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SCOTS PINE TREE RING STRUCTURE MODIFICATIONS AND RELATION WITH CLIMATE

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Abstract

In this study we assessed the tree ring structure modifications and the relation with climate in Scots pine from Aleşd region (Romania). Tree rings structures were analysed based on microscopic sections obtained from the core sample. The analysis on the area of the incomplete lignified cells (IC) and the lignified cells (CL) was made. The results show a high frequency of false rings, and unlignified cells. The tree ring with the highest unlignified cells part could be observed in the years 2007 and 1989. A reduced number of the unlignified cells were formed in the year 1998. An anomaly was analyzed in the tree ring structure of the year 1986. The temperature below 10 °C in the second period of the growing season has stopped the process of lignification of the wood cell walls. This study confirms the influence of temperature on the formation of the Scots pine tree rings.

Key words: Scots pine, anatomical structure, radial growth, tree rings, temperature.

Özet

Bu çalışmada Aleşd (Romanya) bölgesinde bulunan sarıçam bireylerinde yıllık halka yapılarındaki değişimler ve bunun iklim bileşeniyle olan ilişkisi incelenmiştir. Ağaçların yıllık halka yapıları, ağacın özünden alınan mikroskobik kesitler üzerinden analiz edilmiştir. İncelenen kesitlerdeki tamamlanmamış odunlaşmış hücreler ve odunlaşmış hücreler analiz edilmiştir. Sonuçlar, yalancı halkaların ve odunlaşmamış hücrelerin çok sık olduğunu göstermiştir. En yüksek odunlaşmamış hücreye sahip yıllık halkalar 2007 ve 1989 yıllarında gözlemlenmiştir. Odunlaşmamış hücreli yıllık halkaların 1998 yılında daha az olduğu tespit edilmiştir. Anormal hücrelerin bulunduğu yıllık halkaların 1986 yılında daha fazla olduğu görülmüştür. Büyüme döneminin ikinci yarısında gerçekleşen 10°C'nin altındaki sıcaklıklardan dolayı, odun hücre duvarlarının gelişimini durdurmuştur. Bu çalışma, sarıçamlarda sıcaklığın yıllık halka oluşumunu engellediğini onaylamaktadır.

Anahtar kelimeler: Sarıçam, anatomik yapı, ışınsal büyüme, yıllık halkalar, sıcaklık.

INTRODUCTION

The evolution of radial growth stages throughout the growing season is reflected ultimately in the anatomical structure of the tree ring. The tree ring structure is the outcome of interactions between the processes of growth and environmental factors. Detailed anatomical analyses have described the correct course of xylogenesis during a year (Rossi et al. 2006, Rossi et al. 2008, Deslauriers et al. 2008). The tree ring growth is controlled by external factors but also by internal factors. Thus, the physiological processes are important in the wood's cells development (Denne and Dodd 1981, Schweingruber 1992, Kozlowsky and Pallardy 1997, Larcher 2003).

The climatic factor, mainly the temperature has an important influence on anatomical structure of the ring. The process of the wall cells formation is restricted by the climatic factor reflected in the final structure of the tree ring (Schweingruber et al. 1990, Vaganov et al. 1996, Vaganov et al. 2006, Piermattei et al. 2014). Temperature induced stress is argued on long period into the structure of the tree rings (Camarero et al. 1998, Wimmer et al. 2000, Gindl et al. 2001, Schmitt et al. 2003, Camarero et al. 2010).

The impact of drought and temperature on the formation of the tree rings at Scots pine has been analyzed in many studies (Antonova and Stanova 1993, Oberhuber et al. 1998, Gruber et al. 2010, Ziaco et al. 2014, Pacheco et al. 2016). A response of radial growth effect may be given by the species inadaptability to climate changes (Thompson 1998). The effect of heating and cooling in the development of the cells was analyzed in a forest of Ljubljana (Gričar et al. 2006). The radial growth slowdown is reflected in the formation of the false rings influencing the tree ring width (Hoffer et al. 2009, Marchand and Filion 2012). Donaldson (2002) studied the anormal deposition of lignin in the cells walls of *Pinus radiata* in the dry period. The drying of the Scots pine meant a good indicator in starting our study in order to assess the structure of tree rings and discover the factors involved in the process of radial growth.

MATERIAL AND METHOD

The study area is located in the Western Carpathians, Aleşd area (47°00'N latitude and 22°23' E longitude) and at about 500 m altitude (Figure 1). The annual mean air temperature is 10.5°C and the annual level of precipitation 635 mm. The trees in the studied area show sign of mortality with a low, moderate and strong intensity.

To analyze the impact of climatic factor with negative effect on radial growth were been extracted core samples from Scots pine trees without visible defects on the surface of the trunk. The samples for analysis were processed and analyzed in the laboratory

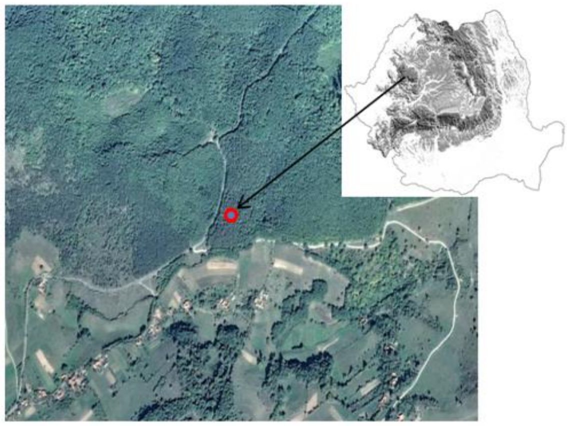

Figure. 1 The map with the location of Scots pine in Aleşd (Google Earth source).

according to the studies (Gärtner and Schweingruber 2013, Piermattei et al. 2014). The core with a length of about 15 cm was cut into five equal pieces. With the microtome type GSL_1, were obtained 10-15 μm microsections. These samples were colored with astra blue dye (1 g/200 ml distilled water) mixed with safranin-dye (2 g/200 ml distilled water) to distinguish the lignified cells from the unlignified ones. Finally, for preservation, the microscopic sections were permanently fixed with Canada balsam. After completing the procedures, all microscopic sections were analyzed with the Axio Imager A1m Zeiss microscope and stereomicroscope. The evaluation of anatomical structure was made on the entire length of the core starting from the bark up to the pith.

The analysis on the annual ring growth was done on each ring, both the lignified cells (CL) and the area of the incomplete lignified cells (IC). The lignified cells are completely colored in red and unlignified cells is in blue. The area with incomplete lignified cells was identified after the blue color in the wall cells (Rossi et al. 2006, Piermattei et al. 2014). Other observations have been made at false rings made up of small-sized cells colored in red (Marchand and Filion 2012). The cells with thick walls and small size found in the inside of the ring form the false annual ring (FR). Observations were made on the whole surface of the ring analyzing the tree ring structure. The climate data were obtained from the meteorological station located in the Aleşd area.

RESULTS AND DISSCUSIONS

The tree ring growth reduction was highlighted beginning with the year 2010 until 2015. In the period 2010-2015 the radial growth has a regular cellular structure without deformations. A representative increase in number of cells could be noticed in 2008 with a slight discontinuity noticed in the latewood. Also in the year of 2007 latewood was noticed an area with incomplete lignified cells (IC). This area is distinguished by blue colored cells forming the limit of tree ring (Figure 2).

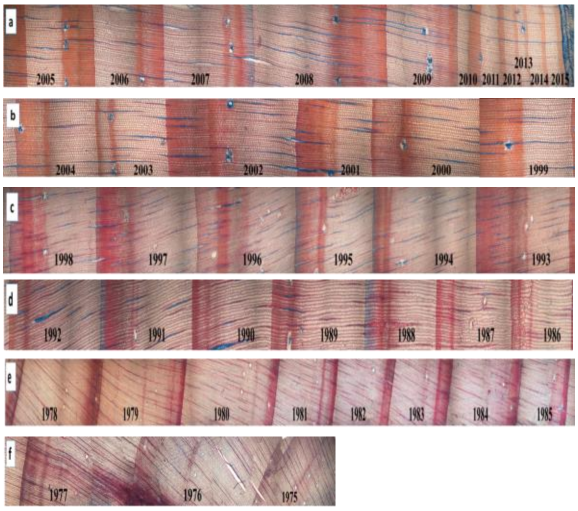

Figure 2. Transversal core section of *Pinus sylvestris* (period 1975-2015).

In 2005 the early and late wood have equal increase. The false rings well distinguished are observed in 2003 and 1981 (Figure 2b, Figure 2e). Each tree ring has a late wood specific variability in structure and width. In the late wood of the years 2007, 1998, 1995, 1994, 1991 and 1988 there are several rows of unlignified cells colored in blue. The process and duration of lignification were different from one year to another. Thus in the year 1991, area of completely lignified cells (CL) is well delimited (Figure 3a) from unlignified cells (IC) compared to the year 1988 in which cells are interleaved (Figure 3b). A cellular anomaly was observed in the late wood structure in the year 1986, in which the growth process has been stopped producing new cells (Figure 3d). Thus, the anatomical structure has shown an extreme phenomenon which was held during the development of the late wood. In the 1980 tree ring structure, only two rows of radial cell were incompletely lignified (Figure 4a, Figure 4b). In this case the process of lignification has not been completed. There have also been noticed false rings (FR) in the tree ring structure, with small cells and completely lignified (Figure 3c).

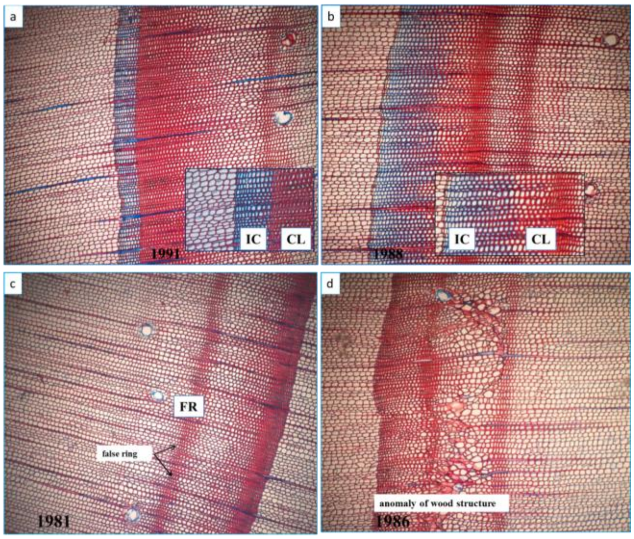

Figure 3. Different abnormalities in the wood structure of Scots pine. In the year 1991 and 1988 cells incompletely lignified (a, b); in 1981 the false tree ring (c) in 1986 deformed cell (d), (CL) lignified cells and (IC) incomplete lignified cells, (FR) false tree ring.

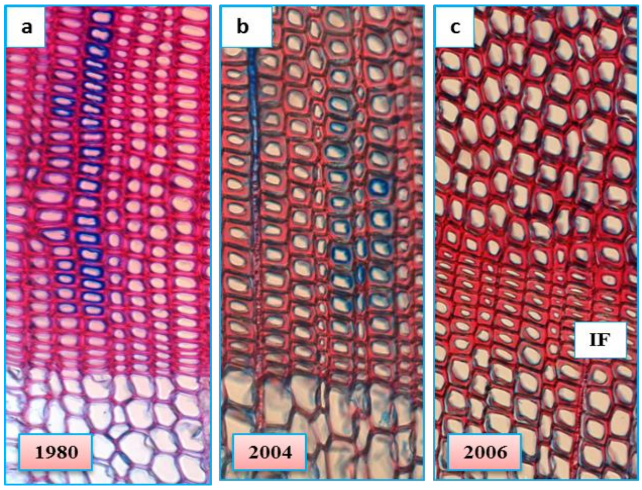

Figure 4. Rows of cells within completely lignified walls (a, b) and cells with thickened walls (c) false ring.

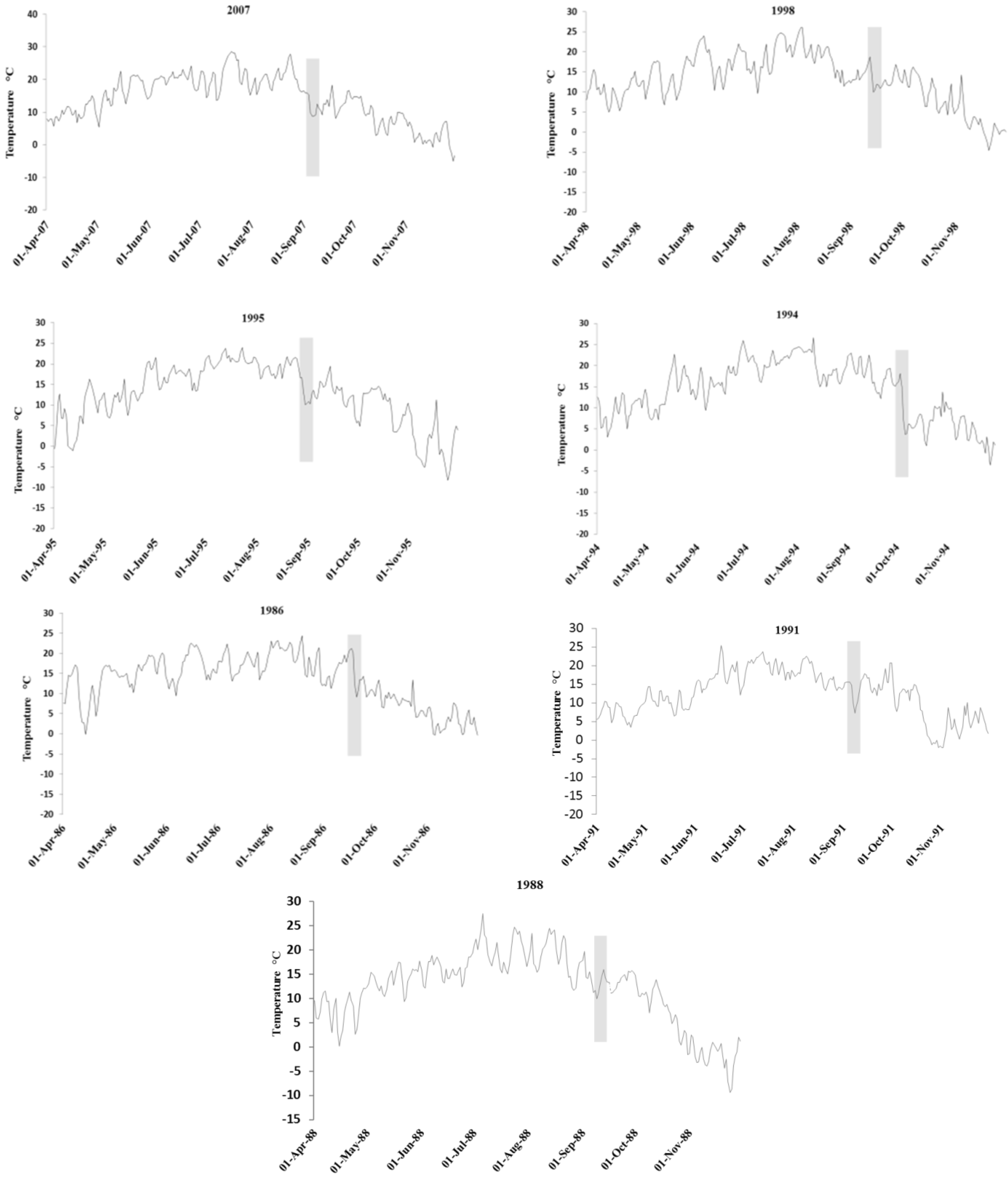

Figure 5. The average daily temperatures in the period of vegetation (2007, 1998, 1995, 1994, 1991, 1988, 1986). The vertical bar represents the temperature below 10°C.

On 6 September of 2007, the temperature dropped to 9 °C, thus the lignification process of cells was stopped on a larger surface of the late wood (Figure 2). The lowest number of the cells unlignified can see in the year 1998 and the process of lignification was stopped on 14 September. In the years 1994 and 1995, the number of unlignified cells in radial growth is about equal, but the difference between these years is reflected in the period in which the temperature drops sharply earlier in 1995 (September 24) compared to 1994 (October 6). The process of lignification is stopped early in 1991 (September 8) in which the temperature fell to 7 ° C, and in the 1988 (September 9) registering a temperature below 10 ° C (Figure 5).

From the analysis of the structure of tree rings we can see the impact of environmental factors during the period of their growth. The climatic changes in the second part of the vegetation season influenced the formation of the false rings. Moreover, the temperature below 10°C in early September has stopped the process of lignification. The sudden decrease in temperature from mid-September in 1991 has stopped the process of lignification, perfectly limitating the area of lignified cells of that of incompletely lignified cells. The favorable temperatures from September 1994 has favored the process of lignification until the early month of October when temperatures went down, preventing the process of lignification. A possible cause of this anomaly in the structure of wood in 1986 could be more the influence of a biotic factor, because an extreme cooling has not been noticed in that period leading to the freezing of water inside the cells. The temperature oscillation from the second part is observed in the late wood structure especially in the period 1975-2009. The positive or negative effects of climatic factors in tree ring structure have been described in several studies (Gindl and Grabner 2000, Donaldson 2002, Schimitt et al. 2003, Gričar et al. 2006, Ziaco et al. 2014). The temperature from the end of the vegetation season is very important in the process of lignification. The stopping of the lignification process in many cases is due to the sudden temperature decrease during the end of the vegetation season (Gindl et al. 2001, Piermattei et al. 2014). Cuny and Rathgeber (2016) have estimated a period of approximately two months for the last cells in xylem to reach maturity. The process of lignification can be uniform or non-uniform, case met in our study, also. A non-homogeneous process of lignification has been analyzed on the black pine in a natural park in Italy (Piermattei et al. 2014).

CONCLUSIONS

The tree rings showed different lignification events during the process of the cell formation, especially in the late wood. A long drought period and temperatures below the daily average values of 10 °C clearly influenced the process of cells lignification and also the structure of the xylem. We can accept that 10 0C is a limit, and temperature below this limit value restricts lignification process in the latewood. It is remarkable the fact that starting with the year 2009 until 2015, the radial growth decreased remarkably. Our results allow a better understanding of the reaction of trees to changes in environmental factors in particular climatic conditions during a growing season.

Expanded Abstract

Importanța: Etapele de formare a xilemului precum și variația temperaturei din timpul sezonului de vegetație este reflectată în cele din urmă în structura anatomică a inelului anual. Prin analize detaliate de xilologie se poate evidenția evenimente climatice extreme din perioada de creștere radială.

Scopul și obiectivele: Studiul de caz are drept scop evaluarea și descrierea structurii inelelor anuale începând de la scoarță până la măduvă, cuprinzând toată perioada de creștere. Obiectivele cercetării au constat în analize asupra celulelor nelignificate complet și a inelelor false precum și în analiza relației dintre creștere radială și variația climatului din perioada de creștere.

Materiale: microtom GSL_1 folosit pentru realizarea secțiunilor microscopice. Substanțe pentru colorarea microsecțiunile (astra blue și safranină) necesare în distingerea celulelor lignificate de cele nelignificate complet. Canada balsam, o substanță utilizată în fixarea definitivă a probei pe lamă microscopică. Aparate pentru analiză: microscop Axio Imager A1m Zeiss și binocular.

Metoda: O carotă de o lungime de 15 cm a fost tăiată în cinci părți aproximativ egale pentru realizarea microsecțiunilor pentru analiză. După procedura de colorare, s-a efectuat analiza probelor la microscop și binocular. În urma acestei operațiuni noi am evaluat structura inelelor anuale.

Rezultate și discuții: Creșterii radiale reduse, celule nelignificate cât și inele anuale false au fost descoperite în structura inelelor anuale. Scăderea bruscă de temperatură a avut un impact negativ în procesul de lignificare a pereților celulari. Temperaturile ridicate din ultimii ani (perioada 2010-2015) a redus creșterea radială atât la lemnul târziu cât și timpuriu.

Concluzii: Structura inelelor anuale arată clar efectele variațiilor climatice din perioada unui sezon de vegetație. Variația de temperature s-a remarcat în principal în structura lemnului târziu. În consecință, analize detaliate de microscopie a lemnului aduc informații importante pentru cercetători.

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