. Chronology of annual growth ring size based on mean monthly air temperature (thin line, top figure), total monthly precipitation data (thin line, middle figure) and temperature and precipitation taken together (thin line, bottom figure). The thick line represents the indexed chronology

made on the basis of both temperature and precipitation together. The relationship between ring size and the combined temperature and precipitation data was so reliable that it could almost be expressed in the form of a functional equation. Temperature had a 33% larger effect on ring size than did precipitation. The chronology based on temperature and precipitation data is almost identical to the indexed chronology.

The factor that best correlated with tree ring size was temperature in July (GL=72.0%) (Fig. 4).

The weather during and before signal years also showed certain patterns. Exceptionally wide rings were formed in 1992, 1997, 2001 and 2003. Exceptionally narrow growth rings were formed in 1996, 1999 and 2002. In years with exceptionally wide growth rings, precipitation in July was always high, and temperatures in the preceding November were very high. In years with exceptionally narrow growth rings, precipitation in July was always low, and temperatures in the preceding November were very low.

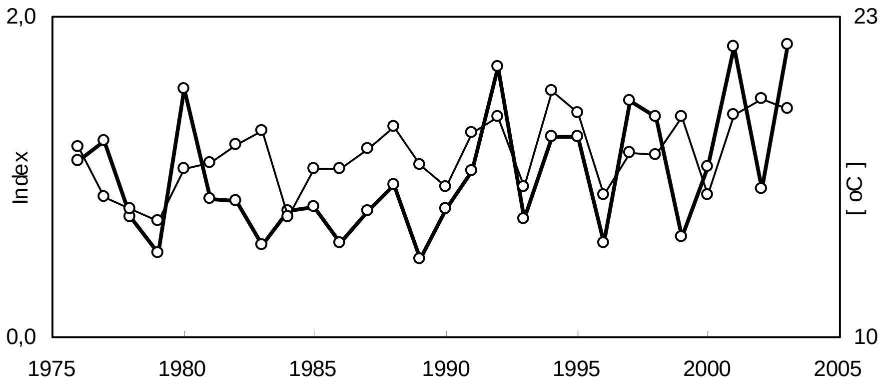

Figure 4. Mean monthly temperature in July (thin line) and the indexed chronology (thick line)

DISCUSSION

There is no comprehensive information on dendroclimatology in the elderberry in the literature. Only a few authors have reported that warm summers favor growth and fruit production in the elderberry (Grime et al., 1988; Atkinson and Atkinson, 2002), that late spring frosts cause leaf loss or even the death of the whole bush (Grime et al., 1988; Vogt, 2001), and that shoots produced during the second half of the growing season are usually damaged during severe winters (Metcalfe, 1948).

This study shows that air temperature and precipitation during the growing season strongly influence the size of annual growth rings. The largest rings were formed in years following a warm November with a cool and wet spring and a warm and wet summer. The elderberry is more sensitive to temperature and precipitation than other trees (Feliksik and Wilczyński, 1998; Feliksik et al., 2000; Wilczyński and Gołąb, 2001; Wilczyński and Skrzyszewski, 2002; Wilczyński, 2003). Further studies involving numerous specimens growing in different sites are needed to elucidate whether this is a feature of the species itself or the site selected for this study. Nevertheless, this study shows that the size of annual growth rings in the elderberry accurately reflect the weather conditions, and in particular air temperature and precipitation, in the growing seasons in which they were formed.

When all growth years were taken into consideration, there was a positive correlation between both precipitation and temperature in July and ring size. However, if only signal years were taken into consideration, there was a positive correlation between ring size and precipitation in July, but there was no correlation between ring size and the temperature in July.

This study also showed that the elderberry is not as susceptible to winter frosts as many other forest tree species, especially conifers (Feliksik and Wilczyński, 2003, 2004; Wilczyński and Skrzyszewski, 2003).

Conditions particular to the site chosen for this study may also affect the size of annual growth rings independent of air temperature and precipitation. Therefore, further studies on numerous specimens from various sites are needed in order to develop a mode which is more generally applicable.

CONCLUSIONS

The size of annual growth rings in the elderberry bushes in this study was highly dependent on air temperature and precipitation during the growing season in which they were formed. The chronology of annual growth rings very accurately reflects the weather conditions, and in particular air temperature and precipitation, recorded at this site.

Exceptionally large rings were formed in years following a warm autumn with a cold and wet spring, a dry June, a wet and warm July, and a warm August, the month in which ring formation ceases.

In this study, the activity of the vascular cambium and the sizes of the rings produced in a given growing season were not significantly affected by frosts during the previous winter.

REFERENCES

Abuja P.M., Murkovic M., Pfannhauser W. 1998. Antioxidant and prooxidant activities of elderberry (*Sambucus nigra*) extract in low-density lipoprotein oxidation. J. AGRIC. FOOD CHEM. 46: 4091-4096.

Atkinson M.D., Atkinson E. 2002. *Sambucus nigra* L. J. ECOL. 90: 895-923.

Cook E.R, Holmes R.L. 1986. Users manual for program ARSTAN. In: R.L. Holmes, R.K. Adams, H.C. Fritts (eds), Tree-ring chronologies of Western North America: California, eastern Oregon and northern Great Basin. CHRONOLOGY SER. 6, Univ. of Arizona, Tucson, pp. 50-65.

Eckstein D., Bauch J. 1969. Beitrag zur Rationalisierung eines dendrochronologischen Verfahrens und zur Analyse seiner Aussagesicherheit. FORSTW. CBL. 88: 230-250.

Ellenberg H. 1988. Vegetation ecology of Central Europe. 4th ed., Cambridge University Press, Cambridge, 731 p.

Feliksik E., Wilczyński S. 1998. Wpływ temperatury i opadów na przyrost roczny drewna świerka, sosny i modrzewia występujących w leśnictwie Pierściec u podnóża Pogórza Wilamowickiego. KOMITET ZAGOSP. ZIEM GÓRSKICH 44: 77-86.

Feliksik E., Wilczyński S. 2003. Termiczne uwarunkowania przyrostu tkanki drzewnej świerka pospolitego (*Picea abies* (L.) Karst.) w reglu dolnym Beskidu Żywieckiego. ACTA AGRAR. SILV. SER. SILV. 41: 15-24.

Feliksik E., Wilczyński S. 2004. Klimatyczne uwarunkowania przyrostu radialnego daglezji zielonej (*Pseudotsuga menziesii* (Mirb.) Franco) rosnącej na obszarze Polski. SYLWAN 148, 12: 31-38.

Feliksik E., Wilczyński S., Podlaski R. 2000. Wpływ warunków termiczno-pluwialnych na wielkość przyrostów radialnych sosny (*Pinus sylvestris* L.), jodły (*Abies alba* Mill.) i buka (*Fagus sylvatica* L.) ze Świętokrzyskiego Parku Narodowego. SYLWAN 144, 9: 53-63.

Fritts H.C. 1976. Tree-rings and climate. Acad. Press, London, 567 p.

Grime J.P., Hodgson J.G., Hunt R. 1988. Comparative plant ecology: a functional approach to common British species. Unwin-Hyman, London, 742 p.

Holmes R.L. 1986. Quality control of crossdating and measuring. Users manual for computer program COFECHA. In: R.L. Holmes, R.K. Adams, H.C. Fritts (eds), Tree-rings chronologies of western North America: California, eastern Oregon and northern Great Basin. CHRONOLOGY SER. 6, Univ. of Arizona, Tucson, pp. 41-49.

Holmes R.L. 1995. Response function – user manual. In: R.L. Holmes (ed.), Dendrochronology Program Library, Univ. of Arizona, Tucson, pp. 50-51.

Huber B. 1943. Über die Sicherheit jahrringchronologischer Datierung. HOLZ ALS ROH- UND WERKSTOFF 36: 263-268.

Hultén E., Fries M. 1986. Atlas of North European vascular plants north of the tropic of cancer. Vol. 2. Koeltz Scientific Books, Königstein, 470 p.

Metcalfe C.R. 1948. The elder tree (*Sambucus nigra* L.) as a source of pith, pegwood and charcoal with some notes on the structure of the wood. KEW BULL. 1: 163-169.

Moszczyński P. 1996. Jak zmniejszyć ryzyko zachorowania na miażdżycę. Cz. IV. WIAD. ZIEL. 6: 13-14.

Obidowska G. 1998. Substancje pochodzenia roślinnego w profilaktyce nowotworów. PRZEG. PIEKAR. CUKIER. 7: 2-4.

Oszmiański J., Lamer-Zarawska E. 1995. Naturalne flawonoidy w profilaktyce chorób układu krążenia. WIAD. ZIEL. 7/8: 27.

Rackham O. 1986. The history of the countryside. J.M. Dent and Sons, London, 445 p.

Schweingruber F.H., Eckstein D., Serre-Bachet F., Bräker O.U. 1990. Identification, presentation and interpretation of event years and pointer years in dendrochronology. DENDROCHRONOLOGIA 8: 9-38.

Schweingruber F.H., Wehrli U., Aellen-Rumo K., Aellen M. 1991. Weiserjahre als Zeiger extremer Standorteinflüsse. SCHWEIZ. Z. FORST. 142: 33-52.

Tomanek J. 1997. Botanika leśna. PWRiL, Warszawa, 506 p.

Vogt U.K. 2001. Hydraulic vulnerability, vessel refilling, and seasonal courses of stem water potential of *Sorbus aucuparia* L. & *Sambucus nigra* L. J. EXP. BOT. 52: 1527-1536.

Waźbińska J., Kawecki Z., Majewska E. 1998. Zawartość związków mineralnych w owocach bzu czarnego u odmian szlachetnych i form dziko rosnących. XXXVII Ogólnopol. Nauk. Konf. Sad., Skierniewice 25-27 sierpnia 1998, pp. 271-273.

Waźbińska J., Nesterowicz J., Rafałowski R. 1996. Przetwory z owoców mało znanych. II Ogólnopol. Symp., "Nowe rośliny i technologie w ogrodnictwie" 1, Poznań 17-19 września 1996, pp. 298-301.

Waźbińska J., Puczel U. 2002. Fruit characteristics of elderberry (*Sambucus nigra* L.) grown on two different soils. J. FRUIT ORNAM. PLANT RES. 10: 111-121.

Wilczyński S. 2003. Modele „klimat-przyrost radialny" sosen z Tatr, Pienin i Ojcowa. SYLWAN 147/12: 27-35.

Wilczyński S., Gołąb J. 2001. Sygnał klimatyczny w słojach drewna buka zwyczajnego (*Fagus sylvatica* L.) z Beskidu Wyspowego. SYLWAN 145, 10: 61-72.

Wilczyński S., Skrzyszewski J. 2002. The climatic signal in tree-rings of Scots Pine (*Pinus sylvestris* L.) from foot-hills of the Sudetic Mountains (southern Poland). FORSTW. CBL. 121: 15-24.

Wilczyński S, Skrzyszewski J. 2003. Dendrochronology of Scots Pine (*Pinus sylvestris* L.) in the mountains of Poland. J. FOR. SCI. 49: 95-103.

WYMAGANIA KLIMATYCZNE FORMY DZIKO ROSNĄCEJ BZU CZARNEGO (*Sambucus nigra* L.) W ŚWIĘTOKRZYSKIM PARKU NARODOWYM

Sławomir Wilczyński i Rafał Podlaski

S T R E S Z C Z E N I E

W pracy badano wpływ temperatury powietrza oraz opadów atmosferycznych na wielkość słojów drewna bzu czarnego (*Sambucus nigra* L.). Badano dwa około 35-letnie krzewy, rosnące w Świętokrzyskim Parku Narodowym, na madzie brunatnej, w zbiorowisku łęgu jesionowo-olszowego *Fraxino-Alnetum*. Z pnia każdego z krzewów pobrano po dwa wywierty, na których zmierzono szerokości słojów drewna. Analiza związków między warunkami klimatycznymi w latach 1976-2003 a wielkością przyrostów radialnych wykazała, że warunki termiczno-pluwialne panujące w okresie wegetacji miały wysoce istotny wpływ na aktywność kambium waskularnego badanych krzewów. Bzy czarne z dużą precyzją rejestrowały w wielkościach corocznie odkładanych słojów drewna wartości temperatury powietrza i opadów atmosferycznych. Szerokie słoje drewna były tworzone po ciepłej jesieni, zimnej wiośnie oraz w czasie suchego czerwca, mokrego i ciepłego lipca oraz ciepłego sierpnia. Mrozy zimowe nie miały negatywnego wpływu na aktywność kambium waskularnego bzów w najbliższym okresie wegetacyjnym.

Słowa kluczowe: *Sambucus nigra*, dendroklimatologia, dendrochronologia, warunki klimatyczne, szerokość słojów drewna