Growth response of Silver fir and Bosnian pine from Kosovo

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Background and purpose:
This paper explore the growth-climate relationships in total ring width chronologies of silver fir (*Abies alba* Mill.) and Bosnian pine (*Pinus heldreichii* Christ). The objective of this study is to quantify the climate influence on radial growth of both species. The relationships between climate and ring widths were analyzed using extreme growing years (called pointer years), simple correlations and response functions analysis (bootstrapped coefficients). The objectives of this study were: (1) to define the pattern of climatic response of each species. (2) to highlight the influence of local ecological conditions on tree's growth, and (3) to compare the response of silver fir and bosnian pine to climate.
Responses of total ring width to climate were estimated by establishing the mean relationship between growth and climate through simple correlations analysis and bootstrapped response functions. The response to climatic variability was also assessed by analyzing pointer years which correspond to abrupt changes in growth pattern and revealing the tree-growth response to extreme climatic events.
For the period 1908-2008 the mean sensitivity (MS) of total ring width chronology for Bosnian pine (0,209) was higher than silver fir(0,169,) suggesting that Bosnian pine is more sensitive to climate (pointer years were more frequent in ring width chronology of Bosnian pine than in silver fir ring width chronology).
The high values of first-order autocorrelations for Bosnian pine (0,674) indicated a strong dependence of current growth on the previous year's growth. Pointer years analysis underlined the high sensitivity to spring temperatures and precipitation for both species. Radial growth for both species depends strongly on spring climate variables (temperatures and precipitation) which play a significant role particularly for earlywood production.

Material and methods:
We selected 12 silver fir trees and 15 bosnian pine trees and took two 5 mm cores per tree perpendicular to the slope. Each core was mounted and sanded following standard dendrochronological procedures.Annual radial growth was measured with a measuring system LINTAB (Rinntech-Germany) where tree-ring widths were recorded using TSAPWin 0.55 software.
Each tree-ring width series was crossdated using visual comparisons and statistical parameters like: Cross Date Index-CDI (Schmidt 1987), an index of

synchronization estimated by TSAPWin derived from GLK% and t value (Baillie and Pilcher 1973). The value of CDI> 10 (Rinntech 2003) were considered as significant. The ARSTAN software was used to remove age trends in the ring width data and build site chronology. Indices were calculated as ratios between the actual and fitted values. Response from both species to climate was correctly shown by pointer years analysis, Pearson's correlation coefficients and DENDROCLIM (2002) software.

Results and Conclusion:
We compiled for each specie a mean chronology of radial growth with good replication. The chronology length of Silver fir is 64 years with mean tree-ring width 3.59mm (0.506), while the chronology length of bosnian pine is 104 years with mean tree-ring width 2.44 mm (± 0.482). The bosnian pine chronology was more sensitive than silver fir chronology (sensitivity 0,209 >0,169). Response of both species to climate was good. That was verified from pointer years analysis, Simple Pearson's correlation coefficients and DENDROCLIM (2002) software.
Pointer year analysis showed that spring temperatures and precipitation are the most important factors that enhance radial growth for both species. The pointer years 1953 and 1955 appear to be the most geographically extended pointer years throughout of Europe. The negative pointer year 1953 was identified in growth of silver fir by Serre Bachet 1986, and positive pointer year 1955 was also observed for silver fir in France.
Both species have reacted strongly to several pointer years but bosnian pine was more affected and more sensitive to climate than silver fir. For A.alba, high temperatures and plenty rainfalls during the first part of growing season are the keys for production of earlywood).
The response of Bosnian pine growth to climate was quite different than response of silver fir. Response functions analysis showed that precipitation during September is important for latwood production (growing season ends on October). While low temperatures during winter (January) and especially frosts cause substantial growth reduction, delaying the growth starting during spring.
Earlier studies has shown that phytosynthesis is possible for A.alba in winter, where high temperatures could play an important role in improving carbohydrate storage and growth at following year. For species grown under a Mediterranen climate high temperatures and low precipitation during growing season may cause water stress, which is the main limiting factor for tree growth. Although the drying season lasts in the study area for 2 months we didn't note any sign of defoliation or needle yellowing in standing trees.

Key words:
tree-ring width, pointer years, sensitivity, Pearson correlation, response-functions.

INTRODUCTION

Silver fir (*Abies alba* Mill.) is widely distributed in Europe and has been proved to be an important species for dendroecological studies. While Bosnian pine (*Pinus heldreichii* Christ.) has a limited distribution mainly in Balkan peninsula and south of Italy. The decline of Silver fir has been subject of great concern in Central Europe and North America since the early 1970's (1, 2).

From an ecophysiological point of view the shade tolerant Silver fir species appears to be rather a more frost and drought sensitive specie (3, 4). Silver fir and Bosnian pine are the most important conifer species regarding both, covered area and standing volume in Kosovo (Kosovo National Forest Inventory 2006). In Kosovo the natural distribution areas for Silver fir and Bosnian pine correspond to mountainous regions. So the natural mixed coniferous forests cover a wide range of substrate, topographic and climatic conditions. In Kosovo dendroecological studies are scarce. By means of this paper we present the first chronologies of tree-ring width for Silver fir and Bosnian pine and their response to climate. The objectives of this study were: (1) to define the pattern of climatic response of each species, (2) to highlight the influence of local ecological conditions on tree's growth, and (3) to compare the response of Silver fir and Bosnian pine to climate.

The response of tree-ring width to climatic variability was also assessed by analyzing pointer years which correspond to abrupt changes in growth pattern, simple correlations analysis and bootstrapped response functions (5).

MATERIALS AND METHODS

The study area belongs to Forest Economy of Koritnik 1, that is under administration of Forest Agency of Kosovo, Region of Prizreni (Figure 1). It has mountainous reddish-brown soils (Haplic Luvisoils) laid on ultrabasic

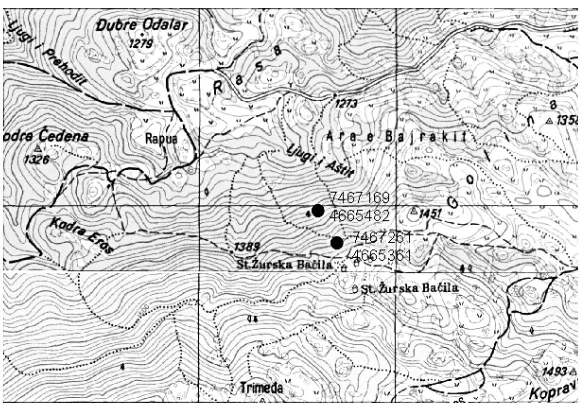


Figure 1
Location of forest plot in Koritnik Mountain (black circles show sample sites)

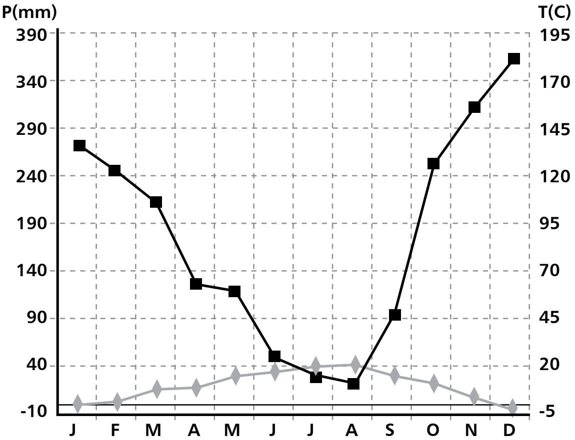


Figure 2
Climatic description of the study area based on climatic data from Dragashi meteorological station (period 1951-2008).

rock formation. Meteorological data are taken from nearby station of Dragashi commune. The climate in the area is Premountanious Mediterranen climate with a summer drought period of ca. 2 months (Figure 2). Maximum temperatures occur from July to August, while minimum temperatures are observed from December to January with a mean annual temperature 11,10 °C. Rainfall has a summer minimum value from June to August. During the 1951-2008 period, the lowest monthly temperatures in December, January and February occurred in 1951 (-5,7 °C), 1959 (-3,1 °C) and 1955 (-2,6 °C). Within the study area understory is missing because of dominant trees shadow, while the ground vegetation comprised species like: *Anemone nemorosa* L., *Rubus idaeus* L., *Pteridium aquifolium* L., *Euphorbia* sp, *Fragaria vesca* L. The radial growth of trees was estimated basing on increment cores taken from sampled trees in two plots. Sampling was carried out using a Pressler increment borer. Two cores per tree were taken at breast height (1,3m) in opposite directions and perpendicular with slope. We selected 12 Silver firs and 15 bosnian pines. Each core was mounted and sanded following standard dendrochronological procedures (5). Tree-ring width was measured to the nearest 0,01 mm in the two cores taken at 1,3m with a measuring system LINTAB (6). Tree-ring widths were recorded using TSAPWin 0.55 software (6). Each tree-ring width series was cross-dated using visual comparisons and statistical parameters like: Cross Date Index- CDI (7), an index of synchronization estimated by TSAPWin derived from GLK% (8) and t value (9). The value of CDI> 10 were considered as significant. The ARSTAN program (10, 11) was used to remove age trends in ring width data and build site chronology. The raw data of tree-ring width were standardized and detrended using a three- step process. First, a negative exponential function was fitted with raw tree-ring data. Second, a cubic smoothing spline with a 50% frequency cut off of 50 years was used to retain the high-frequency variability of radial growth. Third, the mean chronology was built using a robust mean in order to reduce the influence of extreme values (negative or positive) (10, 12). Signal strength in ring width chronology was tested using EPS – Expressed Population Signal (13). Only those series with a high common signal (EPS≥0.85) were included in the analysis. The remained autocorrelations were removed by autoregressive modeling. The residual series were averaged to create total ring width chronologies for each specie. Residual chronologies were compared with climatic data in correlation analysis and response function. For each tree-ring component the effect of climate on growth was investigated on two steps. First, pointer years were compared with climate data. Second, bootstrapped confidence intervals were used to estimate the significance of correlations and response function coefficients (14). Analysis was performed using 12 monthly climatic data (mean temperature and precipitation) of current growth year, starting from January till to December. The pointer years were defined for each tree-ring component as those calendar years when at least 75% of the cross-dated series presented the same sign of change: at least 10% narrower or wider than previous year. Pointer years were identified using Weisser software with a 7 year time window with three level of growth intensity (16, 17). The software package DENDROCLIM 2002 (15) was used to compute the statistical significance of the coefficients by calculating 95% quantile limits based on 1000 bootstrap re-sample of the data (14, 15).

RESULTS AND DISCUSSIONS

Growth dynamics

For both species we have estimated basic dendrometrical parameters. The dendrometrical data were provided from field measurements and are presented in the Table 1. Both studied species have comparable parameters regarding number of trees per hectare and mean diameter ate breast height, but Silver fir has significantly higher growing stock (775 m^3/ha) and basal area 60,9 m^2/ha than Bosnian pine (Table 1).
The mean tree-ring width chronology of *A. alba* Mill. is constructed by using 24 relative series taken from 12 dominant sample trees (Figure 3).
The chronology length is 64 years (time span 1946-2008) with mean tree-ring width 3.59 mm (standard deviation 0.506).
The Silver fir tree-ring chronology shows cyclic fluctuations during entire period of time (see Figure 3). The lowest radial growth is reached on year 1953 (2,51 mm), while the maximal radial growth in years 1958 (4,61mm) and 1994 (4,8 mm). The most important changes which represent long-term oscillations are noted during 1966-1977 period, where trend of radial growth is decreasing and during 1988-1994 period

Table 1
Site descriptions of the sampled plots

	Plot 1	Plot 2
Latitude (N)	7467169	7467261
Longitude (E)	4665482	4665361
Elevation (m.a.s.l)	1500	1540
Aspect	NE	NE
Slope (0)	16	30
Abies alba density (stems ha-1)	375	420
Abies alba average height (m)	23	26
Abies alba basal area (m²ha-1)	58,4	63,4
Abies alba growing stock (m³ ha-1)	720	830
Pinus heldreichii density (stems ha-1)	290	320
Pinus heldreichii average height (m)	21	24
Pinus heldreichii basal area (m²ha-1)	40,4	42,4
Pinus heldreichii growing stock (m³ ha-1)	462	506

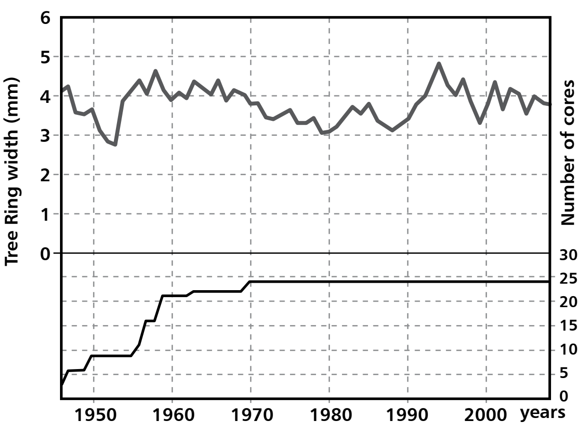


Figure 3
Raw tree ring width chronology of Abies alba *Mill. (Koritnik) for Koritnik. Upper part of the graph is the raw tree-ring width chronology; lower part shows number of cores in particular year.*

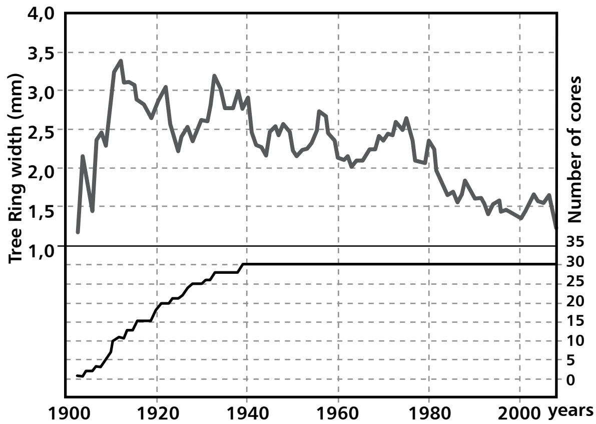


Figure 4
Raw tree ring width chronology of Pinus heldreichii. *Christ for Koritnik.Upper part of the graph is the raw tree-ring width chronology; lower part shows number of cores in particular year.*

radial growth has an increasing trend which culminate on year 1994. The period of Silver fir growth reduction (1966-1977) is also noted in whole Europe and in Piemonte-Italy too (18, 19).

The mean chronology of Bosnian pine is constructed by using 30 relative series taken from 15 dominant sample trees.

The chronology length (Figure 4) is 106 years (time span 1903-2008) with mean tree-ring width 2.44 mm (standard deviation ± 0.482). The chronology of Bosnian pine has an increasing trend till 1915 and this is related to the period of juvenile growth at the beginning of the life cycle. Then juvenile growth of radial growth is followed by a long-term oscillations period that last till to 1980. The longest period with descending trend extended from 1980 till to 2008.

Each period of acceleration in radial growth of Bosnian pine is followed by a period of radial growth reduction. Basing on ARSTAN software we have estimated for each specie's tree-ring width chronology the basic statistical parameters (Table 2).

Table 2
Basic statistical parameters of tree-ring width chronology for both species

Forest species	Time span chronology	Mean ring width (mm)	Standart deviation	Autocorrelation AC(1)	Mean sensitivity
Silver fir	1946-2008	3.59	0.506	0.643	0.169
Bosnian Pine	1906-2008	2.44	0.482	0.674	0.209

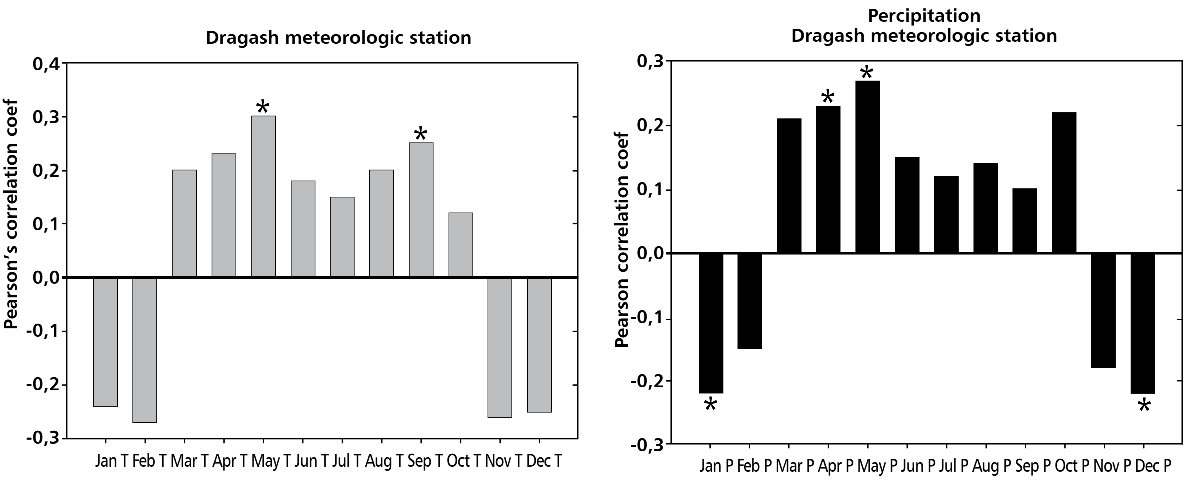
The statistical parameters estimated for each chronology showed that Bosnian pine chronology (MS 0,209) is more sensitive than Silver fir chronology (MS 0,169).Tree-ring width chronologies of both species were synchronized between each other and statistical parameters were estimated.
From estimation resulted that t-BP=0,63 and GLK = 50%. That means that growth behavior of both species was different although site conditions are similar.

Climate-growth relationship

Pointer years

Pointer years identified as years with extreme conditions reflected in tree-ring widths were identified for both species. Strong and negative reactions for Silver fir were observed in 1909, 1953, 1980 and 1995, while the positive pointer years were observed

Silver fir



Bosnian pine

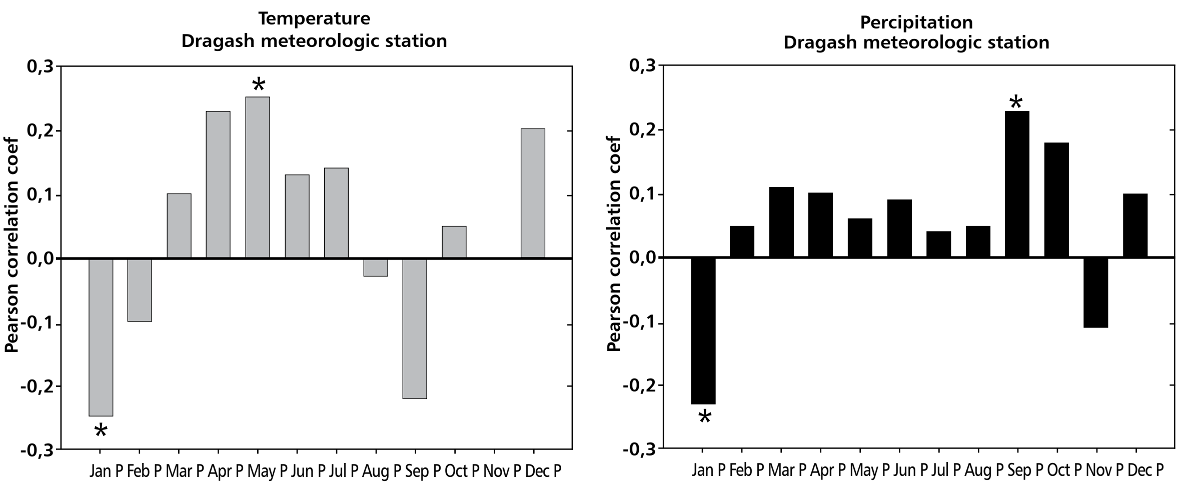


Figure 5
Simple response to climate conditions - Pearson's correlation coefficients between residual chronology and average monthly temperature and monthly sum of precipitation from local meteorological station Dragash-Kosovo. Black circles on the top of the bars show significant correlations.

in 1947, 1955, 1971 and 1994. For Bosnian pine negative pointer years identified from tree-ring width chronologies were: 1911,1951,1968,1997,1998, while the positive pointer years 1924,1940,1957,1973,1981. Pointer years were more frequent for Bosnian pine tree-ring width chronology than Silver fir chronology, meaning that its chronology is more sensitive to climate. Comparison of negative pointer years with climate data showed that main reason for reduction of radial growth were low temperatures. For example temperature in March and April 1980 are lower than long-term mean value for spring months (March 4,6 °C<7 °C; April 8,8 °C<12 °C). Growing period in 1980 started in May or one month later than normally. Annual precipitation in 1980 were 2622.3 mm (2404 mm long term mean value) and 893.3mm during growing season. The same situation was found in 2000, with one exception, amount of precipitation in current growing period (May-October) was 399.8 mm or 2 times lower than long-term average amount of precipitation during vegetation period (399.8 < 752.9 mm). So during this year except of temperature has influenced negatively on tree's growth, the low amount of precipitation.For Silver fir the negative pointer years have been 1955 and 1971, where summer temperatures have been lower and growing period has started with delay. The precipitation has been abundand during the spring months, but smaller in the rest months of year. For Bosnian pine the positive pointer years have been 1924, 1940, 1957, 1973,1981. By the comparison between radial growth with climate data in these years, it is noted that high temperatures and high amount of precipitation during spring months have been main factors that have influenced on radial growth.
This relationship was expected because the samples are collected in the altitude 1500 m a.s.l where the site conditions are not so extreme.

<u>Response to climate</u>

Response of residual chronology for both species to climate is estimated by using Pearson correlation coefficients. The threshold value of correlation is 0.25 for ($p<0.05$). Simple Pearson's correlation coefficients between local climatic data from Dragashi meteorological station and residual chronology of Silver fir showed significant ($p<0.05$) positive response with May and September mean monthly temperature and a negative response with winter mean monthly temperature. The response of Silver fir residual chronology to total monthly precipitation showed a positive response with summer monthly precipitation and a negative response with winter total monthly precipitation. That is important for annual radial growth because the vegetation period start in the middle of April. So the temperature and precipitation in the spring months are significant for earlywood formation. We also analyzed the response of Bosnian pine to climate variables. We noted a highly significant negative correlation between residual chronology with January climate variables (mean monthly temperature and monthly precipitation) and a significant positive correlation with May mean monthly temperature and September monthly precipitation. The response of Bosnian pine growth to climate is quite different than response of Silver fir growth to climate (Figure 5).
The response of Silver fir and bosnian pine index chronology to climate was also tested by means of DENDROCLIM 2002 software (Figure 6): For both species, precipitation during the end of second part of growing season (September) is important for latwood production (growing season ends on October). While low temperatures during winter (January) and especially frosts cause substantial growth reduction, delaying the growth starting during spring.

CONCLUSIONS

Wood anatomical features measured in tree-rings may offer opportunities for obtaining environmental information (20). In many studies growth rate is the only considered parameter (21, 22, 23) since ring widths are usually easy to measure and to interpret. Silver fir is a wide distributed specie, while Bosnian pine is e typical Balkan specie with limited distribution. They form together natural forest stands in Kosovo. Although they are growing under the same ecological conditions they showed differences in tree-ring width chronology. Pointer year analysis showed that spring temperatures and precipitation are the most important factors that enhance radial growth for both species. The pointer years 1953 and 1955 appear to be the most geographically extended pointer years throughout of Europe.
The negative pointer year 1953 was identified in growth of Silver fir (19) and positive pointer year 1955 was also observed for Silver fir in France (24). Both species have reacted strongly to several pointer years but Bosnian pine was more affected and more sensitive to climate than Silver fir. For Silver fir, high temperatures and plenty rainfalls during the first part of growing season are the keys for production of earlywood (24). The response of Bosnian pine growth to climate was quite different than response of Silver fir. Response functions analysis showed that precipitation during September is important for latwood production (growing season ends on October). While low temperatures during winter (January) play also an important role in determining growth, particularly for extremely thin tree-ring widths. Low winter temperatures and especially frosts cause substantial growth reduction, delaying the growth starting during spring. Earlier studies have shown that phytosynthesis is possible for A. alba in winter, where high temperatures could play an important role in improving carbohydrate storage and growth at foolowing year. For species grown under a Mediterranen climate high temperatures and

low precipitation during growing season may cause water stress, which is the main limiting factor for tree growth (25).
Although the drying season lasts in the study area for 2 months we didn't note any sign of defoliation or needle yellowing in standing trees.

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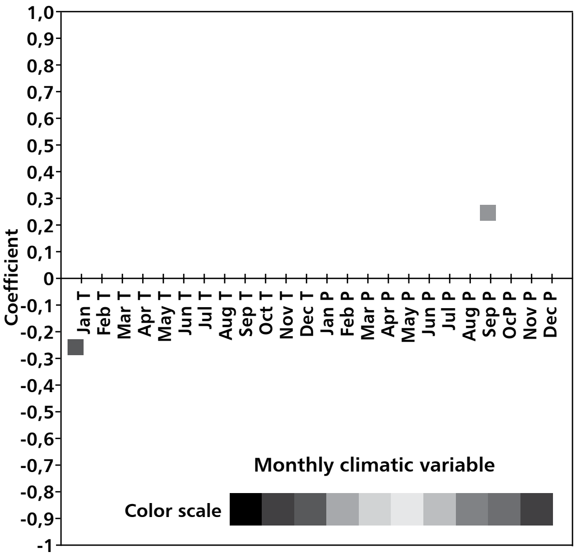
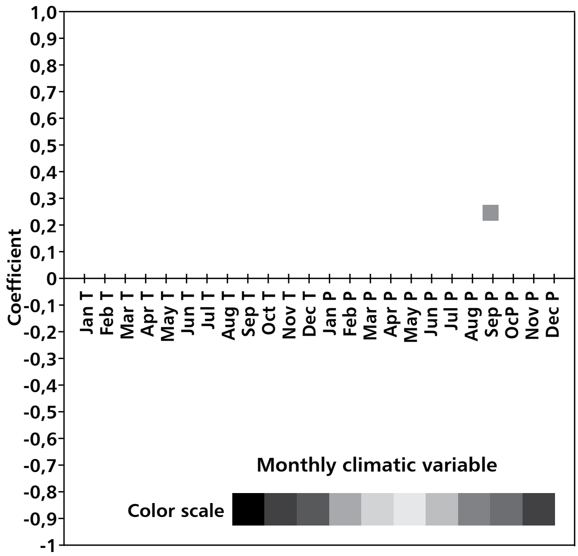
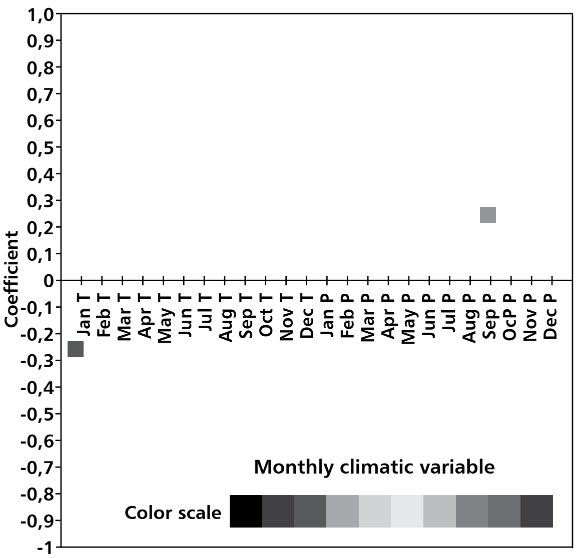
Silver fir





Bosnian fir



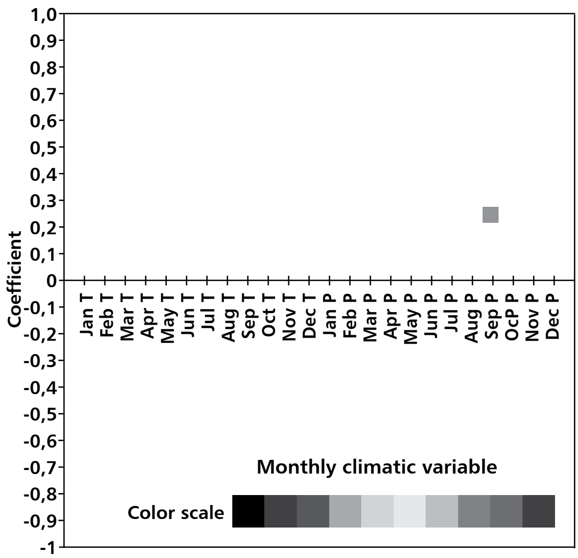


Figure 6
Significant correlations between annual radial growth and monthly climatic variables for both species.

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