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COMPARATIVE ANALYSIS OF TREE RING PARAMETERS VARIATION IN FOUR CONIFEROUS SPECIES: (PICEA ABIES, ABIES ALBA, PINUS SYLVESTRIS AND LARIX DECIDUA)

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Abstract

The objective of this study is to compare yearly variability of the tree ring parameters of coniferous species (spruce, fir, Scots pine and larch) in the north-eastern part of the Eastern Carpathians (Romania). The microcores were collected at the end of the vegetation season in 2012. Micro-sections were prepared in order to analyses the tree-rings characteristics for the last three vegetation seasons. To emphasize the influence of species and interannual climate variation on tree growth, the following parameters were used: total tree ring width, number of tracheids and mean tracheids dimension. All the species showed different dynamics of the tracheids number, as well as of the tree-ring width in the three studied vegetation seasons. The highest growth in term of cells number was observed in Picea abies, whereas a reduced cells number but with higher dimensions was observed in Larix decidua. The variability of radial growth of the xylem in relation with the climate was discussed for each species separately.

***Keywords**: Cell number; Climatic factors; Tree-ring width.*

Introduction

Mixed stands of coniferous species represent important forest types for the Eastern Carpathians, with high ecological value. Many years ago, the forestry authorities decided in favor of mixed plantations of different conifer species, inside of coniferous-broadleaves mixture. Later on, researchers have questioned whether these coniferous species show instability as a result of climate change and also the need for artificially mixed conifer forests in the future. The current state of development for each species based on the comparative analysis of growth in relation to climatic drivers in these mixed forests was of great interest to us. Analyses of the xylem represent a good indicator to observe the dynamics of the past environmental conditions in plant communities [1-3]. The relationship between climate and radial growth was studied for these coniferous species in many regions, like as the French Alps [4]. Investigation on the variability of climatic signal and its effects on tree-ring width was performed on five species [5]. The March temperature increase was show to have positive impacts on tree ring growth of European larch in lowland Poland, thus suggesting adaptability to climatic conditions [6]. The effects of temperature and precipitation variability on xylem cell production in Scots pine and larch stem was studied by *G.F. Antonova* and *V.V. Stasova* [7, 8]). The influence of climate and genetic factors on radial growth varies from one species to

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another. Climatic conditions induce differences in the cell rate production of the annual tree-ring [9]. A comparative study shows that radial growth of *Larix decidua* will increase with higher temperatures, whereas the radial growth of *Pinus sylvestris* will be reduced by moisture limitation [10]. Furthermore, it was noted in the case study performed by *C. Desplanque et al.* [11] that radial growth of spruce and fir is limited mainly by the climatic factor, particularly drought, at low elevation. In what concerns radial growth of silver fir were noted the influence of temperatures in the previous year and drought from May in the current season. Both, early-wood and late-wood cells production induce variability of tree-ring width between species and vegetation seasons. Wood anatomic parameters in *Pinus sylvestris* significantly vary according to provenances [12]. In order to better understand the relationship between the tree-ring width and the cell number, two species of pine were studied: *Pinus sylvestris,* which showed higher growth in terms of the tree-ring width compared to *Pinus uncinata*, where the average cell size was even lower [13]. Studies regarding growth rate in terms of cell number were performed comparatively among species [14].

The aim of our study was to analyses the variation of the radial growth in terms of cell number and annual tree-ring width in four coniferous species. Hence, we tested to see whether the annual tree-ring width varied according to the cell number or only to their size. The present study represents a first step in the attempt to analyses the variability of anatomical tree ring parameters and sensitivity of species to climate conditions in order assess the productivity of artificial mixed coniferous stands in the future.

Materials and methods

The study area is located in the north-eastern part of the Eastern Carpathians, on the south-eastern slope (47°32'12" N and 25°33'40" E) near Câmpulung Moldovenesc town. The altitude of the research plot is 730 meters a.s.l. In order to perform a more accurate assessment of radial growth, trees with similar trunk sizes were selected, with the exclusion of trees subjected to wood compression. The analysis of the radial growth was performed on microcore samples collected with a Trephor tool, with sampling points located at 1.30 m above the ground. Microcores were extracted from 10 trees for each species: spruce, silver fir, European larch and Scots pine. Sampling was conducted in 2012 at the end of the vegetation season, to include in the study the recently formed ring. The microcores were processed in the laboratory according to methodology proposed by *S. Rossi et al* [15, 16]). Following laboratory preparation, the micro-sections were subjected to microscopic analysis. Radial growth was assessed for the last three vegetation seasons (2010-2012). The cells were counted on three radial series for each tree ring, considered in the statistical analysis as repetitions. The annual tree-ring width was measured using the binocular, equipped with an ocular measuring micro-meter with a graded scale, which allowed an accurate examination of the annual ring. The mean cell size was derived from the number of cells and tree ring width.

Data analysis

The normality of data distributions was checked for both the cell number and the annual ring width using the Shapiro-Wilk’s test, whereas for data homogeneity the Levene's test was performed. The ANOVA test was further applied in order to determine whether there are significant differences between species and years. The Tukey’s test was used in order to locate these differences and analyze them for the mean values of ($p < 0.05$), and the Kruskal-Wallis test was applied to compare the values of the annual tree-ring width and the cell size. The radial growth in terms of cell number, annual tree-ring width and mean cell size was assessed by comparing the average values between different species within the same year, marked on the graph by capital letters (A, B), as well as the average values of the same species between years (a, b). The XLSTAT program was used for data processing.

Results

The analysis of the annual tree-ring width

The mean annual tree-ring width varied between 2.31mm for spruce in 2011 and 1.22mm for pine in 2010. In 2010 and 2012 the four species did not significantly differ in respect to annual ring width, and in 2011 a significant difference was only noted between spruce and Scots pine (Fig. 1). In the case of each species, no significant differences were observed between years using mean tree ring width as parameter of comparison.

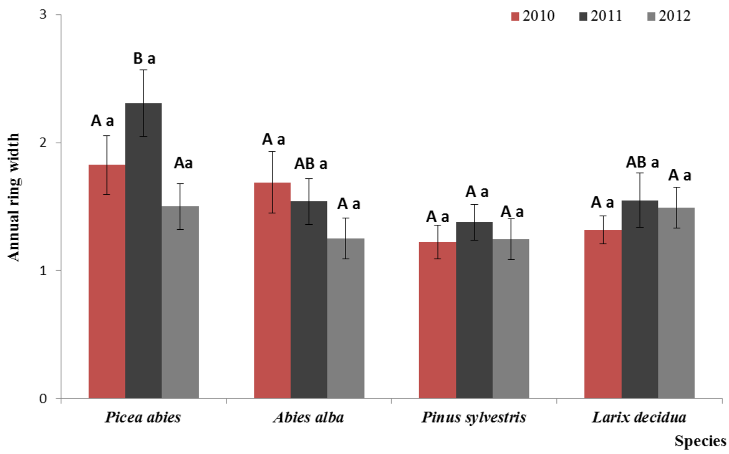

Fig. 1. Variation of the annual tree-ring width per growing season in the four coniferous species. Bars bearing the same capital letters and small letters designate no significant differences between. species within the same year and between years for the same species, respectively. The vertical bar indicates the standard error of the mean

The variation of the cells number

The results show significant variation in radial growth between species in terms of cells number. By comparing the mean cells number values between the studied species for the year 2010 we showed that spruce differs from pine (ANOVA F = 5.27, P = 0.014) as well as from larch (ANOVA F = 5.27, P = 0.003) (*Fig.* 2). Within the same year (2010) fir, larch and pine did not differ significantly by cells number. Comparative assessment of mean cells number variation between species for 2011 highlights that spruce differed significantly from all other species (ANOVA F = 12.10, P < 0.0001). However, for 2012 the mean cells numbers for spruce did not significantly differ from pine, but differed significantly from fir (ANOVA F = 4.44, P = 0.007) and larch (ANOVA F = 4.44, P = 0.02). The evaluation of results for pine, larch and fir points out that the mean cells numbers do not differ significantly between the three vegetation seasons.

Considering each species separately, a significant radial growth in term of cells number is observed for spruce for all the three vegetation seasons. The maximum growth rate was reached in 2011 (65.22 cells), whereas for 2012 the growth reduced to 40.60 cells. The lowest cells number occurred in larch, with a mean of 30.40 cells compared to the other species. One can clearly distinguish a positively significant increase in all species for 2011, in terms of cells number. Comparing the mean values between years within the same species (Fig. 2), significant differences regarding cells number were observed in spruce, between 2011 and 2012 (ANOVA F = 7.8, P = 0.001). The mean cells number in fir shows significant differences between 2011 and 2012 (ANOVA F = 4.9, P = 0.016), as well as between 2010 and 2012 (ANOVA F = 4.9, P = 0.029). No significant differences between annual cells number were detected for pine and larch.

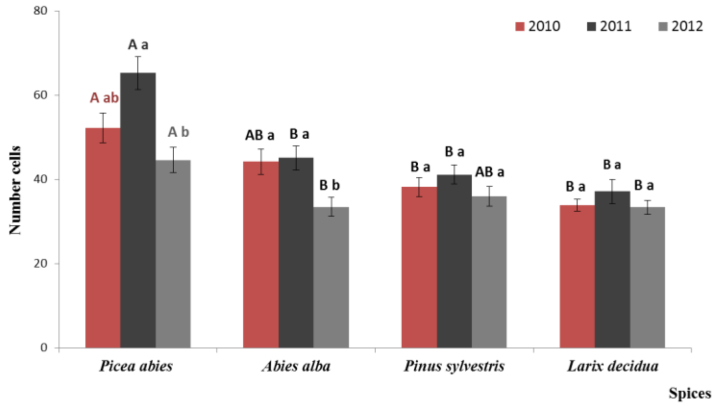

Fig. 2. Variation of the cells number per growing season in the four coniferous species. The vertical bar indicates the standard error of the mean. Bars bearing the same capital letters and small letters designate no significant differences between species within the same year and between years for the same species, respectively

Variation of mean cells size

The comparative analysis of mean cells size between species for 2012 shows significant differences between larch and spruce (Fig. 3), pine respectively (P = 0.001). Similar differences can be observed for 2011 between spruce and larch (P = 0.004), and between larch and pine (P = 0.006). Within each species no significant differences were observed between years regarding cell size.

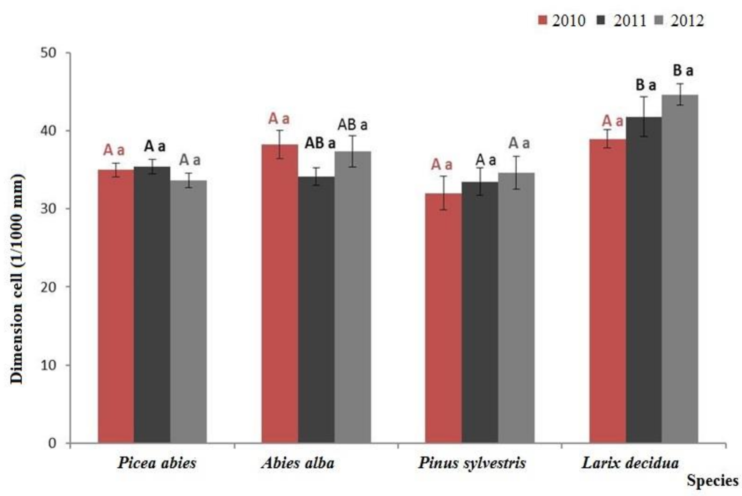

Fig. 3. Variation of cells size per growing season in the four coniferous species. The vertical bar indicates the standard error of the mean

Climatic data

We compared the mean daily temperature and precipitation for the period 2010-2012. We found a positive difference in precipitations in late May in 2010 and temperatures in middle of July in 2012, compared to other years (Fig. 4).

The mean daily precipitation in May 2010 (2.15mm/day) and June 2010 (2.73mm/day) significant positive influence radial growth in 2010. The minimum mean temperature of March (-0.69°C) and the maximum of July (19.26°C) were recorded in 2012.

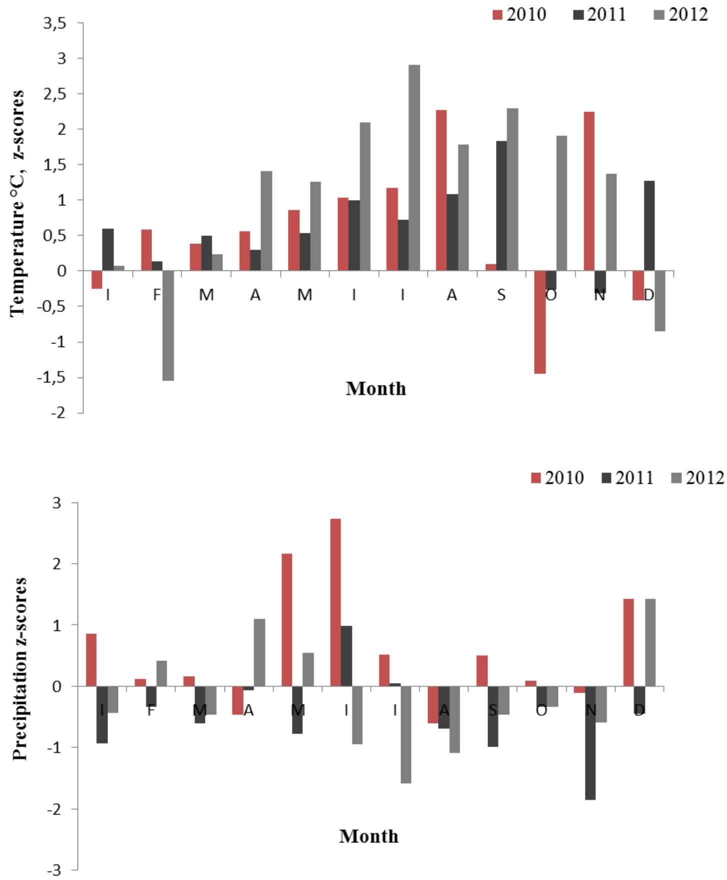

Fig. 4. Precipitation and temperature variability presented as z-score

Discussions

In the future, by expanding joint research in different areas with mixed forest, the competition between species reflected in the annual ring width and number of cells can be better assessed. This can further lead to the development of a forestry plan for performing mixed plantations. It is interesting to analyze the radial growth of these species with different ecological requirements and which were introduced in the same area. We firstly inquired which of the analyzed species reacted to drought and whether they responded by reducing the number of cells or by reducing the annual ring width. Secondly, we examined the radial growth response to climate variations. According to *F. Lebourgeois* [17], variations in radial growth of silver fir were higher than variations in radial growth of spruce, which highlighted the response of fir to climate change. *Larix decidua* was also shown to have responded positively to climate variations [18].

Cells number, cells size and thickness of the cell wall represent important quantitative parameters in the analysis of the annual tree-ring. Our study highlights two opposite situations:

i) high tree-ring width and small cell size (spruce), and ii) high cell size and small tree ring width (larch). The relationship between cells number and annual tree-ring width is obvious, whereas the relationship between radial cell size and the thickness of the cell wall, or cell size and tree-ring width was shown as more complex [19].

Cells size depends on the dynamics of each growth stage of the xylem, being different from one species to another. Moreover, the annual growth rate results from the response of each species to the variation of the environmental factors [9]. According to some studies, the maximum cell wall thickness is encountered in the middle of the latewood area, and not in the last cells of the annual tree-ring. The spruce cells with sizes between 0.02 mm and 0.025 mm show the thickest cell wall [20]. In what concerns tree-ring width, significant differences are noted, as opposed to the total number of formed cells which showed no significant differences between two study years [21]. Other studies found fluctuations in the number of cells in the annual ring formation in balsam fir [22]. The number of cells in the annual ring may be influenced by drought periods in July and September [23]. The variability in the radial growth is linked to the variation of climatic conditions during the current and previous year. For conifers from high elevation sites, the increase in the values of radial growth is linked to summer temperatures increase [24], whereas high spring temperatures influence positively the cell number of the xylem [21]. The impact of climatic factors on total ring-width was studied on Scots pine stands growing on dry, nutrient-poor soil [25]. Cells number depends largely on elevation gradients, as observed in *Larix decidua* 2010 [26]. The highest number of cells was noted in *Picea abies* and *Abies alba*, and a smaller number of cells in *Pinus sylvestris* and *Pinus mariana* [27]. There was no clear relationship between the annual ring width in pine and the length of the vegetation season, but the wood formation in pine and birch largely depended on temperature [28]. Precipitation and temperature positively influenced the rate of cells divisions and the radial diameter of the tracheids [7].

In our study, located at mid elevation, the May-July mean temperature in 2012 was significantly higher than in 2010 and 2011 (with 3.7°C higher that the reference period 1961-1900). Moreover, the precipitation amount was significantly lower in 2012 (with 66 mm lower that the reference period 1961-1990 in June-July). The positive influence of precipitation in June is clearly reflected in the radial growth of the year 2011 for all the analyzed species. The mean value of the highest temperatures in June – July, as well as of the reduced amounts of precipitation in 2012 may be the cause to the non-significant growth of the annual ring for the same year. The sensitivity of coniferous species from middle and low elevation to summer drought was also observed [29].

Conclusions

Our results point towards an enhanced adaptability of the studied coniferous species to the fluctuations of the environmental factors based on different number of cells or cell size in the tree ring. The smaller tree ring width combined with the lower number of cells in 2012, for all studies species, can be explained by the lower amount of precipitation in the growing season. In order to assess the long-term variability of radial growth, further similar research is needed, given that these analyzed parameters may also provide information on the relationship between climate and various species of conifers.

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